FIELD CROPS
IN
SOUTH AFRICA

BY

LEPPAN AND BOSMAN

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FIELD CROPS IN SOUTH AFRICA

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PREFACE

South African agriculture, by reason of extremely diversified climatic conditions and peculiar economic factors, presents a great variety of problems to the beginner, and especially to the settler, who is unfamiliar with local conditions. It is unfortunate, too, that the supply of local agricultural literature is very meagre and often difficult to obtain.

The aim of the authors has been to give a concise account of the cultivation of crops in the Union, in the hope that it will be of service to our farmers and prospective farmers. It has been written not only for these, but to assist students and teachers at the various institutions where agriculture is taught.

To some it may not be sufficiently technical, to others it may appear too much so. The former will have to supplement their reading by the use of more specialised works, a selected list of which is given below; the latter are advised to pass over technical descriptions, and it is hoped that sufficient practical information will be found to be useful.

No doubt a great deal that is contained herein will need to be revised as more data are accumulated; owing to lack of conclusive data, much is necessarily speculative. It is, therefore, the earnest wish of the authors that criticisms and additional information will be sent to them, so that if a new edition is called for, it may benefit by such criticism and information.

A great many publications have been consulted and duly acknowledged. In some cases, however, there may have been unwitting omissions, and here the authors crave the indulgence of those whose publications may have been consulted without due acknowledgment.

This opportunity is taken to thank Dr. J. C. Ross for reading the manuscript of certain chapters, and for his valuable suggestions in regard to Chapters III. and IV. We are especially indebted to him for the account given under "Brak Soils." The authors also wish to express their appreciation of Mr. H. W. Taylor's kindness in allowing them a free use of his articles on tobacco.

The list of text-books given below may prove useful to those wanting an elucidation of points which have not been given in sufficient detail, or, to those requiring further information:

Botany of Crop Plants	Robbins.
Agricultural Botany	Percival.
Breeding Crop Plants	Hays & Gerber.
Genetics in Relation to Agriculture ...	Babcock & Clausen.
Fungous Diseases of Plants	Duggar.
Plant Genetics	Coulter.
Soils, Their Preparation & Management	Lyon, Fippin & Buckman.
Soils	Hilgard.
Soil Physics and Management ...	Mosier & Gustafson.
The Feeding of Crops and Stock ...	Hall.
Principles of Irrigation Practice ...	Widstoe.
Soil Fertility & Permanent Agriculture	Hopkins.

HUBERT D. LEPPAN.
G. J. BOSMAN.

Pretoria,
March, 1923.

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FIELD CROPS IN SOUTH AFRICA

CHAPTER I

HISTORICAL AND GENERAL SURVEY

Field Husbandry, Agronomy and Phytotechny are synonyms used to denote that branch of agriculture which treats of the theory and the practice of the production of crops. The Chinese saying, " Public prosperity is like a tree; agriculture is its roots; industry and commerce are its branches and leaves. If the root suffers the leaves fall, the branches break and the tree dies," is as true to-day as it was centuries ago. On account of its importance to the welfare of humanity a brief review of the development of field husbandry and its present status is not unwarranted.

Early Evolution.—Excepting the very recently developed countries, the embryonic stage of agriculture has presented a development along very similar lines in the various parts of the world. Even the pioneer farming of to-day, as found in parts of Africa, South America and elsewhere, has certain features showing very little advance over that of twenty centuries ago.

During the early history of a tribe and of the comparatively younger pioneer communities, the growing of food crops on cultivated land was seldom the first development. This followed only when the returns from hunting, fishing, and the gathering of wild fruits and roots were no longer sufficiently stable or plentiful to supply the needs of a growing population. In most cases the domestication and herding of animals without the cultivation of crops followed this phase; in some, *e.g.*, the Red Indian, who, before the advent of Europeans had domesticated only the turkey and the dog, the agricultural stage was reached without passing through the pastoral stage. Some nomadic tribes continued for many centuries as pastoralists only.

As populations grew, and for reasons political, economic and otherwise, became more restricted to certain localities, the purely pastoral stage gave way to a combined agricultural and pastoral phase, and animal husbandry slowly merged with field husbandry. The cultivation of crops was necessary to supplement the natural supplies, particularly during those seasons of the year when the latter were unobtainable, and also to support the domesticated animals during the periods when the natural pasturage was inadequate.

Directed by experience, a remarkable choice of animals and crops was effected in the earliest times, since all the domesticated animals and nearly all the important crops of to-day have been employed in farming since the beginning of recorded history. Wheat and barley seed have been found in the remains of the Stone Age; petrified maize ears have been found in Peru, together with evidences of ancient human activities; and so forth. Considering the vast accumulation of botanical knowledge of the last two centuries, it is astounding that of the important cultivated crops of to-day, practically none has been discovered during this period. A few new fodder plants have been found, it is true; but in most cases their superior utility is still to be proved.

The great civilisations based upon agriculture began in three regions which had no inter-communication—viz., China, where rice, the sweet potato, wheat, sorghum and millet (Setaris italica) were grown; the south-west of Asia (with Egypt) growing the bean, lucerne, pea and water-melon; and inter-tropical America, where the potato, maize and tobacco were cultivated.[1] While some of these and other crops were originally grown in other parts, it is generally held that the regions mentioned were really the birthplaces of great civilisations established on the products of cultivation.

Here it might be mentioned that in no case do the progenitors of either domesticated animals or crop plants, when measured by their utility for men, compare with the strains employed to-day. This is due, of course, to the selection of superior and permanent variations, and in later years partly to artificial hybridisation.

Among the early agricultural writers none excels either Cato or Varro in precision and clear description. A great

[1] "Origin of Cultivated Plants."—De Candolle.

many of their observations relate to rural economy—their deductions are amazingly accurate and inaccurate. They attributed a great many diseases and disasters to the influence of certain stars and phases of the moon. It is natural that they should have done so, since, knowing no science, they attributed the inexplicable to the malevolent action of things over which they had no control.

On the other hand, the benefits to be derived from land drainage, seed selection, the use of barnyard manure and lime, and the residual effect of legumes on the soil were recognised by these writers in no uncertain manner.

As previously stated, practice in field husbandry has developed along very similar lines all the world over. In most cases the primary stages were characterised by the small variety of crops grown; the first and most important crop almost invariably being one of the cereals; the same crop was grown continuously on the same land, with the inevitable result that the productivity declined steadily. Finally, the land was abandoned, and virgin land cultivated in its stead. "This custom of abandoning partly worn out land has been almost universal in the history of all nations and their agriculture."

THE EARLY USE OF THE BARE FALLOW.[2]—"Along with such agricultural experience as taught man that cultivated lands continuously growing cereals soon lost their producing power came the knowledge that idle lands had to recuperate their power to yield good crops. The experience of the farmers of many nations, in many climates, showed that idle, abandoned land would regain productivity. In man's early discovery of this principle we find the origin of the practice of 'bare fallowing.' As land became scarcer, and as agriculture increased in importance, the bare fallow became a systematic feature of agriculture. Instead of working land to a condition of unproductivity and then abandoning it to nature, the farmer cropped the land continuously, with regular fallow periods every second or third year.

"Modern agricultural science reveals the fact that, while the bare fallow acts as a temporary stimulus to soil productivity, it is a practice that serves to hasten the ultimate impoverishment of a soil area. It is now used less often, and then only to destroy weeds and, in some regions, to conserve moisture." To-day the green-manure fallow has taken its place among progressive farmers.

[2] "Field Management and Crop Rotation."—Parker.

The Use of Legumes.—As previously stated, the Romans were aware of the beneficial residual effect of these plants on the land, and their use has been since then increasingly advocated. Towards the end of last century bacteriologists discovered the relationship that exists between legumes and nitrogen-gathering bacteria. This definite knowledge gave a decided impetus to the use of legumes, and to-day the greater number of rotations practised in all countries contain one or more of these plants.

Rotations.—In a sense Varro had advocated rotative cropping, and it is known that in a very intensive manner the Chinese have practised crop rotations for centuries. Systematic crop rotations, as understood to-day, were not common until the beginning of the eighteenth century, when Lord Townshend introduced the famous Norfolk rotation. The subject of rotation is dealt with more fully in a later chapter.

Manuring.—The beneficial effect of the use of animal excreta on the soil, and even the superiority of that of certain animals over others, was known to the ancients, and the liming of soils had been practised in the days of Varro. However, it was not until after de Saussure, about 1805, had shown the mineral character of plant-food that the use of artificial manures was practised. Their use has grown rapidly in all parts of the world and they are utilised in the cropping systems of all countries to-day. Apart from the points abovementioned, the remarkable advance in field husbandry of the last two centuries is due to a great many factors, chief among which are the following :—

(1) The discovery of the gaseous assimilation by plants. (2) The use of improved farm machinery. In 1701, Jethro Tull invented the seed-drill, to be followed afterwards by others, with improved ploughs, and, later, mowing and threshing machines. (3) The application of genetic laws to the improvement of plants. (4) Economic entomologists and plant pathologists came forward with remedial measures against insect pests and plant diseases. (5) The establishment of technical agricultural institutions.

Agronomy and Animal Husbandry.—History shows that the productivity of the soil is best maintained, and often increased, in those parts where the rearing of animals is an essential feature of the farming practised; more particularly, of course, where concentrates are fed and the manure returned to the soil. Again, a study of the development of agriculture shows conclusively that, as a system of permanent farming, the practice of utilising the land for pasturage and at the same time feeding the greater part of the crops grown and returning the manure to the soil, has characterised those parts where agriculture is stable and prosperous. Moreover, in a given region, the possibilities for animal production are ultimately dependent upon the potentialities of that region for crop production.

Development in South Africa.—In much the same way as in other countries, field husbandry practice in South Africa was based on a single cropping system. Wheat was, and still is, the principal crop in the Western Province. In a short while the introduction of the bare fallow (braaking) was found necessary, and in that area it is only of recent years that the necessity for crop rotations, manuring and the rearing of stock as an integral part of profitable and permanent farming have been recognised.

It is to be expected that in a new country crops were grown in parts totally unsuited to their profitable cultivation; *e.g.*, wheat in the Eastern Province and Natal. Experience has demarcated the cultivation of the various crops into distinct zones; so that to-day we have a maize belt, definite wheat areas, a sugar cane belt, and so forth. Until recently South Africa imported a great deal of ordinary farm produce, such as meat, butter, eggs and maize; all of which are to-day being exported. In the history of any agricultural country a time comes when agricultural development progresses from petty local trade into world commerce. This stage may be said to have commenced in South Africa in 1907, when maize was first exported in quantity, and to-day the increasing value of her exported agricultural products is fast decreasing the disparity that existed between her exports from mining and agriculture. The total production directly from the soil (apart from the animal industry) approximates in value that of mining. However, bearing in mind our agricultural resources, a survey of the agricultural production of other countries, more favoured in regard to the possibilities of agriculture, forces one to the conclusion that South Africa will never compete seriously in the value of her agricultural production with countries like Canada or Argentine.

The remarkable change in field husbandry that has taken place during the last two decades is due to the introduction of technical men, the establishment of experimental stations and schools, and the importation by the Department of Agriculture of improved strains of crops.

THE SCOPE OF AGRONOMY.—While field husbandry in the broadest sense may be held to include horticulture, with its sub-divisions of pomology, olericulture, floriculture, and forestry, nevertheless it is customary to limit the study to the following crops :—

(a) Grain crops—*e.g.*, Wheat, rye, oats, barley, buckwheat and maize.

(b) Forage and fodder crops—*e.g.*, Lucerne and the various grasses.

(c) Root and allied crops—*e.g.*, Mangels, turnips and potatoes.

(d) Fibre crops—*e.g.*, Flax, sisal and cotton.

(e) Sugar crops—*e.g.*, Sugar cane and sugar beets.

(f) Drug crops—*e.g.*, Tobacco and tea.

The study of agronomy is too comprehensive to be fully dealt with in a small treatise of this nature, and where more detailed data are required the reader must consult the various texts. It involves, broadly speaking, four main avenues for investigation.

(1) *Edaphics.*—This includes a study of the chemistry, physics and biology of the soil in relation to plant culture.

(2) *Phenology.*—Here the effect of climate in relation to growth is studied, *e.g.*, temperature, humidity and movements of air, duration of light, etc.

(3) *Carpoics.*—Which involves a knowledge of plants as crop plants, and embraces questions dealing with adaptation (bionomics), plant breeding (genetics), cultural methods, and the control of pests (plant pathology and economic entomology).

(4) *Rural Economics.*—A study of rural communities, their organisations and problems.

Faculties of agriculture and schools of agriculture are now fully established in the Union, in which agricultural subjects form part of the curricula.

CHAPTER II

AGRO-GEOGRAPHICAL CONDITIONS IN RELATION TO CROP DISTRIBUTION IN SOUTH AFRICA

Agronomic production is, of course, directly correlated with the natural factors of production. It is necessary, therefore, to discuss these somewhat in detail :

Rainfall.—Too often the capacity of a region to produce crops is estimated on the average annual precipitation. That this, especially in South Africa, is misleading will be shown in the following discussion, in which the very important modifying influence of yearly fluctuation, seasonal distribution, character, evaporation and run-off of rainfall are taken into account.

The average annual rainfall on the east coast of England is only 26 inches; in Lincolnshire and Essex the averages are as low as 18 and 20 inches respectively, yet the lack of moisture is never so acute there as in parts of South Africa where the average is nearly 30 inches per annum. The reasons for this are as follow :—

(1) In this part of England the seasonal rainfall is more evenly distributed throughout the year; 20 per cent. of rain falls in spring, 23 per cent. in summer, 31 per cent. in autumn and 26 per cent. in winter.

In the Transvaal approximately 90 per cent. falls in the six hottest months.

(2) The evaporation from a free water surface near London is only 20.6 inches per annum, whereas in South Africa it ranges from 65 inches to 75 inches.

(3) The rain is of a soft, misty character in England, while in South Africa it is precipitated generally in heavy torrential downpours. Consequently the loss from run-

off, while negligible in England, becomes extraordinarily severe in South Africa. Instances are by no means uncommon in the Karroo, where the precipitation during 48 hours has equalled the average annual rainfall for that part.

LOCAL ANNUAL FLUCTUATIONS.—These should be noted most carefully, particularly in those parts of the country where the rainfall is below 30 inches per annum. The following examples will serve to emphasise the importance of this point :—

	Average 13.31 ins. Griquatown, C.P.	Average 18.80 ins. Bethulie, O.F.S.	Average 23.69 ins. Zeerust, Transvaal.
Year.	Total for year.	Total for year.	Total for year.
1901	14.39 ins.	—	—
1902	12.91 ,,	—	—
1903	5.73 ,,	—	—
1904	10.07 ,,	—	24.35
1905	8.92 ,,	—	17.26
1906	11.72 ,,	—	27.37
1907	17.03 ,,	—	28.87
1908	6.06 ,,	8.65	16.04
1909	18.54 ,,	29.24	39.79
1910	9.23 ,,	14.36	18.73
1911	15.15 ,,	22.67	28.73
1912	5.66 ,,	11.76	16.71
1913	15.18 ,,	16.33	20.01

Presuming these to be areas where crop production is general, which they doubtless would have been were the fluctuations more infrequent, and the rain less torrential, then an examination of these figures would tend to show that the farmer at Griquatown growing a crop which might be expected to give fair yields on 13.31 inches per annum would have crop failures during the years 1903, 1905, 1908, 1910 and 1913, while during the three years 1902, 1904 and 1906 he would have three very indifferent crops. Thus out of the thirteen years he would have five normal yields, five total failures and three probably poor crops. Out of the six years at Bethulie, the grower, relying on an average of 18·80 ins. per annum, would have two normal crops, three failures and an indifferent one. At Zeerust, relying on a rainfall of 23·69 ins., he would have five failures and five normal crops. A summary of this nature, while very theoretical, shows how often the expectation of an average annual precipitation might lead to disappointment.

In some areas, fortunately, the fluctuations are less, and in these crop-growing is more assured, *e.g.* :—

Bethal, Transvaal (average 30.39 ins.).

Year.	Inches.
1906	26.69
1907	35.3
1908	22.6
1909	39.81
1910	30.36
1911	33.83
1912	26.44
1913	22.84
1914	42.60
1915	32.88

Bethal is situated in one of the largest and most certain maize and potato producing districts in the Union. That it is so is attributable not only to the high average rainfall, but to the small yearly fluctuation. In the period taken, only once (in 1908) was the precipitation as low as 74 per cent. of the average annual rainfall, whereas at Griquatown, Bethulie and Zeerust, during several of the bad years, the rainfall was between 42 and 45 per cent. of the average annual rainfall.

In parts of Natal, too much rain occurs in some years, resulting in crop failures, because of the water-logged condition of the soil in those seasons.

Evaporation, Character, Distribution and Run-off.—In considering the dissipation of the rainfall, these factors are intimately connected. Generally speaking, in a country like South Africa, where the evaporation is usually three to four times as large as the precipitation, a precipitation of half an inch or less is of very doubtful utility, since the penetration of the rain is so small that the evaporation of the whole would take place probably before capillary connection with the lower soil moisture has been accomplished, and before succeeding showers have taken the penetration to an effective depth. Over the greater part of South Africa 20 to 30 per cent. of the annual rainfall occurs in light showers of this nature, which on the whole is of very little advantage in crop production. With the exception of a few localities, to be mentioned later, the rainfall in the Union is mainly of a pelting, torrential character which soon deflocculates the surface soil particles into a relatively impervious layer. The air is imprisoned in the interstices of the soil, consequently the water is admitted very tardily and the run-off becomes very heavy. The amount of run-off depends largely, of course, on the topography of the ground, whether mountainous or otherwise, the nature of the soil and the date of the occurrence of the last rains. If the region is mountainous and rocky, the run-off might very well be as high as 80 per cent., and on heavy clay soils it will naturally be much higher than on porous, sandy soil. It is not an exaggeration to say that under most South African conditions, when measured agronomically, the run-off varies from about 20 per cent. to 80 per cent. of the rainfall occurring in heavy showers, and is seldom as low as 5 per cent.

The causes are now sufficiently clear of the low crop productivity in South Africa as compared with parts of England or countries similarly favoured, notwithstanding a superior total rainfall.

Seasonal and Annual Distribution Throughout South Africa.—The average annual rainfall in South Africa varies from about 50 inches on the Natal coast to less than 2 inches at Luderitzbucht, on the coast of the South-West Protectorate. With the exception of the south coast and the south-west corner of the Cape Province, the rainfall decreases from east to west, and naturally the agriculture changes in correlation.

At Wemmer's Hoek and Berg River Hoek, in the south-western Cape, the rainfall is as high as 200 inches per annum, and in some limited localities in the north-eastern Transvaal and near Maritzburg, in Natal, it is nearly 70 inches per annum. Over one-half of the territory comprised in the Union receives a rainfall varying from 20 inches to less than 5 inches per annum. Less than a quarter receives more than 24 inches, sufficient, in effect, for grain crops to be reasonably productive and profitable without the aid of irrigation. Nearly the whole of this latter territory lies in the eastern portion of South Africa, in which about 80 per cent. of the precipitation falls during the summer months.

The whole of Natal, Basutoland, approximately one-third of the Transvaal and Orange Free State, and less than one-tenth of the Cape Province, Griqualand East, Pondoland and a few isolated areas receive about 25 inches of rainfall during the year.

The Union, generally speaking, may be divided into three distinct areas as far as the seasonal distribution is concerned, viz.: (1) The winter rainfall area, which includes the Western

Province as far as Cape Agulhas and in which the precipitation is of a less torrential character than in the remaining areas. Here the rainfall is more effective, since the loss from evaporation is less because of the relative low temperatures found in winter. (2) The all-the-year-round area, which includes the coastal section from Agulhas to Port Alfred. (3) The summer rainfall area, which includes the coastal parts east of Port Alfred as well as the plateaux inland. The agriculture practised in these three areas is necessarily directly related to the seasonal rainfall. In (1) winter crops, in (2) summer and winter crops—though neither are very assured because of the torrential character of the rainfall—and in (3) summer crops are those which are most successful. Based on the average annual precipitation in the summer rainfall area, crops without irrigation are roughly successful as follows :—

Rainfall.	Crops.
45 inches and above.	Sugar-cane.
24-45 inches.	Practically all common summer field crops.
20-24 inches.	Peanuts, cotton, sorghums, millets and sunflowers.
15-20 inches.	Fodder crops such as Sudan grass and millets.
5-15 inches.	Saltbushes, prickly pear, Mexican aloe, Prosopis juliflora, etc., *i.e.*, perennial fodder trees and shrubs.

The cultivation of crops is rapidly becoming demarcated and characterised for the different rainfall zones, and doubtless will become more marked as experience of our conditions increases. Running from east to west up to the 24-inch isoheyt (isoheyt, an imaginary line connecting places which have an equal annual rainfall), summer grain growing is reasonably secure and the favourable precipitation has permitted the inauguration of more intensive farming. Thus on the high veld of the north-eastern Free State and the Transvaal, in East Griqualand and Natal, besides crop cultivation, dairy, pig, poultry and fruit farming are increasing markedly.

Between the isoheyts of 20 and 24 inches we find grain farming as the chief feature of agronomy is fast being supplanted by the cultivation of the more drought resistant cereals, *i.e.*, flint maize, grain sorghums and fodder crops.

West of the 20-inch isoheyt farmers are wisely paying more attention to fodder crops, except on irrigated land, where the winter cereals are still commonly grown. Even on this irrigated land there is evidence that lucerne will take the place of wheat and oats where soil conditions allow. A number are also recognising the necessity of growing fodder trees and shrubs, such as the saltbushes and spineless cactus, where climatic conditions are too uncongenial even for the drought-resistant fodder crops, *e.g.*, millets, Sudan grass, etc.

In the south-west Cape, where the rainfall is a wintry one and fairly high, the winter cereals, vetches, field peas and other winter crops are being grown. It is likely that in this region dairy farming will become a more prominent feature, as already the poor sandy soils are fast becoming unproductive, owing to the policy of growing grain for sale, instead of growing grain and fodder for stock on the farms. The latter policy will conserve the plant food, in that the manure of the animals will be applied to the lands. Where the grain is sold, naturally the land is severely drained of plant food, since the valuable elements in the grain are not returned to the fields from which the crops are taken.

In the south-eastern Cape, where the rainfall is a constant one, but for the greater part insufficient and too uncertain for summer or winter crops without irrigation, farmers are giving their attention more to the production of fodders than cereals.

On irrigated land in the Union both summer and winter crops are grown, and among the more progressive farmers the tendency is to grow fodder crops, if possible lucerne. While the possibilities for successful irrigation in the Union, especially in the lowveld, are undoubtedly immense, at the same time the pitfalls are numerous, and, before embarking upon this type of agriculture, the uninitiated should obtain full information in regard to the suitability of soils, alkali and silt. A wise policy is to stimulate individual enterprise rather than spectacular irrigation schemes, on which too much capital is often expended.

Hail and Snow.—Hail is of considerable severity in some parts, particularly in the middle districts of Natal, in the south-eastern Transvaal, eastern Free State, and in Kaffraria. While fruit growers are the chief sufferers from hail in the parts mentioned, it is also a serious factor to the grain grower. In the eastern Free State, where wheat and oats are sometimes extensively grown on dry lands, these crops mature in November and December, at a time when not only most susceptible to hail, but also when hailstorms are most prevalent.

Snow, unfortunately, is of infrequent occurrence and is usually confined to the mountainous districts, e.g., Basutoland and Barkly East.

Length of Growing Season.—This is affected by the days of the commencement of the rainy season, the intervals between killing frosts, the altitude and, of course, the latitude.

In some parts the commencement of the rainy season is frequently so late as to delay agricultural operations very considerably, and the growing season becomes a short and unsatisfactory one. This is especially the case in central and north-western Transvaal.

The modification of the length of the growing season by frosts is often a serious one, more particularly to the horticulturist, but also to the farmer dependent on summer crops. In the Karroo, at Colonies Plaats, records show that during the period of twenty years there is no month throughout the year in which frosts are not liable to occur. However, in general, the interval between killing frosts is usually sufficiently long not to affect the maturity of most of our commonly grown summer crops. It is in seasons when the commencement of rains is late that frosts are apt to be a very limiting factor.

As with the rainfall, it is found that there is a gradual increase in temperature along any parallel from west to east. This is true in a general way, provided the stations chosen to exemplify this are fair distances apart, since there are limitations imposed by local circumstances.

Almost throughout the whole of South Africa the mean temperature is approximately 62° Fah. However, the mean maximum and the mean minimum temperatures differ widely in the different parts. The mean daily range in temperature for the whole of South Africa is approximately 24.5° Fah. It is interesting to compare these with those occurring in the tropics, e.g., at Colombo, where the daily range is only 11° and the thermometer practically never registers lower than 75° or higher than 86°.

The peculiar and marked difference between the conditions on the east and west coasts alluded to has been accounted for by the fact that the warm Mozambique current washes the eastern shores in its southerly course, while the colder Benguela current in its northerly course performs an exactly contrary office for the western shores. The first gradually loses its warmth, while the second rises in temperature as it approaches the equator.

Altitude is also of importance in this connection. The growing season is naturally shorter and the nights often cooler on the inland plateaux than at low altitudes. Thus we find that cowpeas in high altitudes will be found more useful than velvet beans; flint maize better than dent maize, and so on.

Latitude naturally also affects the length of growing season, but its effect is not so apparent in the Union, because this is largely offset by the increase in altitude from south to north.

Soils of South Africa.—As must be expected from the widely differing geographical formations, the soils from these are very divergent in character and productivity. For example, those derived from the Bokkeveld series, composed of soft sandstones and shales, are very fertile soils and markedly different from the poor sandy soils formed from the often adjacent Table Mountain sandstone series, composed of highly siliceous rocks which weather into coarse, angular fragments.

In general it may be said that the soils of the sub-continent are markedly deficient in phosphates, but moderately well supplied with potash and nitrogen. That they usually contain sufficient nitrogen is fortunate, as the application of artificial nitrogenous fertilisers is an expensive item in countries not favourably situated in regard to supply.

It is impossible to deal with the subject of South African soils in detail. However, certain areas have predominating types, and these are briefly given :—

(1) *The South-West Cape*.—The soils of this region are on the whole poor in fertility, of a light, sandy texture, and of low humus content. Loams do occur, but unfortunately the physical condition of these has deteriorated owing to the poor methods of farming practised.

(2) *South and South-Eastern Coastal Belt*.—Fine sandy loams prevail here; the nitrogen content is usually higher than in those of the south-west Cape, and more lime is found, but phosphates remain low.

(3) *Namaqualand*.—Chiefly sandy soils, poor in humus and nitrogen, occur. In some cases calcareous soils are found, and a clay soil found in the Calvinia area appears to be well supplied with phosphates.

(4) *The Karroo.*—As a whole these are probably the most fertile in the Union. In some cases, due largely to the aridity of this part, alkali has proved a serious obstacle. Further, the heavy charges of silt carried in the irrigation waters of this part have an injurious effect on crops like lucerne. The Karroo abounds in dolerite, which accounts largely for the fertility of the soils found there.

(5) *North-Eastern Cape and Griqualand East.*—This area is to a great extent the extension of the Karroo area. In the Albert division a red sandy clay is found. Some very fertile soils are found, but in some parts of East Griqualand some extremely infertile soils occur. Throughout the soils are extremely variable in character and fertility.

(6) *Eastern Orange Free State and Transvaal Highveld.*—These soils are somewhat sandy in character, but much superior to the inferior soils of the south-west Cape and Namaqualand. On the whole they are deficient in phosphates. In both the Transvaal and the Orange Free State large tracts of heavy soils sometimes occur, which, because of their undesirable physical characteristics, are generally not well suited for the growth of ordinary crops.

(7) *Natal.*—Natal soils may be divided roughly into three types, viz. :—

(a) A compact calcareous clay loam, found in the sweet-veld and in most parts where crops are successful.

(b) An open red soil deficient in lime on which crops do badly.

(c) Soils of a very ferruginous character of poor physical condition. Aeration and soil moisture movement are poor, resulting in crop failures because of water-logging in wet seasons and drought in dry seasons.

(8) *Western Orange Free State.*—In the south the soils resemble those of the north-eastern Cape; possibly alkali is more prevalent, and in the north they are of a very sandy character, though fairly productive.

LABOUR.—As compared with North America, farm labour, generally speaking, is plentiful, cheap and at present inefficient. The South African farmer in many areas finds difficulty in obtaining labour because of the higher wages paid by the organisations of the big mining companies.

In the cotton growing areas, which coincide with the densely populated native areas, labour is plentiful and sufficiently efficient for the requirements. Much might be done to mitigate this inefficiency, as witness the eastern Free State, where the system in vogue, operating through a generation, has produced very satisfactory results.

The apathy of the European employer, coupled with the pernicious three months' system of the Transvaal, are the chief factors preventing the same efficiency being attained in other crop producing districts. The three months' system may be well adapted to ranching, but to no other system of farming.

Transportation.—Under the poor facilities for transportation, one finds one of the most serious drawbacks to crop production. This factor, coupled with the sparse population, is mainly the reason why some areas of enormous crop potentialities are relatively undeveloped. Unfortunately, too, South Africa does not possess the inland waterways offering cheap transportation such as are found in a country like Canada.

Capital and Rural Organisation.—On the whole farmers are under-capitalised for the projects undertaken. In most cases the South African farmer invests too much in acquiring his land, probably because he wishes to avail himself of the unearned increment due to the abnormal increase in the price of land found in young countries.

They are extremely unorganised, and in consequence the long term, cheap credit required by them is unobtainable, and they therefore farm under disadvantageous conditions with regard to capital when compared with their brothers in, say, Denmark.

Disease.—The development of some areas, particularly in the lowveld, has been seriously restricted owing to diseases like malaria in human beings and ngana in animals.

Natural Features.—The amount of arable land, owing to the rugged mountainous condition of the country, is very limited in parts like East Griqualand. Indeed, the percentage of valuable arable land in the Union is very much less than many optimists would have us believe.

CHAPTER III.

SOIL MANAGEMENT—TILLAGE, IRRIGATION, DRAINAGE AND BRAK SOILS

TILLAGE.

Jethro Tull (1674-1741) made the statement " tillage is manure," his belief being that if soil particles are sufficiently fine they can be absorbed by the plant. Although the reason he gave was incorrect, nevertheless the practice resulting from his belief proved to be substantially correct.

Tillage has been defined as " the manipulation of the soil by means of implements so that its structural relationships may be improved for crop growth." It includes the use of all those implements that are employed to stir the soil in any way in the practice of crop production. The most common operations performed with these implements are ploughing, harrowing, rolling and cultivating.

Objects of Tillage.—These may be briefly summarised as follows :—

1. To stir and loosen the entire soil to a sufficient depth for the roots of plants to extend themselves fully.

2. To pulverise the soil and to mix thoroughly its constituent parts.

3. To develop various degrees of structure and uniformity of soil conditions suitable for the planting of seeds and the setting of plants.

4. To modify the movements of moisture and air in the soil.

5. To place beneath the surface manure, stubble, stalks, and other organic matter, where it will be out of the way and where it will be rapidly converted into humus.

6. To destroy or to prevent weed growth, and in some cases to control insect pests. Weed seeds dormant in the soil are often (through tillage) induced to germinate, after which they can be destroyed by further tillage.

7. To promote optimum conditions for the development of beneficial soil micro-organisms.

8. To increase the available plant food.

9. To keep the soil in good condition during growth.

The most important function of tillage is the preparation of a good seed-bed, which may be defined as " land free from weeds and surface trash, sufficiently mellow to permit easy penetration of the plant roots, sufficiently compact to hold moisture, and to be free from large air spaces, and sufficiently fine in structure to bring many soil particles in contact with the seed and thus to supply an abundance of moisture to the germinating plant."[1]

TERMS COMMONLY USED.—Even a brief survey of the subject of tillage, such as given herein, necessitates the use of certain terms which are defined below :—

Texture has reference to the size of the individual particles of which a soil is composed.

Structure refers to the arrangement of soil particles independent of size, *i.e.*, the grouping of the particles.

Tilth has reference to the mechanical condition of the soil and is largely dependent upon the texture and structure of the soil particles. Good tilth implies a thorough, deep and strong granulation resulting in a well-marked crumb structure and, consequently, a friable soil.

Plasticity.—" Any material which allows a change of form without rupture, and which will retain this form not only when the pressure is removed, but also when dry, is said to be plastic."[2]

Cohesion.—" The tendency of the particles of a soil to stick together and conserve the mass intact."[2] The cohesion of a soil in the moist condition is generally known as " tenacity." Cohesion is closely related to plasticity.

Granulation.—" By this is meant the drawing together of the small particles around a suitable nucleus, so that a crumb structure is produced. It is nothing more or less than a condition brought about by a variable water film and the pulling and binding capacities of colloidal material operating at numberless localised foci."[2] In this condition plasticity and cohesion are at a minimum.

Puddling.—This process is directly opposed to granulation, and implies a complete breakdown of crumb structure. In a puddled soil plasticity and cohesion are at a maximum.

"*Light*" *and* "*Heavy*," when used in connection with soils, are terms referring to their mechanical condition—whether or not they are easily workable. Thus a sandy soil is said to be light on account of the ease with which it is ploughed. These terms have no reference to the specific gravity of soils.

Root-zone may be regarded as that layer of soil in which the roots of plants are distributed and in which all the physical, chemical and biological processes are most active.

Pore-space is the total volume of the spaces between the soil particles and usually amounts to about 30 to 50 per cent. of the volume of a soil. Structure to a great extent determines the amount of pore space. In puddled soils the granules are deflocculated (*i.e.*, broken down), the pore-space is at a minimum and, consequently, the aeration is poor. It has been estimated that in a clay soil of good granular condition 50 to 65 per cent. of its volume is pore-space, while in the same soil when puddled this is reduced to 25 to 45 per cent. The average size of the pores is more important than the total volume, and soils of intermediate texture, and consequently of intermediate size of pores, are suited to a large variety of crops and command the highest prices.

Hardpan is a layer of soil that is particularly dense and difficult to penetrate. It may be due to a thin stratum of clay or to the packing caused by continuously ploughing at the same depth; but in arid areas it is more frequently caused by the cementing together of soil particles under the influence of such substances as lime, iron compounds, carbonate of soda, etc.

Soil Tilth.—The promotion and maintenance of good tilth are of fundamental importance in crop production. The state of tilth is closely related to the condition of the soil in regard to granulation. A puddled soil is necessarily in a bad state of tilth, and the promotion of granulation is the first step towards improving the tilth.

The chief agencies which promote granulation, and consequently good tilth, are as follow:—

(a) *Wetting and Drying.*—The changes in volume due to alternate wetting and drying tend to reduce the soil mass into a large number of small aggregates, *i.e.*, granules.

(b) *Freezing and Thawing.*—The soil moisture on freezing exerts an enormous force, shattering the soil. On thawing the water is further distributed and on freezing again the soil is broken up to a further extent. Drying and freezing have a tendency to coagulate the soil colloids and by so doing promote a granular condition.

(c) *Plants and Animals.*—The root residues of plants upon decay assist granulation. Earthworms and other burrowing animals have also a beneficial effect on the tilth of the soil.

(d) *Addition of Lime.*—Lime tends to granulate clay, thus making it more friable.

(e) *Tillage.*—At the correct time, *i.e.*, under proper moisture conditions, tillage tends to promote granulation.

(f) *Drainage* assists granulation by the removal of surplus water.

(g) *Addition of Organic Matter.*—Decaying organic matter assists granulation directly, but also to a very large extent indirectly, due to its great changes in volume upon wetting and drying, thus making processes (a) and (b) more effective.

The chief agencies which destroy good tilth are :—

(a) *Excessive Moisture*, which causes deflocculation or breaking down of the granules. The poor physical condition of over irrigated (water-logged) soils bears testimony to this.

(b) *Tillage* at the wrong time, *i.e.*, when certain soils are too wet or too dry.

(c) *Depletion of Humus.*—The tendency of soil to settle and bake into large clods after years of cultivation is often due to humus depletion.

(d) *The Presence of Sodium Carbonate.*—This substance has a strong deflocculating effect. It is a characteristic constituent of black " brak " in soils.

When to Till.—The correct stage at which the various classes of soil should be tilled is indicated when a mass of moist soil pressed in the hand retains its form but does not show free water. A clay soil will become puddled if worked when too wet and if ploughed when too dry will produce a cloddy condition. Sandy soil, however, can be manipulated without detrimental results even when the moisture content is very high or very low.

A brief review of some of the fundamental facts relating to plasticity and cohesion of soils will make the matter clear. The following is a short summary of the remarks of Lyon, Fippin and Buckman in this connection :—[2]

"The main cause of plasticity is probably the presence of gelatinous colloidal matter, together with a certain optimum amount of water. These conditions facilitate the ready movement of the particles, while at the same time sufficient force is exerted to prevent the body from splitting apart at the time of movement or when the pressure is removed or the material dried. When highly developed, plasticity promotes ease in puddling. The three factors that affect plasticity to the greatest extent are texture, granulation and moisture. The finer the texture the higher the plasticity, and the more granular a soil the lower is the plasticity or the tendency to puddle when ploughed. The amount of water is the third vital factor. A soil will exhibit its maximum plasticity at a definite moisture content. This point will be somewhere between the flowing, or viscous, condition and the point at which a soil refuses to mould, or, in other words starts to become crumbly. With a soil such as clay, in which the plasticity is high, ploughing should be done when the moisture condition is such that there is no likelihood of puddling, and yet the soil will turn over with a maximum granulating effect . . .

"In general the greater the plasticity of a soil the higher is its cohesion. Cohesion exists under two conditions—when the soil is wet and when the soil is dry. When a soil is moist cohesion is developed by the moisture films and the colloidal materials that may be present (tenacity); when dry by the inter-locking of the particles and the deposition of cementing materials. The greatest force, however, is developed by the drying and shrinking of the gelatinous colloidal material. As a general rule the greater the amount of colloidal material, the more firmly the soil is bound together when dry, or, in other words, the greater is its cohesion.

"Cohesion is important in tillage operations, in that soils having a high co-efficient of cohesion tend to become cloddy when ploughed and may thus be rendered poor in physical condition. This may be avoided by timing the operation so that the moisture content is somewhere above the point at which excessive cohesion is exerted. As cohesion is not greatly developed, except in a heavy soil, it is only when fine texture is found that such a danger exists. The danger is a double one, for, since high plasticity and high cohesion go together, a soil ploughed when too wet may puddle, while one ploughed when too dry may clod. . . . "Every soil has a moisture zone at which neither cohesion nor plasticity is excessive.

The finer the texture the narrower is this zone, *i.e.*, the shorter the period during which good ploughing can be done. Granulation lowers cohesion and plasticity, thereby widening the moisture zone for proper ploughing. It follows then that the promotion of granulation tends not only to eliminate the danger of bad structural relationships, but also to bring the soil into condition for easier and more convenient tillage."

Soil Class.—Soils are composed essentially of varying proportions of sand, silt and clay, together with more or less decayed and decaying organic matter. The leading types of farm soils are roughly classified according to the relative proportions of these constituents present. The chief physical difference between sand, silt and clay is in regard to size of the particles. Thus, we may arbitrarily designate as sand all particles the diametres of which lie between ·04—1 mm; as silt, those between ·002—·04 mm; and clay those smaller than ·002 mm.

The clay properties are of great importance to fertility from both chemical and physical points of view. No soil constituent is more necessary in proper proportion; at the same time, however, no constituent is more harmful in excess. For practical purposes the sand properties may be regarded simply as the negatives of those which characterise clay, while silt occupies an intermediary position. The percentage of clay present is very generally the dominant consideration in determining the class of a soil. For our present purpose the following classification of soils, based on their relative content of the three "separates" as defined above will serve:—

(*a*) Coarse sands—consisting almost entirely of sand alone.
(*b*) Sandy soils—about 75 per cent. or more sand and a small amount of silt, but very little clay.
(*c*) Sandy loams—about 50 to 75 per cent. sand, a fair amount of silt and about 10 per cent. clay.
(*d*) Loams—about 40 to 50 per cent. sand, 10 to 15 per cent. clay, and the rest silt.
(*e*) Clay loams—about 15 to 25 per cent.; the rest sand and silt.
(*f*) Clays—about 25 to 35 per cent. clay; the rest sand and silt.
(*g*) Heavy clays—over 35 per cent. clay; the rest mainly silt.
(*h*) Silt loams—about 50 to 75 per cent. silt; 10 to 15 per cent. clay; the rest sand.

(*i*) *Silts*—more than 75 per cent. silt and a small amount of sand, but very little clay.

The name in every case indicates the fraction whose properties dominate in the soil, except in the case of loams, where the properties of no one fraction dominate.

It is understood, of course, that all normal soils contain a small amount of organic matter, and frequently also a small amount of free carbonate of lime. When present in relatively large quantities these substances modify the soil structure to such an extent that the above classification is of little or no value, and the soil is given a class name which indicates the dominance of organic matter or lime, as the case may be.

TILLAGE, TREATMENT AND CHARACTERISTICS OF VARIOUS SOILS.—(1) *Coarse Sands*.—These are quite useless for general farm crops and will, therefore, not be discussed.

(2) *Sandy Soils*.—Their cohesiveness is low, consequently they are light (easily worked) and in extreme cases show a tendency to blow. They are generally poor in plant food and leach readily, especially if the particles are large. Their retentive power for moisture is low, but the movement of soil moisture is rapid. Consequently, they are apt to dry out quickly and very soon suffer from drought. Irrigations must be more frequent than on the heavier types of soil. Sandy soils are usually poor for general farming crops, but since they warm up rapidly they are eminently suitable for vegetable-growing. Moreover, in the intensive cultivation practised by the vegetable-grower, heavier applications of manures are employed than can be afforded by the ordinary farmer. The former finds it profitable to maintain and to increase the fertility of a sandy soil, while the latter may find it uneconomical.

Organic matter is required to give body to these soils and increase their moisture retention. Consequently, their treatment should include a rotation having a leguminous green-manure. Stable or kraal manure is particularly valuable for these soils.

The character of the sub-soil must not be overlooked, since a sandy soil resting on a more impervious sub-soil may be a very good soil for general farming. On the poorer types sweet potatoes and rye are the most successful crops.

(3) *Sandy Loams*.—These possess the same characteristics as sandy soils, but in a less marked degree. They are more retentive of moisture and plant-food, fairly easy to

work and, on the whole, are fairly good for ordinary farm crops. Rye, maize, potatoes, peanuts and lucerne are among the best crops for these soils.

(4) *Loams*.—These are the most useful " all-round " soils, combining the lightness and earliness of the sands, with the strength and retentiveness of the clays. They are easily manipulated, do not readily crush or crack, and are usually well supplied with plant-food. Water moves through them freely yet they do not leach badly. Practically all farm crops thrive satisfactorily on loam soils. They require no special treatment, except such attention to good tillage, manuring, and the addition of organic matter as is a necessary part of a good farm practice.

(5) *Clay Loams, Clays and Heavy Clays*.—Soils containing a high percentage of clay are often worthless for ordinary cropping. However, the lighter types under favourable conditions may be considered to be among the most productive of soils. Their characteristic properties are to a great extent the reverse of those of sandy soils. Air and moisture move slowly through them, the percentage of colloidal matter is higher than found in sandy soils, and they are more retentive of moisture and plant-food than the lighter types of soil. They tend to form surface crusts after rains and on drying-out crack badly. The cracking is due to the great shrinkage of the gelatinous colloidal matter when drying-out.

The treatment of a clay soil should be of such a nature that it will remedy the chief defect of this type of soil—viz., heaviness. This may be brought about by green manuring, tillage at the right time, drainage where the soil happens to be waterlogged, and by liming.

Clay soils are usually rich in plant-food, and plants once established in them thrive well. Grasses and wheat are the most profitable crops on these soils. They are relatively difficult soils to work, because when too wet they puddle readily, and ploughing when too dry results in a cloddy condition. When too wet, plants growing in clay soils suffer from poor aeration, and during drought crops suffer prematurely. They heat up slowly and are therefore looked upon as cold soils. While sandy soils should be disturbed as little as possible by tillage, clay soils should be worked as often as is economically possible.

(6) *Silt Loams and Silts*.—These soils exhibit the same qualities as clay loams and clays, but to a much less marked

extent. As a rule they possess sufficient tenacity to give the necessary stability without being unduly heavy. They are highly retentive of moisture, yet sufficiently coarse to allow free movement of water, and consequently form some of the best soils for resisting drought. They are well supplied with plant-food, are suited to a wide range of crops and are generally highly productive.

In some cases the quantity of fine silt present is so large that the soil is very intractable, closely resembling clay. Liberal incorporation of organic matter will most efficiently remedy this condition.

Implements and Their Uses.—According to their effect on the soil implements may be divided roughly into two groups: (1) those that loosen the soil, *e.g.*, ploughs, and (2) those that compact the soil, *e.g.*, rollers.

Ploughs.—"The primary function of a plough is to take up a ribbon of soil, twist it upon itself and lay it down bottom side up or partially so. In the process two things result: (1) If the soil is in proper condition for ploughing it will be shattered and broken up. The furrow slice is sheared or split into many thin layers both vertically and horizontally, resulting in the complete pulverisation of the soil; (2) the soil is partially inverted and any rubbish is put beneath the surface."

The degree to which ploughs will pulverise the soil is dependent on the condition of the soil, the type of plough and the rate at which it is drawn along.

Ploughs are of two general types: the mouldboard and the disc. The latter has a lighter draft for the same amount of work done because of its rolling friction as opposed to the sliding friction of the former. While not suited to sod or stoney land, the disc plough is especially effective on very dry, hard soil, and for turning in and covering rubbish.

The mouldboard ploughs have more varied shapes and consequently more varied uses than the disc ploughs. For general purposes those having a decided overhang are the most useful, because they have a marked pulverising action. On the other hand, those with a long sloping mouldboard are more adapted to ploughing sod land, because the furrow slice is well packed against its neighbour without being broken.

Besides taking the precaution to plough only when the soil is in a suitable condition, some other considerations should also be observed. The furrow slice should not be completely inverted but should be at an appreciable angle with the horizontal. By so doing a mat of vegetation does not separate the soil from the sub-soil, consequently soil moisture and air move to better advantage, and in subsequent operations the organic matter is better distributed throughout the soil. A drag chain is of service in ploughing under ground heavily covered with vegetation, and a coulter lessens the draft and gives a clear cleavage. Harrowing, if required, should always follow ploughing almost immediately, because the soil is not so liable to form clods as when a period of a day or two or even a few hours is allowed to elapse.

The Sub-Soil Plough "consists essentially of a small mole-like point on a long shin. It is drawn through the bottom of the furrow and loosens the sub-soil to a depth of 18 inches to 2 feet without mixing the sub-soil with the soil." Its use in South Africa has never been popular. It is apt to loosen the soil to such an extent that excessive drying-out will take place. Moreover, since the condition of the sub-soil cannot be readily seen, if of a clayey nature, it may be badly puddled by sub-soiling.

The Lister Plough is a double mouldboard plough, used in the drier parts for planting maize and sorghum in the furrow. It leaves the ground in ridges which, by subsequent cultivation, are spread over the roots of the plants. It is used chiefly in sandy soils, and is supposed, by promoting lower root growth, to enable plants to withstand drought.

Cultivators.—These implements are to-day extraordinarily varied in design. They are used chiefly for destroying weeds, reducing clods and for bringing the soil into a good condition for seeding purposes. Wheeled cultivators are fast coming into general use and have many advantages over other types, *e.g.*, the depth of cultivation can be better regulated, the man operating them is less fatigued, and they are easier to manipulate.

The spike-tooth, smoothing, spring-tooth and disc harrows and weeders are used to level the ground as well as to loosen and pulverise the surface of the soil. The spike-tooth is used for shallow cultivation, the spring-tooth for deeper cultivation and the disc harrow often takes the place of the plough in deep soils. Weeders are modified spring-tooth harrows, having numerous long, narrow prongs, used principally for killing weeds while in the seedling stage. Harrows are also used for covering broadcasted seed. The use of cultivators must be regulated according to the stage of development of the crop.

At first inter-tillage of maize may be fairly deep and close to the row, but as the roots extend cultivation must become shallower, and more restricted to the centre of the space between the rows. In the early stage of growth, certain crops, like wheat and maize, seem to profit by harrowing, especially when heavily infested with weeds, or when small crusts have formed after showers.

Seeders may be looked upon as cultivators, since most of modern make stir the soil while seeding.

Packers and Crushers.—The action of the former is to compact the soil, while the latter by crushing clods acts as a pulveriser—the results having something in common. The best known of these implements in the Union is the ordinary barrel-roller, although experienced farmers are now using types like the Cambridge roller, which is more of a sub-surface packer. Hard, lumpy ground cannot be pulverised so easily by the barrel roller as by a corrugated roller. The latter has a number of V-shaped wheels, and in its action compacts the soil and leaves a mulch. The clod crushers are either barred, or more commonly, irregular-rimmed types of sub-surface packers, but not so heavy. These break lumps and, unlike the barrel roller, do not tend to push the clods into the soil without breaking them. The planker or float consists of a heavy, broad weight, which is dragged over the soil, the clods are rolled underneath, and by being ground together, their size is effectively reduced. "The soil at the same time is levelled, smoothed and, to a degree, compacted."

General.—With due allowance for the genuine difficulties which are often encountered, it is generally true that winter ploughing is not sufficiently undertaken in the summer rainfall area. Winter ploughing permits of earlier planting, makes the soil more receptive for the early rains, assists in controlling insect pests and promotes weathering.

Many of our farmers are unacquainted with some of the more modern implements, the use of which would not only facilitate their tillage operations, but would also prove profitable.

In some areas the soils are shallow and have extremely raw sub-soils. In such cases ploughing should at first be shallow and subsequently gradually increased in depth. Crops grown on these soils injudiciously ploughed are often disappointing in growth, having a stunted and yellowish appearance.

IRRIGATION.

The artificial watering of land for agricultural purposes is termed irrigation. It forms an essential feature in the profitable production of crops in areas of insufficient rainfall. The undesirable characteristics of the rainfall in many areas of the Union are such that the annual precipitation, although judged sufficient for the requirements for cropping in many parts of the world, must be supplemented by irrigation.

The main considerations may be discussed under the headings: (*a*) Climate: (*b*) character of the water supply; (*c*) nature of the soil; (*d*) surface conditions and topography of the land, and (*e*) kind of crop grown.

(*a*) Climate.—This has been dealt with in Chapter II. It cannot be over-emphasised that in parts of South Africa where irrigation is practised the evaporation is extraordinarily high—anything from 65 to 90 inches. This has a practical bearing on the duty of water and on the construction of reservoirs. With more depth many of the farm dams in the country would be more effective, even if less water were stored, than in the shallow dams so often found.

(*b*) The Character of the Water Supply.—The water of highest value for crops is the sewage from large towns. Such water has an added value due to its definite fertilising action. Irrigation with water of this nature is not confined to arid parts, as the larger towns are usually found in humid and sub-humid areas. Next in value to sewage water is the water of streams carrying considerable quantities of suspended matter and valuable salts in solution. The soils of the Nile owe their fertility to water of this nature, and afford an interesting illustration. When the sediment from turbid streams settles on sandy soils, they are not only enriched by the plant-food added, but their physical condition is greatly improved by the addition of silt and organic matter. In Egypt the old system of basin irrigation, which allowed the mud to settle out, kept the fields fertile for thousands of years. Recently introduced systems which have not permitted the utilisation of the mud have effected a rapid deterioration in the productivity of the Nile soils.

According to Juritz, a sample of Orange River silt from the Prieska District gave the following figures upon analysis:

	Per cent.
Water	5·99
Organic matter	14·81
Nitrogen	·099
Lime	1·444
Potash	·473
Phosphoric oxide	·221

Juritz says: "The specific gravity of the silt is 2·03 on the basis of the dry specimen, so that a cubic foot would weigh about 127 pounds. One acre of land covered with this silt to a depth of half an inch, thus receiving a deposit of 1,815 cubic feet, or 115 Cape tons, would, therefore, be enriched to the extent of 3,314 pounds of lime, 1,086 pounds of potash and 507 pounds of phosphoric oxide."

Some irrigation water in South Africa, having its source in dolomitic formations, contains a high percentage of lime. On this account lucerne, a crop preferring calcareous soils, will often thrive on relatively acid soils when irrigated with water of this nature.

Apart from the value indicated above, the fact that irrigation water often carries enormous numbers of beneficial soil micro-organisms should not be overlooked. On the other hand some waters in South Africa carry a high charge of dissolved salts, and the irrigated lands gradually become impregnated with those salts to such an extent that typical "brak" soil results. In this way the productivity of valuable fields may be ruined. In some cases, too, especially on lucerne lands in the Karroo, the silt carried in flood water forms a hard impervious surface which is very detrimental to the crops.

(c) The Nature of the Soil.—The following table indicates the importance of the soil factor in irrigation practice:—

Soil.	Final mean water content per cent.*	Approximate per cent. of water at which crops wilt.	Per cent. of available water.
Coarse sand	10·6	3	7·6
Fine sandy loam ...	18·0	5	13·0
Light silt loam ...	20·9	10	10·9
Clay	30·4	17	13·4
Muck	250·0	80	170·0

* Maximum capillary capacity.

It will be readily appreciated from the above that soils rich in humus, as well as those of fine texture, will not only have a higher percentage of available water than sandy soils without humus, but that they will require irrigation at less frequent intervals. In general sandy soils should receive water frequently, a small amount at a time. Clay soils and those rich in humus should require relatively large but less frequent applications, since their available water content is high, and percolation both slow and small.

The nature of the sub-soil is also an important factor. A sandy soil resting on a clay sub-soil will lose water by percolation very slowly. Again, a clay soil resting on a sandy sub-soil will require more frequent irrigations than a clay soil on a clay sub-soil, but the former will have a very much better mechanical condition and will suffer less from water-logging.

A point often disregarded is, that when grown on a highly fertile soil plants have a smaller water requirement than on a soil of low fertility. For this reason soils should be cultivated where practicable as soon after irrigation as possible, as this enables the various physical, chemical and biological changes to take place more rapidly. Working with maize, Widstoe[4] obtained the following results :—

Pounds of Water Transpired for One Pound of Dry Matter.

Soil.	Not cultivated.	Cultivated.
Fertile sandy loam	603	252
Fertile clayey loam	535	428
Infertile clay	753	582
Infertile sand	454	732

In every case, excepting the abnormal infertile sand, the careful stirring of the soil enabled the plant to produce one pound more of dry matter with a smaller quantity of water than when the soil was not cultivated. Apart from this, with increasing richness in available plant-food, the rate of evaporation of water from the soil tends to decrease.

(d) The Surface Conditions and Topography of the Land.—On this will depend the method of water distribution. "Flooding" and "furrow" irrigation are the two methods commonly employed. The former method is used as a rule on gently sloping land, while furrows are used where the slope is more decided, where the water supply is limited, and for certain crops like potatoes, tobacco, etc. Flooding is conducted in two ways. One way is to cover the field with a thin sheet of running water, maintained until the desired degree of saturation has been reached. The alternate method is to cover the surface with a sheet of standing water until the soil has absorbed enough, when the balance is drawn off; or, more simply, to place as much water as is desired upon the land and allow this to be completely absorbed. Flooding is used mostly for crops like the winter cereals and lucerne. The preparation of the land for flooding may be briefly described as follows:—When ploughing is commenced the entire fields are divided into lands about 10 to 15 yards in width, so that after the ploughing and harrowing is completed the land forms parallel ridges at the same distance apart; along these parallel ridges furrows are made by using a double mouldboard plough, which throws the earth both ways and thus forms distributing furrows. The ridge of earth on either side of each furrow serves as a border, which prevents the return to the furrow of the water after it has been thrown out by damming. Too much care can hardly be exercised in the preparation of the land by levelling and obtaining a desirable slope for crops like lucerne. Often where the land shows a decided slope, a system of terracing may be found necessary, the terraces, of course, following the contour of the ground. In using the furrow method there is a danger of erosion. To minimise this the furrows should closely follow the contour of the ground. The furrows may be from two to five feet apart, depending upon the crop and the soil. Difficulty is experienced in obtaining an even distribution on account of variations in the soil and the length of furrows. Where a furrow is unduly long, the end nearest the supply receives generally considerably more water than the further end. It is, however, a method economical of water, giving a comparatively smaller evaporation from the soil than flooding, because the whole of the surface is not wet. In this connection it is worthy of note that a wet soil surface loses water by evaporation more rapidly than the same area of a free water surface. Furrow irrigation is the only practicable method for inter-tilled crops like potatoes or mangels.

(e) THE KIND OF CROP GROWN.—The duty of water or the quantity of water needed to mature the crop will vary with the different crops grown. "The *absolute* duty of water is the total amount that the crop receives by irrigation, by rainfall, and that contained in the soil. It is expressed as acre-inches. The *net* duty of water is the amount actually delivered to the farmer through his head-gate."[5] The duty of water varies according to (1) the rainfall; (2) porosity of the soil; (3) fertility of the soil; (4) the frequency of irrigation and amounts applied; and (5) the average humidity of the air.

Crops require to be irrigated when the soil moisture has reached the point of lento-capillarity, *i.e.*, the point at which the capillary movement of the soil moisture becomes too slow to satisfy the requirement of the crop. At and below this point the plant is obliged to expend an unnecessary amount of energy in securing water. At this stage the plants become flaccid and a slight change of colour in the leaves and stalks is apparent. In general irrigation should be curtailed during the early development of crops, so that a deep root development may be stimulated. In the case of grain crops, irrigation should be liberal from the time of flowering to just before maturity, because during this stage translocation of food material and various anabolic processes which involve the use of water are most active. In South Africa the most common error of farmers who have abundance of water at their disposal is over-irrigation, particularly during the early stages of growth. Often, too, the fact is overlooked that, although increased irrigation may give increased yields, it is apt to do so at an increased water cost. Where the amount of water available is limited, and land relatively cheap, the yield per acre is not as important as the yield from a given quantity of water. Widstoe[5] found that the amounts of dry matter in pounds produced by the same quantity of water (30 acre inches) spread over one acre and four acres respectively were as follow :—

Crop.	One acre.	Four acres.
Wheat	6,951	22,180
Maize	15,294	43,028
Lucerne	8,133	3,272
Potatoes	3,660	10,920

The approximate amount given per irrigation may be taken as 3 inches for a light, 5 to 6 inches for an average, and 8 inches for a heavy irrigation.

The irrigation of specific crops is dealt with in later chapters in which the various crops are discussed. It should be borne in mind that for all crops, where possible, the soil should contain sufficient moisture at the time of planting to ensure germination and a vigorous seedling growth.

EFFECT OF IRRIGATION ON THE CROP.—Liberal irrigation tends to delay maturity, to increase the percentage of carbohydrates and ash, and to decrease the protein content of the crop. Besides these effects it is apt to encourage lodging in the cereals and to predispose them to disease, *e.g.*, rust. Injudicious irrigation often has the effect of promoting vegetative growth at the expense of fruiting. Losses due to frost may sometimes be lessened by irrigating when frost is expected.

DRAINAGE.

Land drainage is the quick removal of the excess of free water from the pores of the soil.

Effects of Drainage.—(1) Gravitational water is removed by drainage from the pores of the soil and replaced by air, thus ensuring a sufficiency of oxygen. A deficiency of oxygen restricts plant growth, and therefore the crop yield. Moreover, this deficiency results in an increased activity of anærobic bacteria, with the result that nitrates may be reduced to injurious nitrites or even to nitrogen gas, which is then lost from the soil. Harmless ferric compounds may also be changed into harmful ferrous compounds.

Further, by drainage the water is lowered, thus enabling crops to root deeper, and, what is more important, abnormal fluctuations of the water-table are reduced. Crops, which may be thrifty with a water-table at a reasonable depth, are in many cases destroyed should the water-table rise considerably for any length of time. A water-table fluctuating widely in its distance from the surface is often more inimical to plant growth than one which is relatively stationary, even if comparatively shallow.

(2) In a water-logged soil the crumb structure becomes broken down, and the tilth of the soil suffers in consequence. Under these conditions aeration, too, is poor. Drainage induces the formation of granules, thus improving the tilth, and incidentally allows longer periods for tillage operations after rains or irrigation.

(3) Drainage does not remove available water. In fact, by reason of the improved tilth of the soil and the deeper penetration of the roots of plants, a larger amount of capillary water is made available, and it is found that on drained land crops withstand dry weather better than on land intermittently water-logged.

The fluctuations of soil moisture are much greater near the surface than deeper down, where the moisture content is relatively uniform; therefore the deeper the root zone the more uniform is the water supply likely to be.

(4) Drained soils have a higher average temperature than similar soils in an undrained condition, consequently an earlier growth is obtained on the former than on the latter. Sandy soils, as compared with clay soils, are looked upon as warm and early, due to the fact that the water-holding capacity of clay soils is higher than that of sandy types.

(5) The supply of available plant food is increased by the better aeration, higher temperature, deeper root penetration, better tilth, better moisture supply, and more active and favourable bacterial growth in the soil, all of which conditions result from improved drainage of a wet soil. The organisms that cause the decay of roots and manure and those that use the free nitrogen of the air are particularly affected in a beneficial way.

(6) Drained land is more receptive of moisture either in the form of irrigation or rain, and because of this incidentally checks erosion.

(7) The provision of adequate drainage prevents the accumulation of brak salts in the surface soil. This is in fact the only method of keeping land permanently free from harmful accumulations of brak salts in areas where the trouble is common.

The necessity for drainage is indicated when the tilth of the soil is poor, where the crumb structure of the particles is absent, where the water-table is within 2 to 3 feet of the surface, and where the growth of the plants is of an unthrifty character and the vegetation of a yellowish colour. Where land is relatively cheap, as in South Africa, artificial drainage will be restricted to land which for some outstanding reason requires it, *e.g.*, horticultural land near a homestead. However, in parts of Natal and Griqualand East, where arable land is often scarce, due to the mountainous character of the country and the high rainfall, drainage effected by open furrows has been profitable and necessary. In many parts of the country land under irrigation might be profitably drained with some cheap form of under-drainage.

Types of Drains.—The oldest, apart from open surface ditches, but the least efficient, are those which are made by placing loose stone or closely packed logs in furrows which have been dug with the necessary fall, and then filling in with soil. These are usually short lived.

The objection to open surface ditches is that they are difficult to keep free from weeds and, further, that they restrict cultural operations and occupy valuable land. However, a great deal of unprofitable land can be reclaimed by this method. Care should be taken that the sides are sloping so that they do not become under-washed and subsequently collapse.

The most efficient system is tile-draining. Two kinds of tile are in common use—(1) clay tile, well burned, cylindrical and straight, and (2) concrete tile, both being made in about 12-inch lengths. These are placed end to end at the bottom of the furrows, the joints being uncemented. The water percolates through the sides of the tile and through the joints and then down the drain.

System of Drainage.—Naturally the outlet should be towards the lowest part of the land, and the mains should run along the lines of natural drainage. The laterals are generally single lines serving as collecting drains and usually arranged in parallel systems. Intercepting or cut-off drains are those laid at the base of a slope to collect the water that the heavier sub-soil layers are carrying to the lower level lands.

Depth and Distance Apart of Drains.—These are matters of extreme importance and are governed by a number of considerations. From the point of view of drainage, the sub-soil is of more importance than the surface soil. In general the finer the texture the shallower the drains and the closer together must the lines be placed. The depth varies from 2 feet in heavy soils to 4 feet in more open types. In clay soils the drains are usually placed from 40 feet to 60 feet apart, whereas in open sandy soils they may be placed from 80 to 150 feet apart. Naturally, too, in most soils, except heavy clays, the deeper the drains are placed the wider should be the intervals between the lines. The size of the tile will vary according to the area to be drained and the grade. The laterals usually consist of 4 to 6 inch tiles, while the sub-mains and mains are composed of tiles 9 and 12 inches in diameter. The grade should be as steep as possible, with a fall not less than six inches in every 100 feet.

Obstructions may be caused by roots, animals and silting. Usually little difficulty is found in locating these, and if the ends are closed with small meshed wire-netting, small animals will be prevented from entering. It is remarkable how seldom even a deep-rooted crop like lucerne will obstruct a drain.

BRAK SOILS.

The two great factors withholding from cultivation millions of acres of land in arid and semi-arid parts of the globe are drought and brak; and even if the drought factor is eliminated by irrigation, the presence of brak may still prevent successful crop production. In fact, practical experience has demonstrated time and again that the brak evil may be greatly aggravated by irrigation, and in many cases brak salts appear in the surface soil in harmful quantities only after the land has been brought under irrigation.

Brak is commonly known as "alkali" in America and other countries. It refers to the presence of soluble salts in the soil in sufficient concentration to injure plants, and may include salts which in smaller concentration are decidedly beneficial to plant growth, *e.g.*, nitrate of soda.

All arid soils are, of course, not necessarily affected with brak, but arid conditions in general are favourable to the accumulation of brak salts, whereas humid conditions are not. In the latter case abundant rainfall, coupled with natural drainage, will effectively prevent any harmful accumulation of soluble salts.

Arid and semi-arid conditions prevail over a great part of South Africa, and brak is very commonly present in the soils of these areas. Furthermore, irrigation is playing an ever-increasingly important part in South African agriculture, so that the brak problem demands, and must receive, particular attention in this country.

Frequently the concentration of brak salts in the surface soil is not as yet sufficient to injure crops, but unless proper precautions are observed, the almost invariable natural tendency is for the concentration to increase.

Crops vary greatly in their tolerance for brak soils, so that concentrations which are decidedly injurious to certain crops may have no harmful effect upon others. There is, however, a limit to the amount of brak which can be tolerated by any crop, and occasionally the concentration is so high that the growth of ordinary farm crops is impossible. The natural vegetation of such lands is generally confined to plants useless to man, known commonly as "saline vegetation." Notable exceptions occur, however, as instanced by much of the Karroo vegetation which forms valuable pasture, and by Australian salt bushes, which are readily eaten by all kinds of stock. In extreme cases brak lands are wholly destitute of vegetation, or bear only such saline growth as is rejected by all domestic animals.

Reclamation of land badly affected with brak is very costly, and frequently not worth attempting, save in the case of exceptionally valuable land; but if the brak tendency is recognised while the concentration is still small and comparatively innocuous, the adoption of simple precautionary measures may prevent further accumulation and maintain the crop producing power of the land indefinitely.

A noteworthy feature of brak soils is the fact that high concentration of soluble salts generally coincides with richness in plant food, so that these soils are characterised by high potential fertility, which manifests itself in the good crop yields following removal of the brak salts or their reduction to innocuous concentration.

Nature and Composition of Brak.—In general brak may consist of carbonates (or bicarbonates), chlorides, sulphates and nitrates of sodium, potassium, calcium and magnesium, with the following reservations :—

(1) Sodium salts are almost invariably the chief constituents, particularly the carbonate (or bicarbonate), chloride and sulphate.

(2) The bicarbonate and sulphate of calcium are not sufficiently soluble to be directly injurious.

(3) The quantity of potash salts present is generally low, forming as a rule from 5 to 20 per cent. of the total salts.

(4) Sodium phosphate is fairly frequently a constituent of brak salts, though never present in large quantities. It may form up to about 4 per cent. of the total salts present.

Two general types of brak are recognised, the "black" and the "white" varieties.

Black Brak is characterised by the presence of sodium carbonate (or bicarbonate) in considerable quantity. This substance has a solvent effect upon soil humus, thus imparting a dark colour to the soil solution and any incrustation that may appear on the surface of the soil. As a rule there are also present more or less sodium chloride and sulphate, a little sodium phosphate (due to the solvent effect of sodium carbonate upon insoluble phosphates in the soil), and probably small amounts of potash salts, but no sulphates or chlorides of calcium or magnesium, and very little or not nitrates of any description.

White Brak consists essentially of chloride and sulphate of sodium, together with smaller quantities of the corresponding salts of potassium, and very frequently more or less sulphate and chloride of magnesium and calcium. When these salts come to the surface of the soil they may frequently be seen as a white incrustation. Little or no sodium phosphate is found in white brak, but occasionally large amounts of nitrates are present, up to 20 per cent. of the total salts.

The black variety is far more injurious than the white in its effect upon both soil and plant.

ORIGIN OF BRAK SALTS.—For the present purpose it is unnecessary to consider in any detail the various natural agencies responsible for the existence of brak in soils.

Brak salts are, of course, ultimately derived from the decomposition of soil-forming minerals. When leaching occurs the soluble salts are carried away, but in comparatively dry areas gradual accumulation during ages of decomposition may account for the brak condition of the present.

In other cases the underlying shales and sandstones have been found to be richly impregnated with pre-formed soluble salts, which readily account for the presence of these salts in the soils. Such shales and sandstones are said to have been deposited in past ages from inland seas and lakes containing large quantities of soluble salts.

In still other cases the existence of brak is attributed to more recent evaporation of saline lakes and shut-off arms of the ocean, the soluble salts of course being left in the soil.

The occasional occurrence of considerable quantities of nitrates in soils has been traced in some cases to pre-formed nitrates found in the underlying shales and sandstones; in others it is attributed to intense local nitrogen fixation by non-symbiotic bacteria.

Secondary reactions are liable to occur in the soil with the possible formation of carbonates of sodium and potassium from other less injurious salts of these metals.

Finally, of great significance in present soil management, the use of impure water for irrigation may at least in part account for the presence of harmful salts in the soil. Seepage water from brak areas or from rock formations rich in soluble salts should never be used for irrigation. The safety limit of soluble salt content of irrigation water will vary according to the soil, the crop, the amount of water applied, the drainage and other factors. Hilgard states that 685 parts per million should be the limit under average conditions, though as little as

342 parts per million of sodium carbonate alone may cause serious injury in three or four years, while as much as 2,740 parts per million of the less toxic salts would not be harmful. Mackie considers from 600 to 700 parts per million to be the limit when the salts are mainly sodium bicarbonate and sodium chloride; when the salts are largely of the sodium sulphate type, larger quantities are permissable. Harris considers that under average conditions the limit is 500 parts per million for sodium carbonate, 1,000 parts for sodium chloride, 4,000 parts for sodium sulphate, and for the mixed salts, 4,000 parts per million; on poorly drained soils the limits must be placed lower.

MOVEMENT OF BRAK SALTS IN THE SOIL AND THE EFFECT OF IRRIGATION.—The greatest problem in connection with the utilisation of brak soils is to control the movement of the soluble salts. If kept in the lower depths of the soil, brak salts would be harmless, but it is their natural upward movement and gradual accumulation in large quantity in the top foot or two that finally ruins the land.

Under natural conditions in arid regions, when the water-table is far below the surface, the soluble salts tend to accumulate, not at the surface, but at some little distance beneath, approximately at the lowest point to which the natural rainfall penetrates, perhaps three or four feet deep. The actual point of maximum accumulation will vary according to the rainfall and the porosity of the soil. Any soluble material in the upper soil is carried downward by percolation, and the subsequent upward movement of the moisture by capillarity is greatly restricted, because the rather deep-rooted vegetation extracts most of the water rapidly at some depth below the surface, and at the same time the rapid drying of the surface soil reduces the upward capillary movement of the moisture. Thus the soluble salts are generally not brought to the surface to any appreciable extent.

When such lands are brought under irrigation, however, this condition of balance is upset. The soil is kept so much more moist that capillary action is greatly increased and considerable evaporation takes place at the surface. The soluble salts then move upwards and are left at or near the surface. When drainage is poor the condition is still worse, for then the water-table may be raised to within a few feet of the surface. Soluble salts washed downwards in such cases go only as far as the water-table, and are later readily drawn up to the surface again.

Harmful Effects of Brak Salts.—The injury to crop production due to the presence of brak salts in the soil is partly direct, due to their harmful effect on the plant and germinating seed, and partly indirect, due to their effect upon the soil and its micro-organic flora.

Summarised briefly, the following are the most important points :—

A. Injury to Plants.—(1) Plasmolysis of Plant Cells.—The high concentration of salts in the soil solution retards the rate of water absorption and therefore also retards general development. In extreme cases where the soil solution is more concentrated than the cell sap of the root hairs, the movement is reversed, water passing from the root hairs into the soil solution. This results in plasmolysis of the plant cells followed shortly by the death of the plant.

(2) Germination of Seeds.—If the soil solution is concentrated enough, water absorption may be entirely prevented, and the seed, therefore, fail to germinate. In this case it merely lies dormant in the soil. In less extreme cases the water absorption is retarded and, therefore, germination is delayed. In such cases the seed may take three or four times the normal time to germinate.

(3) Structure of Plant.—The presence of considerable quantities of soluble salts appears to affect the structure of plants. Harter, working with cereals found a very noticeable thickening of the cuticle and outer walls of the epidermal cells occurred, and a conspicuous bloom or waxy deposit formed on the surface of the leaves.

(4) Corrosion of Surface.—Particularly noticeable in the case of trees which have become well-established, and later subjected to a gradual accumulation of soluble salts at the surface. The effect is to corrode the plant at the base of the stem or trunk, *i.e.*, at the root-crown. The bark at this point becomes dark in colour and crumbles away readily. The corrosion may go deeper and partly or completely prevent the upward passage of food from the roots to the upper parts of the plant. This effect is most marked in the case of the carbonates of sodium and potassium.

(5) Direct Toxicity.—It is possible that certain brak salts exert a direct toxic effect on the plant, but to what extent this is a factor in the general injury to the plant is not known. Some of the salts are extremely toxic when alone in far lower concentrations than frequently occur in soils with little

or no harmful effect; but combinations of several toxic salts in solution often show greatly reduced toxicity, apparently due to antagonism between different ions, *e.g.*, highly toxic solutions of magnesium salts may be rendered innocuous by the addition of a small quantity of a soluble calcium salt. The absence of pronounced toxic effects in many brak soils is probably due to such antagonism among the various salts, and perhaps partly to adsorption of soluble salts by the soil.

B. Injury to Soil.—(6) Structure.—Carbonates of sodium and potassium are strong deflocculants. The presence of appreciable quantities of these salts in the soil then leads to puddling with all its characteristic harmful effects upon mechanical properties. Surface crusts may form of such hardness that seedlings cannot push through. Most of the other common brak salts are flocculants and do not injure structure, except in so far as they may be changed in the soil to the harmful carbonates referred to, *e.g.*, repeated application of nitrate of soda to lands is frequently observed to cause deterioration in physical condition, due not to the nitrate itself, but to the residue of sodium carbonate which is apparently left in the soil by this fertiliser.

(7) Hardpan Formation.—The presence of brak in soils seems to facilitate the formation of hardpan.

(8) Movement of Soil Moisture.—In general capillary movement is retarded by the presence of brak salts, though in low concentrations this effect is very small. Sodium carbonate appears to differ from the neutral salts in that it gives a much greater capillary rise than the neutral salts in equal concentration.

(9) Evaporation of Moisture.—Evaporation from the soil is lessened by the presence of brak salts, as these reduce the vapour tension of the soil solution. For this reason, brak spots in soils tend to remain moist much longer than the surrounding normal soil.

C. Injury to Micro-Organisms.—(10) While a great deal of the present evidence is conflicting, it seems to indicate that decreased bacterial activity is an important phase of the injury to crop production caused by brak salts. Ammonification, and nitrification in particular, are greatly retarded, in some cases at least.

Reclamation of Brak Soils.—Observations in regard to the growth of crops, coupled with chemical analysis, will clearly indicate the presence of brak. The limit of the quantity of salts that may be present without injury to crops varies greatly, depending upon the kind of salts present, the nature of the soil, the crops grown, and the drainage. In any case it is highly important to recognise the brak tendency before definite injury to crops occurs, so that measures can be taken to prevent harmful accumulation at the surface. The economy of methods of reclamation must be carefully studied; it may frequntly not pay to reclaim cheap land which is badly affected.

Briefly, the chief measures for preventing future harmful accumulation in present mild cases, and for reclaiming badly affected lands, are as follows :—

(1) *Reduction of Surface Evaporation.*—Practise deep and thorough tillage, and maintain an efficient surface mulch.

(2) *Changing the Form of the Soluble Salts.*—This refers particularly to carbonates of sodium and potassium, the most harmful forms.

(*a*) By application of finely ground gypsum (sulphate of lime). The soluble carbonates are thereby at least partly changed to less injurious sulphates.

$$\underline{Na_2CO_3} + CaSO4 \longrightarrow \underline{Na_2SO4} + CaCO$$

In order to be effective, the application of gypsum must be several times as great as the amount of Na_2CO_3 present. It is said that gypsum will have no effect if the soil or irrigation water used contains appreciable quantities of sulphates.

(*b*) Other methods suggested are based upon neutralisation of the soluble carbonates with acids. Symmonds has used nitric acid with good results, and Lipman found sulphuric acid also useful. The latter has suggested the use of applications of sulphur. This is oxidised in the soil by bacteria to sulphuric acid.

(3) *Removal of the Salts from the Surface Soil.*—

(*a*) By encouraging the rise of the salts to the surface and then scraping off the incrustation.

(*b*) By flooding heavily and thus washing the soluble salts into the lower soil depths well beyond the reach of the roots of crops. The salts will, of course, rise to the surface again after a time.

(*c*) By encouraging the rise of the salts to the surface, and then flooding over the surface and running the water off the land.

(4) *Drainage.*—The institution of efficient drainage is the only really effective and permanent remedy. In this way the water-table can be kept at a desirable distance from the surface and prevented from rising after irrigation. With good drainage the soluble salts can then be washed out of the soil by successive floodings. When much soluble carbonate is present, the percolation of water may be facilitated by previous application of gypsum or large quantities of coarse straw. While, unfortunately, rather costly good drainage is the secret of brak prevention.

(5) *Avoidance of the Use of Unsafe Irrigation Water.*—Before being used for irrigation, water should always be analysed to determine whether it contains harmful quantities of dissolved salts.

(6) *Growth of Brak-Resistant Plants.*—Absence of vegetation promotes surface accumulation of brak salts; so it is desirable to maintain some kind of plant growth, even if not very useful. Crops differ greatly in their tolerance for brak salts, some, such as citrus, being extremely sensitive, while others, such as various types of salt-bushes, are highly resistant.

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CHAPTER IV

SOIL MANAGEMENT (continued), FERTILISER PRACTICE, GREEN-MANURING AND WEED CONTROL.

FERTILISER PRACTICE.

Without attempting to take up the subject of fertiliser practice in detail the authors have considered that a very brief discussion of the matter, giving some of the underlying principles, as applied to South African conditions in particular, would be helpful to some readers.

A fertiliser may conveniently be defined as a substance which is applied to soil for the purpose of directly increasing the amount of available plant food present.

The fertiliser itself carries the plant food in question, and is to be distinguished from other substances occasionally added to soils, which may stimulate the production of available plant food from the soil's reserves, but do not themselves contain the plant food in question; *e.g.*, gypsum contains no potash, but when applied to soil it is known to increase the availability of the soil's supply of potash. Such substances are more correctly termed " stimulants."

Of the various plant foods known to be indispensable for the proper growth and development of crops, nitrogen, phosphoric oxide and potash are the ones whose supply is most likely to be deficient in soils. In some cases the supply of lime may be insufficient to meet the food requirements of crops; as a general rule, however, the lime supply is of interest chiefly by virtue of its indirect effects on the soil. It is possible that rare cases may occur where the supply of certain other plant foods, such as sulphates and magnesia, is deficient, but none such has been definitely recorded.

Available Plant Food.—The productivity of a soil, so far as the food supply is concerned, is determined not so much by the total amount of plant food present as by the rate at which the reserves of plant food become available for nutrition of crops. There is, however, generally a close relationship between these two factors, and under normal conditions large reserves of plant food, as determined by chemical analysis, usually indicate a sufficiency of available food. A deficiency in respect of any one plant food implies an insufficient production of available food from the soil's reserve supply of that particular constituent. This will generally correspond with an insufficient reserve supply, but not necessarily so.

The generation of readily available plant food in soil is influenced largely by the mechanical condition, particularly in regard to aeration. Another important consideration is the presence of actively decaying organic matter, as the by-products of this decay process aid in rendering plant food constituents soluble. Virgin soils generally contain an accumulated supply of readily available plant food, and are, therefore, usually highly productive when first brought under cultivation. Continuous cropping without the addition of fertilisers or manures, however, rapidly exhausts the available food supply and leads to diminished yields, the condition being aggravated by the depletion of humus and the consequent deterioration in mechanical condition.

Plant Food Deficiencies.—In connection with the relative supplies of the various plant foods, it is well to bear in mind the "law of the minimum" as applied to soils. This may be stated as follows:—"Any essential plant food that exists in the soil in relatively small amount as compared with the other important constituents naturally becomes the controlling food factor in crop development. Any reduction or increase in the supply of this constituent will cause a reduction or increase in the crop yield"; or, more briefly: "The crop yield is determined by the quantity of that plant food which is most deficient in the soil." Rational fertiliser practice is based upon the application of this law, and obviously implies the recognition of the specific plant food deficiencies of the soil.

The manurial requirements of soils may be determined either by chemical analysis or from the results of accurately controlled field experiments.

(*a*) Soil Analysis.—By chemical analysis we obtain an invoice of the soil's total reserve supplies of the various essential plant foods. A marked deficiency in respect of any one constituent generally indicates that addition of this constituent is necessary. Availability is, however, not always proportioned to the total supplies, and deductions from chemical analyses may be somewhat at variance with field observations. Analytical methods have also been devised for the determination of readily available plant food in soils at the time of analysis. These results, considered in conjunction with the total reserve supplies, in most cases make clear the manurial requirements of the soil.

(*b*) Field Experiments.—In this method a representative portion of the land is divided into a number of equal plots, certain of which are fertilised, and others (every second or third plot) left untreated as "checks." Standard one-constituent fertilisers are used, *e.g.*, blood meal as a source of nitrogen, superphosphate as a source of phosphoric oxide, and sulphate of potash as a source of potash. These are applied both singly and in combination. The effect of each fertiliser treatment is gauged by the increase of yield, as compared with the untreated plots. If the land chosen is uniform, the plots properly laid out, and the underlying principles of experimental work observed, this is probably the most satisfactory method of ascertaining a soil's deficiencies. The results of the first year will often indicate positive requirements. The farmer is advised, before undertaking a heavy expenditure on fertilisers, to test these in some simple manner on his land. The chief points for him to observe are to choose uniform and representative ground, to have unmanured plots as checks contiguous with the treated plots and, if possible, to duplicate or even triplicate the series.

Relative deficiencies or excesses of those plant foods with which we are most concerned in fertiliser practice, if marked, can frequently be detected by merely studying the appearance of crops growing on the soil in question.

Nitrogen appears to be closely associated with the rate of growth. Insufficient nitrogen results in a weak, stunted growth and a poor colour. Excess, on the other hand, promotes a vigorous vegetative growth of good colour, often at the expense of fruiting and the strength of the stems; decreases the plant's resistance to disease (*e.g.*, rust in cereals), delays maturity, and tends to increase the nitrogen content of the crop.

Phosphoric oxide seems to be associated particularly with root development and the fruiting process. A sufficiency of phosphoric oxide to some extent counteracts the ill effects of an excessive nitrogen supply. It promotes root development, hastens maturity, and stimulates fruiting; thereby ensuring, in the case of grain crops, a larger proportion of grain to straw.

Potash is said to be closely concerned with the formation of carbohydrates in the plant. A sufficiency of potash apparently strengthens the vegetative tissues, thereby increasing resistance to disease, and assists in the formation of plump, heavy seed; and more particularly of good tubers, roots, bulbs and fruit.

The most marked deficiency of South African soils as a whole, as shown by chemical analysis, field tests, and practical experience, seems to be in respect of phosphoric oxide. With reference to Transvaal soils, Juritz says: "An average of 100 analyses of Transvaal soils out of various parts of the Province, done by the Department of Agriculture, show the average soil to be poor in phosphates, medium in nitrogen and good in potash." Broadly speaking, this generalisation may well be applied to the soils of the other Provinces too.

Throughout the Union, with rare exceptions, the judicious use of phosphatic fertilisers is necessary and profitable.

With regard to nitrogen, deficiency, though not so general, is fairly common, and is invariably associated with a deficiency of soil humus. In the summer rainfall area nitrate formation in the soil is rapid during the summer, and the need for nitrogen is not so urgently felt by summer crops as by winter crops. In any case, the demands for nitrogen are most economically met by leguminous green-manuring, or by the incorporation of stable or kraal manure with the soil, or by a combination of both. In this way not only is the nitrogen supply increased, but a large quantity of humus is added to the soil, and in the case of animal manures considerable quantities of phosphoric oxide and potash are also added to the soil's supply.

Potash is usually present in sufficient quantities, and its application is seldom profitable in South Africa, except on certain sandy soils, and possibly on even better supplied soils where potash feeders such as potatoes, tobacco, etc., are grown.

Commercial Fertilisers.—The following are a few of the principal commercial fertilisers available to the farmer in South Africa:—

(1) *Nitrate Soda.*—Containing about 15 per cent. nitrogen immediately available to crops. It is soluble in water and apt to be leached out of the soil by heavy rains. For this reason it is usually applied in comparatively small quantities as a top dressing after the crop is up.

(2) *Sulphate of Ammonia.*—Containing about 20 per cent. nitrogen, which rapidly becomes available. It is less liable to be leached out of the soil than nitrate of soda.

(3) *Nitrate of Lime.*—Containing about 13 per cent. nitrogen immediately available. It is similar to nitrate of soda in most respects.

(4) *Blood Meal.*—Containing about 12 per cent. nitrogen, which becomes available fairly rapidly.

(5) *Government Guano.*—Containing about 10 per cent. nitrogen, 11 per cent. phosphoric oxide, and a little potash, all fairly readily available. Its composition is liable to vary somewhat.

(6) *Superphosphate.*—Containing, if of good grade, 15 to 20 per cent. phosphoric oxide. Soluble in water, and therefore immediately available to crops.

(7) *Bone Dust.*—Containing about 3 to 4 per cent. nitrogen and 23 to 24 per cent. phosphoric oxide. Should be as fine as possible, as fineness increases availability. For best results should be applied early.

(8) *Basic Slag.*—Containing about 8 to 20 per cent. nitrogen and 20 per cent. free lime. It is slow in action and should, therefore, be applied early. It is said to act best on heavy, wet soils.

(9) *Sulphate of Potash.*—Containing 45 to 50 per cent. potash in readily available form.

(10) *Muriate of Potash.*—Containing 50 to 55 per cent. potash in readily available form. Muriate (*i.e.*, chloride) of potash seems to injure the quality of certain crops, like tobacco.

Use of Lime.—It is commonly stated that all normal fertile soils should contain a certain amount of free lime (in the form of calcium carbonate). Total absence of free lime gives rise to the condition known as "acidity" or 'sourness," which is unfavourable to many plants and soil micro-organisms. Lime exerts both chemical and physical effects in the soil, which may be summarised as follows :—

(1) It prevents the formation of "acidity," thereby stimulating the activity of desirable micro-organisms in the soil. Notable among these are micro-organisms engaged in the decomposition of organic matter, nitrification of organic nitrogen, and fixation of atmospheric nitrogen. Stated otherwise—the effect of lime is to stimulate the decomposition of organic matter and the production of nitrogenous plant food.

(2) By interaction with mineral compounds in the soil, it stimulates to some extent the production of available potash and phosphoric oxide from the soil's reserve supply of these plant foods. In this respect it must be classed as a "stimulant," not "fertiliser."

(3) It gives rise to soluble bicarbonate of lime in the soil, which flocculates clay, thus greatly facilitating granulation. Therefore, the addition of lime greatly improves the mechanical condition of soils that are inclined to be "heavy."

(4) In cases, probably rare, where the soil not only lacks free lime, but is also markedly deficient in other compounds of calcium, addition of lime may have a beneficial effect by virtue of the plant food element calcium which it furnishes in readily available form. In this respect it acts as a direct "fertiliser."

Of greatest importance are the effects of lime as related to soil activity and mechanical condition, and from the point of view of these functions it is termed a soil "amendment."

Agricultural experience in Europe and America shows that the presence of free lime commonly plays a controlling part in soil fertility, and it has frequently been found that acid soils of low fertility become highly productive after lime has been added.

Under South African soil and climatic conditions, however, it should be stated that, except in the case of a few crops, such as sugar cane and certain legumes, practical experience has not clearly established the genuine necessity of a sufficient supply of free lime in the soil. On the score of economy, therefore, the advisability of liming soils for field crops in South Africa, with the exceptions already noted, is still problematical, although there is no doubt as to the beneficial effect of lime upon the mechanical condition of heavy soils. On some acid soils, however, where transport facilities are reasonable, and lime easily and cheaply obtainable, liming will, no doubt, be found to be lucrative; more particularly on soils that are naturally rich in humus, or have recently received large applications of organic matter in the form of manure or green-manure.

Lime may be applied to the soil in the mild form of finely-ground limestone, commonly known as "agricultural lime," or in the more energetic caustic form of slaked lime. The former is generally to be preferred, because the energetic action of slaked lime is liable to cause excessive decomposition of organic matter, leading to rapid depletion in this respect. In the case of heavy soils, where the mechanical effect is chiefly sought after, slaked lime will cause more rapid improvement.

In general, lime should be applied early, by spreading over the ploughed soil and then harrowing it in.

Maintaining Fertility.—The most important economic problem of any extensive agricultural country is to maintain the fertility of the soil. In young countries, where land is plentiful and cheap, this is at first not so evident, but the gradual reduction of the productive power of the land, together with increasing population, must in time compel recognition of this truth. The frequent periods of famine in India, China and Russia, due largely to improvident methods of farming, afford cases in point.

The ideal of agricultural practice, in the case of highly productive lands, is obviously to maintain crop yields permanently at this high level, and, in the case of poor lands, to gradually raise the productivity to a higher level, and then maintain it permanently; due attention being paid to economy in either case.

Under highly intensive systems of farming this ideal is comparatively easy of achievement, because relatively small areas are cultivated and crop yields are large, and so more efficient methods of management are possible.

Over the greater part of South Africa, especially in the summer rainfall area, the farming is largely extensive in nature. In many agricultural districts, truly intensive methods are hardly possible, because, apart from the fact that on the whole the soils are not rich in plant food, the rainfall is extremely erratic in regard to both quantity and distribution. The areas under cultivation are frequently far larger than can be efficiently managed, and as a result the average level of production is extremely low. As a fairly general rule, however, it can hardly be doubted that the adoption of somewhat more intensive methods would pay.

While the maintenance of fertility depends primarily on the plant food relations in the soil, the absolute necessity of good tillage must be kept in mind, and the system of farming practised must be such as will not lead to deterioration in mechanical condition, nor affect adversely the activities of useful soil micro-organisms.

Soil fertility cannot be maintained in field practice by use of commercial fertilisers alone. On the score of economy, firstly, the idea is untenable, because there are cheaper methods of supplying certain of the requirements: notably in regard to nitrogen, which is the most costly of all commercial plant foods. In the second place, commercial fertilisers provide little or no humus, and the inevitable depletion of the soil humus leads to bad tilth and decreased availability of other plant foods in the soil.

Nitrogen and humus go hand-in-hand and proper attention to the humus supply will in part or completely solve the nitrogen problem. The best methods of supplying humus and nitrogen are :—

(1) By crop rotation, including a green manure; preferably leguminous. (*See next section.*) Where practicable, the residues (straw, etc.) of other crops should also be returned to the soil.

(2) By the use of animal manures, either by feeding crops to stock on the land or by applying stable and kraal manure.

A ton of fresh stable manure, consisting of cattle and horse excrements, together with more or less straw, etc., contains as a rough average about 10 pounds nitrogen, 5 pounds phosphoric oxide, and 10 pounds potash. Partly decomposed kraal manure is generally richer if kept under proper conditions.

In feeding crops to stock, under average conditions, it is said that about one-third of the total dry matter of the feed, about three-fourths of the total nitrogen and phosphoric oxide, and practically all the potash, are recovered in the excrements, liquid and solid. On this basis, for every ton of dry feed consumed, rather more than a ton of fresh manure is produced, assuming the latter to contain 75 per cent. water.

To summarise the foregoing, the principal facts that should be noted, and made use of in regard to the maintenance of fertility, are as follow :—

(*a*) The beneficial effects of the rotation of crops as opposed to the single crop system.

(*b*) That most South African soils are deficient in humus, and in many cases present cropping methods are causing further rapid depletion of the soil's supply, resulting in nitrogen deficiency, poor mechanical condition, and decreased availability of other plant foods. Provision must be made for maintaining the humus supply, as already described.

(*c*) That proper maintenance of the humus supply will in large part, and under best conditions, wholly maintain a sufficiency of nitrogen in the soil. In no other way can nitrogen be maintained so economically. The nitrogen alone in one ton of average kraal or stable manure, at current market prices, is worth over ten shillings.

(*d*) That practically all South African soils are deficient in phosphoric oxide. Therefore, regular and adequate applications of commercial phosphatic fertilisers, such as superphosphate bone dust or basic slag, are absolutely essential.

(*e*) That the supply of potash is rarely deficient, and that the use of commercial potash fertilisers for common farm crops is seldom profitable. Stable or kraal manure contains a fair amount of potash, so that if much of this material is used for soil improvement considerable quantities of potash will be brought into the soil in an extremely economical form. Old sheep kraal manure is exceptionally rich in potash. Commercial forms of potash may frequently be used with profit for a few special crops, such as tobacco and potatoes.

(*f*) That the supply of lime as a plant food is practically never deficient, but in the case of "acid" soils applications of lime, in the form of finely-ground limestone, are probably desirable. Before incurring heavy expense by the purchase of large quantities of lime, the farmer is advised to test the effect of lime on small experimental areas.

Mixing of Fertilisers.—Most fertiliser materials can be mixed, if necessary, before application to the soil, but the following precautions should be observed :—

(1) Do not mix fertilisers containing all or part of their nitrogen in ammonia form (*e.g.*, sulphate of ammonia, Government guano, kraal manure) with lime or fertilisers containing free lime (*e.g.*, basic slag, manure ash, wood ashes). Such mixtures cause volatilisation of ammonia gas, hence loss of nitrogen.

(2) Do not mix superphosphate with lime or fertilisers containing free lime, because the latter cause "reversion" of the water-soluble phosphoric oxide to form insoluble in water.

(3) It is commonly stated that superphosphate should not be mixed with nitrates of soda, potash or lime, and that basic slag should not be mixed with potash salts.

Application of Fertilisers.—This subject is dealt with in the discussion of the various crops.

GREEN-MANURING.

Green-manuring is the practice of incorporating green organic matter into the soil by ploughing down a crop grown on the land. Partially decomposed organic matter is known as humus, and the rôle of humus in the soil is so important (*see chapter on Rotations*) that the value of any operation which tends to maintain or increase the amount present in the soil can hardly be over-emphasized.

Light-coloured soils are notoriously low in productivity, a condition largely attributable to the small humus content of these soils. The reverse applies in the case of dark soils, where the humus content is usually high and the productivity good.

The formation of humus is due to the activities of soil micro-organisms, and is facilitated by good aeration, proper drainage, high temperatures, and by the presence of lime.

While the prime object of green-manuring is to increase the humus content of the soil, it serves at the same time a number of additional useful purposes. The various useful functions of green-manuring may be summarised briefly, as follows :—

(1) It adds easily decomposable organic matter to the soil.

(2) It increases moisture retention bv the soil.

(3) It improves tilth, giving " body " to sands, and rendering clays more friable.

(4) It stimulates the activity of useful soil micro-organisms.

(5) It stimulates the production of available mineral plant food from the soil's reserves.

(6) It increases the amount of available plant food in the surface soil, because the plant foods taken up by the crop from various parts of the soil during the entire period of its growth are left in the surface soil when the crop is ploughed down, and are soon set free in available form.

(7) It increases the nitrogen content of the soil if the crop used is a legume, and the necessary nodule bacteria are present.

(8) Green manure crops serve to some extent as cover crops by preventing leaching and conserving the available plant food.

The yield of dry matter of crops used for green-manuring varies considerably, both in the above-ground parts and in the roots. At the Delaware Experiment Station, the weights of dry roots of various crops per acre in the first foot of soil were found to be :—

Red Clover, 1,202 pounds;
Vetch, 600 pounds; and
Soy Beans, 756 pounds.

From this it will be seen that when the above-ground parts are removed the residual effect of the roots will vary with the crops grown, and consequently the extent of humus depletion will also vary.

The humus content of the soil is best maintained where the cropping system involves comparatively frequent green-manuring, coupled with the use of manure and the return of crop residues to the land.

CONSIDERATIONS IN THE CHOICE OF CROP.—The choice of a crop for green-manuring will be governed by the following considerations :—

(*a*) The suitability of the climate and soil. In the summer rainfall areas naturally crops like cowpeas will be used, while vetches will find a place in those parts having a winter rainfall.

(*b*) The cost of seed, *e.g.*, Sweet Clover, is an excellent crop for this purpose, but the seed is costly as compared with that of cow-peas, consequently the latter is more commonly used.

(*c*) On foul lands certain weeds can often be controlled by a green-manuring crop which is also a smothering crop, *e.g.*, Kweek (*Cynodon dactylon*) can be sometimes effectively smothered by cowpeas.

(*d*) The rooting system. As previously shown, this varies with different crops, and therefore the residual effect of the roots on the succeeding crops also varies.

(*e*) The value, quality and quantity of feed or pasture it may produce. The farmer in adverse seasons may be compelled to utilise as stock feed the crop intended for green-manuring. Where this possibility is present he should grow legumes, because of their high nutritive value, their extensive and deep root-systems, and their capacity for gathering atmospheric nitrogen.

(*f*) The possibility of the crop growing with a cash or other crop is also a factor, *e.g.*, cowpeas with maize. The maize may be harvested for silage, or if an early variety, for seed, and the cowpeas then ploughed down during the end of March or early in April.

GREEN-MANURING CROPS.

(1) *Legumes or Pod-Bearing Plants.*—These obtain part of their nitrogen from the atmosphere, through the agency of the nodule bacteria attached to their roots. Other conditions being equal, the amount of atmospheric nitrogen " fixed " depends upon the nitrogen content of the soil—the richer the soil in available nitrogen the less the amount of fixation, and

vice-versâ. Under favourable conditions legumes can make normal growth in soil completely devoid of available nitrogen. These crops are of particular value for improvement of soils low in nitrogen, as they tend to correct the deficiency in this respect. The total nitrogen content of legumes is generally much higher than that of non-legumes, consequently they are of greater nutritive value as stock feed.

(2) *Non-legumes.*—These take their nitrogen directly from the soil's supply, and therefore do not enrich the soil in this respect.

The principal crops grown in South Africa for green-manuring are :—

Legumes.—Cowpeas, velvet beans, soy beans, and lupines, are all summer annuals adapted to parts of the Transvaal, Orange Free State, Natal, and Cape Province. Field peas and vetches are winter annuals used chiefly in the South-West Cape, but also under irrigation in other parts of the Union.

Lucerne residues provide some green manure when the crop is ploughed down after it ceases to give profitable yields.

Non-legumes.—Buckwheat, a summer annual, is one of the best known. Mustard is often grown as a green manure.

The aftermath of certain hay and pasture crops frequently supplies a certain amount of green manure. Towards the end of the season teff grass will often make a growth insufficient for hay, but of appreciable value as green manure. Rye and oats are frequently grown for grazing, and after this they may make a fair growth, which is sometimes ploughed under.

Although not strictly green manures, the residues of certain crops when ploughed down contribute to no small extent to the humus control of the soil, *e.g.*, the straw of headed wheat.

The turning in also of a heavy growth of weeds provides a certain amount of green manure.

The Ploughing Down of Green Manures.—This should be done when conditions are such that rapid decomposition will be ensured. If the crop is in a succulent condition, the prevailing temperature high, and the soil reasonably moist, humification will be certain and quick. If the soil is too dry at the time when ploughing takes place, its consequent loose, open condition may cause excessive evaporation of soil moisture, especially in semi-arid parts. Again, if the crop is ploughed under when very mature, and consequently in a hard, fibrous condition, decay will be slow. If possible, therefore, plough these crops down before maturation is too far advanced, *i.e.*, at flowering or soon after, and when moisture conditions are favourable, *i.e.*, before the last rains.

Under irrigation the soil moisture can be regulated, consequently the time of the year when green manures should be ploughed under is not so critical.

After ploughing the land should be worked down, preferably by discing, to ensure thorough incorporation of the organic matter into the soil, and more or less even distribution.

When Inadvisable to Practise Green-Manuring.—It is a questionable procedure under arid, and sometimes semi-arid conditions, because, firstly, the crop may leave the soil in a very desiccated state, and, secondly, the nitrogen added in this way may stimulate too succulent a growth of the succeeding crop, thus causing the latter to suffer prematurely from drought.

In general, excessive green-manuring may furnish a superabundance of nitrogen, which acts detrimentally towards many crops. Crops often show a tendency to mature late on land heavily green-manured, and where rust is prevalent this fact should be taken into consideration. In some, the growth of straw will be excessive, lodging will take place, and the yield of grain will be disappointing.

Crops to Follow Green Manures.—Where practicable cultivated crops, *e.g.*, potatoes and maize, are the best to grow after green-manuring, as their cultivation assists in changing the organic matter into available plant food. Of the winter cereals, wheat and rye give the best results after green-manuring. Oats is apt to lodge badly and to be coarse strawed, and the quality of barley for malting purposes is usually poor if grown immediately after a green manure. As the winter cereals require a compact seed-bed, the green manure should be ploughed under as early as possible, so that decay may be well advanced before the cereals are sown. Nitrification during the South African winter is slow, so that on the whole the use of leguminous green manures on land where winter crops are grown is particularly good practice.

In grain farming, green-manuring is a much more urgent and necessary operation than, for example, in dairy farming, where large quantities of manure are available for application to the land.

WEEDS.

To most the harmful effects of weeds are obvious; nevertheless, it is safe to say that in South Africa no general cultural operations would have a greater beneficial effect on crop production than would the determined control of weeds. Not only do weeds reduce crop yields, but in seasons when moisture is a limiting factor they may be responsible for complete failures of crops.

A weed may be defined as a plant out of place, or, any plant growing where it is not wanted.

The following is a list of the noxious weeds proclaimed in the various Provinces of the Union :—

Scientific Name.	Common Name.	Proclaimed in
Acanthospermum spp.	Prostrate Star Bur	Transvaal.
	Upright Star Bur.	Transvaal.
Alternanthera Achyrantha R. Br.	Khaki Weed, Amaranthus Weed, Native "N'Kunzana"	O.F.S. and Cape.
Agemone Mexicana L.	Mexican Poppy, Mexican or Blue Thistle, Steekbossie	Cape.
Brassica Sinapistrum Boiss.	Wild Mustard, Wilde Mosterd	Cape.
Centaurea Calcitrapa Pers.	Purple Star Thistle ..	Cape, Transvaal.
Centaurea militensis L.	Malta Thistle	Cape, Transvaal.
Centaurea solstitialis L.	Yellow Star Thistle ..	Cape, Transvaal.
Cnicus lanceolatus L.	Spear Thistle Native "Kakaka"	Cape, Transvaal, Natal.
Cuscuta spp.	Dodder	Transvaal.
Cuscuta trifolii	Dodder	Natal, O.F.S. Transvaal.
Datura Stramonium L.	Stinkblaar	Cape.
Datura tatula L.	Blaauw stinkblaar ..	Cape.
Eichhornia speciosa Solms.	Water Hyacinth ..	Cape.
Emex australis Steinh	Duiveljtes, Devil's Horn	Cape.
Euryops laterifolius Less.	Harpiusbosje	Cape.
Gunnera perpensa L.	Wild Ramenas	Cape.
Inulea graveolens Desf.	Khaki Bosch	Cape.
Ipomoea purpurea Roth.	Morning Glory	Cape.
Opuntia aurantiaca Lind.	Jointed Cactus	Cape.
Opuntia decumana Haw.	Prickly Pear	Cape.
Opuntia imbricata Haw.	The Imbricate Cactus ..	Cape.
Ricinus communis L.	Olie Boom	Cape.
Salsola Kali L.	Salt Wort, Russian Weed, Russian Tumble Weed	Cape.
Schkuhria bonariensis L.	Dwarf Marigold ..	O.F.S.
Tagetes minuta L.	Khaki Bosch, Mexican Marigold	Cape, Transvaal.
Xanthium strumarium.	Cockle Bur, Native "N'Kunzana"	Cape, Transvaal, Natal, O.F.S.
Xanthium spinosum L.	Bur Weed	O.F.S. Natal, Transvaal.
Xanthium spp.		Transvaal, Natal.

Injurious Effects of Weeds.—(1) Over the greater part of South Africa the most serious of these is the fact that they utilise soil moisture and thus decrease the supply of water available for the crop plants. A ton of Lamb's Quarters (*C. album*), according to American investigation, has a water requirement of over 800 tons, or roughly 8 inches of water. When a loss of this magnitude is added to those due to evaporation and run-off, it is easy to see why crops often fail in areas having an average annual rainfall of about 22 inches.

(2) They deprive the crop of a considerable amount of available plant food.

(3) They smother crop plants. A young stand of lucerne may be ruined in this way by species of Chenopodium.

(4) Weeds are a constant source of expense, as they increase the cost of every operation—preparing of land, seeding. cultivating, harvesting and marketing the crop.

(5) The growing of certain crops often has to be abandoned on account of weeds, *e.g.*, maize in fields badly infested with Rooibloem or Witchweed (*Striga lutea*).

(6) Some weeds are poisonous to livestock. *e.g.*, Stinkblaar (*Datura stramonium*) and Dubbeltje (*Terrestris tribulis*).

(7) Milk is often tainted when certain weeds are eaten by stock. *e.g.*, Stinking Mayweed (*Anthemis cotula*).

(8) The value of grain, lucerne and grass seed is much decreased by the presence of weed seeds. The value of hay containing weeds is lessened. Further, weeds lower the price obtainable for land—a farmer will pay a higher price for clean land than for weedy land.

(9) Parasitic weeds rob their hosts of nourishment, *e.g.*, dodder on lucerne, and witchweed on maize.

(10) Weeds often harbour or favour the development of injurious insect pests and fungus diseases, *e.g.*, early blight of potatoes (*Alternaria solani*), also affects species of Datura (Stinkblaar).

(11) They may injure stock, as in the case of Jointed Cactus (*Opuntia auriantiaca*), or the products from stock, *e.g.*, the value of wool is much depreciated by the fruits of Bur-Weed or Boetebosje (*Xanthium spinosum*).

Weeds are distributed naturally by wind, birds, and other animals; but their distribution is also attributable partly to impurities in agricultural seed, to seeds contained in livestock manures, to threshing machines and to tillage implements which carry weed seed from one field to another.

Factors Affecting Weed Control.—(1) Seed production. The following table shows the extremely prolific seed production by certain weeds, the figures representing the number of seeds per single weed plant :—

	Highest recorded.
Common Groundsel (*Senecio vulgaris*)	20,000
Sow Thistle (*S. arvensis*)	19,000
Ox-Eye Daisy (*C. leucanthemum*)	26,000
Scentless Mayweed (*M. inodora*)	310,000

From this the necessity for preventing the production of seeds is obvious.

(2) Germination. The longevity of weed seeds depends largely on the condition of the soil in regard to moisture, temperature, and oxygen supply. Mustard seed is supposed to remain viable in the soil for two or more years, while under the same conditions the seed of other weeds may lose their vitality in two years or less. Some will not germinate until a certain period has elapsed after apparent maturity of the seed, *e.g.*, Wild Oats (*Avena fatua*). *Xanthium spinosum* produces a plant one year, and often another from the same fruit the following year. Witchweed seed germinates only when in contact, or nearly so, with the roots of certain grasses, *e.g.*, maize and sorghum. These characteristics will naturally govern the methods of control.

(3) Life histories. It is important to know the life history of a weed in order to ascertain the stage at which it may be most easily destroyed. For example, Johnson's Grass can be controlled quite easily if ploughed down before it sends out rhizomes, which occurs relatively late in its growth, but if left until beyond this stage its eradication is both difficult and expensive.

Annuals and biennials can be effectively dealt with by judicious ploughing and frequent cultivation. They are most easly controlled when in the seedling stage, *e.g.*, Khaki Bos (*Tagetes Minuta*) can be eradicated with ease by repeated harrowing at this stage.

Perennials, especially those having rhizomes and adventitious roots, are the most difficult to eradicate. In most parts of South Africa these can be easily controlled by ploughing, and thus exposing the rhizomes to adverse conditions, such as dry atmosphere and frost. In the summer rainfall area weeds like Kweek (*Cynodon dactylon*) are destroyed by ploughing in the early winter and leaving the soil in such a condition that it will dry out thoroughly, the rhizomes then being destroyed by frost and by desiccation. In those parts having a winter rainfall the ground should be ploughed in spring. These weeds will then be killed by desiccation during the hot, dry summer. On sandy soils ploughing at the times stated will have to be followed by frequent harrowings in order to keep the rhizomes exposed.

General Methods of Weed Control.—(1) Prevent as far as possible the production and introduction of weed seeds.

(2) Practise a rotation of crops—annuals can be destroyed to a great extent during the growth of the cultivated crops, and perennials by the various ploughing and harrowing operations.

(3) Delay planting, if necessary, in order to harrow frequently as the weed seedlings appear. Harrow most crops until just before they are appreciably injured.

(4) If the land is very weedy it may be necessary to bare fallow.

(5) Ploughing as soon as the crop is removed will prevent seed production to a considerable extent.

(6) Smothering crops such as Buckwheat and Cowpeas will be found useful.

(7) Some weeds are readily eaten by stock, in which case heavy stocking will be of assistance.

(8) Frequent mowing is often helpful in weakening the plants and in preventing the production of seeds.

(9 In some cases hand-pulling and hoeing, followed by burning, is necessary.

(10) Spraying is resorted to where farming is very intensive. Effective solutions are : 12 pounds of copper sulphate, or 100 pounds of iron sulphate, or 125 pounds of common salt to 50 gallons of water.

Below are given some practical details in regard to the control of a few common and very troublesome weeds :

Dodder (*Cuscuta trifolii*).—This weed is parasitic on lucerne. The seed germinates in the soil, but the plant subsequently becomes wholly dependent on its host for existence. The plants should not be removed. Dry brush or grass should be piled on infested spots and then burned. Care must be taken to watch for subsequent infestations. If fields are badly infested it is necessary to plough under the whole crop, and for several seasons following to plant crops like potatoes or wheat. Dealers selling lucerne seed containing Dodder seeds are liable to be prosecuted.

Witchweed or Rooibloem (*Striga lutea*).—As the seeds germinate only when close to or in contact with grass plants, and may germinate year after year for a considerable period, it is an extremely difficult weed to exterminate. In very badly infested fields often the best course is to change permanently the class of crop, avoiding grasses. Peanuts, potatoes, lucerne, cowpeas, pumpkins, and so on, may be grown instead. If the infestation is not very marked, germination of the seed may be stimulated by growing a crop like teff or Sudan grass thickly. A hay crop is then harvested before the weed flowers, and the field ploughed before the seed stage is reached. This practice should be repeated, and the class of crop changed for one or two seasons.

Khaki Bos (*Tagetas minuta*).—This weed has become notorious. Although it seeds heavily it can be readily controlled by frequent harrowings when in the seedling stage, and before crops are planted. If necessary, planting should be delayed for a few weeks in order to allow extra harrowings. Plants which have found a footing along fences or ditches should be destroyed by hand before they produce seeds.

Kweek (*Cynodon dactylon*).—In areas of summer rainfall plough during the latter part of summer or later, if the soil permits, leaving the furrow slice standing on its edge. Before the early rains commence, cross plough and harrow. As previously stated, in winter rainfall areas the operation must be commenced by ploughing during the early summer months. Lucerne lands are often so badly infested with this weed that the stand becomes very sparse and consequently the crop must be ploughed down. The growth of kweek in lucerne can, however, be checked to some extent by watering the crop once in winter and then harrowing with a heavy type of lucerne cultivator. Poorly screened lucerne seed often introduces kweek seed into fields which are unlikely to become infested from other sources. Every care, then, should be taken to buy pure seed.

CHAPTER V.

THE ROTATION OF CROPS.

The term " crop rotation " is used to define the successive growing of different crops upon the same fields in order to assist in maintaining soil productivity. It is used to differentiate between the system defined and that of " continuous cropping." In the latter practice the same class of crop is grown continuously.

According to the similarity in their effect on the soil, of the methods employed in their production, and the purposes for which they are grown, crops are classified into groups having common characteristics.

The following is a rough classification of the more common groups :—

(1) Cultivated, Hoed or Cleaning Crops.—These are crops planted so as to facilitate inter-tillage during growth, e.g., maize, potatoes, kaffir corn and mangels. Cultivation between the rows destroys weeds, and by improving aeration assists in making plant food available. While the immediate effect of the cultivation is beneficial when a delicate feeding crop is to follow, the effect of continuously growing crops of this group is to impoverish the soil. Little organic matter is added to the soil, and cultivation accelerates the rate of oxidation of soil humus; consequently the tilth of the soil is impaired unless the system of farming practised provides measures for restoring the humus content. In general, cultivated crops must be regarded as humus destroyers.

(2) The Small Grain Crops.—These crops, *e.g.*, winter cereals, millets, and flax, are seeded in rows close together by means of grain drills, or are broadcasted very thickly. No ordinary inter-tillage is possible, although they are usually harrowed shortly after germination; but from this time on no cultivation of the land is possible until after the crop has been harvested. A cereal is any graminaceous crop grown for its edible grain, e.g., wheat, rye, maize, rice, etc.

(3) Green Manure Crops.—These are crops grown for the purpose of being ploughed under, the object being to increase the organic matter content of the soil, *e.g.*, cowpeas, lupines, soy-beans, vetches, rye and buckwheat. They are used chiefly on heavy clay, sandy and worn-out soils. Legumes are usually preferred, since besides adding to the humus supply, they increase, very cheaply, the nitrogen content of the soil.

Since this group is used to increase the humus content, it may be well to review briefly the role of humus in the soil.

Chemically : (a) It is the source of nitrogen for ordinary farm crops.

(By nitrification the nitrogenous compounds of humus are changed to nitrates, in which form the nitrogen can be assimilated by crops.)

(b) The carbon dioxide liberated by the decomposition of vegetable matter renders insoluble mineral plant food available, *e.g.*, orthoclose is probably decomposed as follows, with liberation of carbonate of potash :

$$2\ KAl\ Si_3O_8 + 2H_2O + CO_2 = H_4Al_2\ Si2O_9 + ASiO_2 + K_2CO_3$$

To some extent the organic acids formed may have a similar effect.

(c) The carbohydrates of humus supply certain useful soil micro-organisms with energy.

(d) It increases the retentive power of soils for soluble mineral salts.

Physically : (a) It renders clay soil more friable and thus improves aeration and enables more effective tillage.

(b) It gives body to sandy soils and makes them more retentive of moisture. Incidentally it checks the " blowing out " of light sandy soils.

(4) Grass or Sod-Forming Crops.—The chief characteristics of the crops comprising this group are that they require little or no cultivation, and that during the time that they occupy the land a turf or mulch of roots and stems is developed, filling the surface soil with vegetable matter; and that they occupy the land for several successive years. They assist in maintaining the humus content, *e.g.*, paspalum, lucerne, kikuyu and Rhodes grass. Because of their long stay on the land they usually become weedy, consequently they should be followed by a cultivated crop.

(5) Catch Crops.—These are crops (a) used to take the place of crops which have failed through adverse conditions, such as insect attack or drought; or (b) grown with regular

crops, *e.g.*, beans in young orchards; or (c) grown between the seasons of regular crops, *e.g.*, maize after early potatoes, to be followed by wheat. Examples of this class, generally quick maturing crops, are buckwheat, teff, cowpeas and millets.

(6) Cover Crops.—These are grown for soil protection chiefly. They protect the soil from erosion and leaching, and may be used to modify orchard growth, *e.g.*, to retard early or too succulent growth of fruit trees. Examples of this group are buckwheat, rye, rape and vetches. Often they have a duality of purpose in that they may at the same time serve as green-manuring or as catch crops.

(7) Soiling Crops.—These are cut green and fed to stock off the land on which they have been grown, *e.g.* barley, lucerne and Phalaris bulbosa. Where the practice is to return the manure to the lands, this method cannot be looked upon as very exhaustive of soil fertility.

Some crops, as has been indicated in the above rough grouping, have a tendency to deplete soil humus, while others restore and increase this part of the soil content. This is clearly shown from the results of experiments conducted by the Minnesota Experiment Station.

Plot.	Description of Rotation.	Humus percentage. 1895.	1905.	Diff.
7.11	Maize continuously ...	3.23	2.96	— 0.27
9.11	Mangels continuously ...	3.03	2.85	— 0.18
10.11	Field peas continuously...	2.87	3.28	+ 0.41
2.111	Wheat continuously ...	3.96	3.44	— 0.52
4.111	Wheat 1st yr., clover 1st yr., plough under second crop	3.08	3.92	+ 0.84
1.1	Wheat 1st yr., clover and timothy 2nd yr., oats 1st yr., maize 1st yr	3.47	3.71	+ 0.24
2.11	Maize 1st yr., peas 1st yr., barley 1st yr., clover 1st yr.	4.33	4.63	+ 0.30
4.11	Barley 1st yr., oats 1st yr., timothy 2nd yr. ...	3.78	4.31	+ 0.53
6.IV	Wheat 1st yr., clover and timothy 2nd yr., oats 1st yr., maize 1st yr.	3.38	3.44	+ 0.06
10.IV	Wheat 1st yr., timothy and clover 2nd yr. ...	3.18	2.79	— 0.39

Fertilisers.—1.1 received eight tons stable manure per acre once in five years applied to the maize crop.

4.11 timothy top-dressed, after mowing first hay crop.

6.IV. Same as 1.1.

The legumes, plants which gather atmospheric nitrogen through the nodular bacteria attached to their roots, increase, or at least maintain, the nitrogen content of the soil, and usually because of their extensive root systems give an increase in humus content even when the aerial parts are harvested, and this has a very beneficial effect on the tilth of the soil.

Certain crops again are regarded as "gross-feeders" and others as "delicate feeders." The former are crops whose extensive much-branched rooting systems make them more effective in reaching through the soil for plant food and soil moisture. Some gross-feeding crops seem to possess a greater power of assimilating plant food which to delicate feeding crops would be less easily assimilated; thus, maize, rye and oats will yield profitable crops on soil often too poor for wheat and barley, which are generally classed as "delicate-feeders." The latter should therefore be placed in the most favoured positions as regards available plant food, in rotations. The principal gross-feeding crops in South Africa are maize, rye, some varieties of oats, sorghums and the coarser millets; while among those having comparatively fine, slender and restricted root systems may be mentioned wheat, barley, some varieties of oats and potatoes.

Again crops differ radically in being either shallow or deep-rooted, and in general correspond, but not always, to the delicate and gross-feeding crops just mentioned. Barley, teff and flax are crops whose roots are more or less confined to the furrow slice, while lucerne, cowpeas and soybeans have strong laterals and taproots penetrating to considerable depths; lucerne roots have been found sixty feet below the surface. Many shallow-rooted crops, when grown continuously, soon lower the productivity of the upper layer of the soil, and for this reason are looked upon by farmers as exhaustive crops.

The effect of growing deep-rooted crops is to improve the physical condition of the soil; the sub-soil is opened up, and the soil rendered more porous and receptive of moisture; the feeding area for succeeding crops is markedly improved. Certain heavy clay soils in England on which only pasture grasses could formerly be grown have now been reclaimed and can successfully grow ordinary crops. This has been done by persisting in the growth of the deeper rooted crops.

Before discussing the reasons for rotative cropping and the conditions modifying this form of cropping, the following results of experiments might be given :—

Summary of Results of Crop Rotation in Adgell Field, Rothampstead, Since 1848.

Period.	I. Unmanured. Turnips.	Barley.	Wheat.	II. Phosphates. Turnips.	Barley.	Wheat.	III. P2O5 and Nitrogen. Turnips.	Barley.	Wheat.
(1) 1st crop 1848	19,534	46·5	29·7	25,004	36·3	30·0	25,032	35·9	30·0
(2) Average of 1st 20 years	5,264	38·0	29·6	18,561	36·8	32·5	31,198	46·3	35·3
(3) Average of 2nd 20 years	1,723	22·5	21·1	17,669	28·1	30·1	31,790	41·1	32·0
(4) Average of 3rd 20 years	967	13·7	18·9	25,275	22·2	38·9	41,739	29·2	36·4

The rotation practised was the Norfolk four-year rotation, *i.e.*, turnips, barley, clover and wheat. In this rotation the clover is cut as hay, but a fair aftermath is ploughed in. The above experiment is probably the most authoritative of its kind, and shows clearly that a rotation, without the application of fertilisers, will not maintain yield.

Effect of different cropping systems on yield of Maize—Illinois University.

Crop years.	Crop System.	Average yield during 13 year experiments.	Average yield during 29 year experiments.
1905-6-7 etc.	Maize continuously.	35 Bushels.	27 Bushels.
1903-5-7 etc.	Maize and Oats.	62 Bushels.	46 Bushels.
1901-4-7 etc.	Maize, Oats and Clover	66 Bushels.	58 Bushels.

Several points should be noted in this experiment : (1) the increase in yield over maize grown continuously by simply changing the crop every year ; (2) that a good cropping system in itself gives a tremendous advantage over crops grown continuously, still without the addition of fertilisers the yield is not increased or even maintained. The land on which this experiment was conducted originally yielded 70 bushels of maize per acre. " Undoubtedly the rapid reduction during the first 12 years of continuous maize growing is due in large part to the destruction of the more active decaying organic matter, resulting ultimately in insufficient liberation of plant food within the feeding range of the maize roots."[3]

Yield of Maize at Missouri University (after 17 years).

Maize continuously	11.8 bushels.
Maize, wheat, clover	50.7 ,,
Maize, wheat, clover, manure ...	77.6 ,,

Here again the rotation alone showed to great advantage over the maize grown continuously. However, only when manure was added was yield maintained.

Extensive experiments at Indiana showed conclusively that in a rotation experiment when only grain crops were employed, and even when fertilised, the yield was not maintained. The addition of organic matter through the use of humus adding crops (clover and grass), when fertilised, increased the original productivity of the land.

The following South African experiments show the effect of previous crops on those following :—

Potchefstroom School of Agriculture.

	Yield of wheat in pounds. 1916.	1917.	1918.
Velvet beans cut for fodder, wheat following	1,240	1,080	1,040
Cowpeas cut for fodder, wheat following	1,400	1,380	1,240
Maize, summer crop, wheat winter crop	800	520	540
Sunflowers, summer crop, wheat winter crop	400	600	600

Not only is there a consistent and marked difference between the residual effect of the legumes, but an enormous reduction is apparent when wheat follows non-leguminous cultivated crops.

Cedara School of Agriculture.
Average of Results from three farms:
Maize in pounds.

Check Plots.	First year after Cowpeas.	Second year after Cowpeas.
(1) 1,329.0	1,876.0	1,589.0

In this experiment the legume was cut for hay, consequently this marked effect is due chiefly to the residual effect of the roots.

(2) Another experiment gave the following figures for maize, following cowpeas used as a green-manuring crop :—

Check plot.	1st Year.	2nd Year.	3rd Year.
1,430	1,901	1,546	1,430

The importance of frequent green-manuring in South African maize farming is shown by the large gain due to the ploughing down of the cowpeas, and by the transient character of the residual effect of the green manure. These South African experiments, while inconclusive because of their short duration, give ample proof of the necessity for rotative cropping.

So far the results of the American, English and South African experiments give abundant evidence that in a good rotation provision must be made for the addition of humus and for the application of manures. Besides the detrimental effect on the soil, continuous cropping is generally characterised by excessive weed growth, largely because certain weeds thrive better in conjunction with some crops than with others. Lucerne is usually ploughed down when the weed growth becomes predominant, and in small grains no inter-cultivation is possible, consequently if continuously cropped to these crops, the fields tend to become infested with weeds. Therefore, while cultivated crops deplete soil humus, they should be included in a rotation to effect weed control.

To summarise, then, the essentials in a good crop rotation are : (1) To have a cultivated or cleaning crop, *i.e.*, one grown in relatively wide rows ; (2) to provide for the maintenance of the soil humus ; and (3) to restore and to increase the available plant food by the application of manures, commercial or otherwise, to one or more crops in the rotation.

The chief reasons for rotative cropping are briefly :—

(1) Labour is more evenly distributed throughout the year, and consequently is more economically utilised. Where only one crop is grown abnormal call is made on the available labour during certain periods, *e.g.*, planting and harvesting. However, if a diversity of crops is grown, the times of planting, cultivating and harvesting will vary, and the requirements from labour will be continuous rather than spasmodic.

(2) It must be apparent that, where several crops are grown, the risks of failure are minimised, since adverse seasonal differences affecting one crop may not affect another so severely, because crops vary in the time of year at which they make their maximum growth.

(3) This system of farming, embodying as it usually does a number of crops, furnishes a variety of food for stock.

(4) One crop tends to correct the faults of another and often leaves land in better condition for the succeeding crop. Thus the cowpea, when used as a green manure, naturally adds to the humus and nitrogen content of the soil, and consequently the soil is better able to support a crop like maize than if the maize had followed another cultivated or humus-destroying crop.

(5) Rotative farming is one of the most effective means of controlling weeds. Certain weeds thrive better when grown with some crops than with others. Dodder is parasitic on lucerne, and rooibloom (Striga lutea) on plants of the Gramineæ; therefore, if crops are grown which are not hosts of these parasites the latter are not so easily perpetuated.

(6) The losses due to insect pests and plant diseases are lessened by shifting the locality of the crop they affect; and by changing the host on which they thrive they are deprived of their means of subsistence. In this connection, it must be remembered that insect pests and the organisms causing plant diseases are more or less specific in their choice of host plants; thus those affecting solanaceous plants may not affect leguminous crops. Decreased yields are too often caused by badly infected soil—the cumulative result of the pathological condition arising from the continuous cultivation of the same crop.

(7) It is the best and most economical method of maintaining and increasing the productivity of the soil.

(*a*) Crops differ in their requirements of plant food. Certain plants make greater demands on certain plant foods than do others; therefore, a succession of crops requiring different quantities of potash, nitrogen and phosphorus for each crop will maintain a better balance between the quantities of these plant-food elements in the soil. It is easily seen, therefore, that an alternation of crops will retard the excessive reduction of certain necessary compounds. Moreover, an opportunity is afforded the soil to regain its normal content of the available element reduced through the specific assimilation of certain crops. On the other hand, the residues of some crops are beneficial to a succeeding one, thus crops following a legume are benefited by its nitrogen accumulation. If manures and fertilisers are employed to guard against the exhaustion of these elements this system of farming gives greater possibilities of their profitable use.

(b) The range of roots of crops varies, so that shallow-rooted crops benefit by the decaying residues of deep-rooted plants which have accumulated plant food in the upper stratum from lower strata of the soil.

(*c*) The humus supply is maintained.

(*d*) As a result of rotative cropping the soil is kept in a better physical condition, the soil micro-organisms consequently thrive better, and the decay and disintegration of the soil forming materials are more continuous than where the same crop is grown year after year. The annual natural accumulation of available plant food is greater, and consequently smaller dressings of manures are necessary than would otherwise be the case.

(8) Volunteer crops are more easily controlled, and therefore varieties are more easily kept pure. Where maize is grown continuously an undesirable cross-polination—*e.g.*, yellow on white varieties—may occur from plants grown from the seed left in the soil from the previous crop.

(9) Some crops are supposed to accumulate compounds in the soil, toxic to themselves, which are rendered harmless by the growth of other crops.

(10) The land is more fully occupied with crops than where a single cropping system is followed.

(11) Lastly, rotative cropping necessitates organisation and good management, which in turn stimulate business development. A farmer following good rotative farming knows that each year he can expect approximately the same proportion of each crop, a fact important not only because of its bearing upon the profitable use of his labour, but valuable in its relation to his whole business as a farmer. He knows how much he is likely to have to handle of each crop, how much stock he can keep, the variety of food he can feed them, and the amount of money he is likely to receive from the sale of certain of his crops. To be weighed against the advantages of practising rotations are the smaller considerations; firstly, that it requires greater skill to handle a variety of crops well; and, secondly, more machinery is required.

The factors to be considered in planning a rotation are many and varied, and in South Africa, where cultivation in most parts is of an extensive rather than an intensive nature, certain difficulties, due largely to the small variety of crops grown and the very uncertain climatic conditions in many areas, are encountered. On some rich soils, and where land is comparatively cheap, the necessity for rotative cropping is not so apparent, and, indeed, in some localities it is questionable whether a change would be economically sound at present. However, these areas are limited, and the capacity of all soils to yield productive crops must sooner or later diminish. As a system in maintaining permanent agriculture, there can be no question of the advisability of rotative cropping all over South Africa. Even the " maize rancher "—growing from 500 to 1,500 acres and more of maize on rich soils—will find it profitable to use a green manure on a third or fourth of his land each year. However, the rotation to be followed will be governed by considerations, such as transportation, market requirements, labour, locality, the individual farm and kind of farming practised, whether grain or stock farming, and, further, the kind of stock.

In general, the rotation must be built on the main crop to be grown, *e.g.*, maize in the Transvaal, Orange Free State and Natal. Where the crops are fed to stock and the manure returned to the land, green-manuring is less necessary than on those farms where the bulk of the crops grown are sold. Further, the dairy farmer requires a greater variety of crops than does the sheep farmer. The former wants silage, grain for concentrates, hay and pasture; the latter in South Africa is concerned chiefly with pasture and hay.

The nature of the soil, too, will determine to a certain extent, the crops to be grown. Potatoes prefer loose open soils, while wheat will grow better than most crops on relatively heavy soils. Mangels are a much more successful crop on alkali soils than maize. Lucerne cannot be grown profitably on acid soils, where rye, potatoes and cowpeas might yield quite good crops. Sandy soils require more frequent green-manuring and fertilising than clay loams. Bulky crops, like potatoes, require good transport facilities, a consideration not so important to the cotton grower. Obviously, too, the climatic requirements of crops will play an important part in planning a rotation. Cotton must have a longer growing season than teff, millets, and most varieties of maize; the winter cereals have completed their growth shortly after, or even before, maize has been planted; millets and sorghums give good crops in regions having a rainfall too low for successful maize farming; and whether the precipitation is chiefly in winter or summer will, naturally, have a very material bearing on the choice of crops.

After the choice of crops has been decided, the question of field management arises. The simplest procedure, but by no means always practicable, is to have as many fields of the same size as there are years in the rotation. Thus, if the rotation is maize the first year, sudan grass the second, and kaffir beans the third year, no difficulty is found in rotating the crop on three equal-sized fields. Often, however two or more smaller fields will have to be combined and looked upon as one. Often several rotations will be practised on one farm, in which case the large fields are used for the main rotations while the smaller ones are used for minor rotations—a situation found on many farms where a small area is irrigable and a large area is employed in growing crops without irrigation. Given such a case in the Transvaal, a rotation of maize, teff and cowpeas might be found on the dry lands, and a rotation of lucerne, potatoes and wheat on the irrigated lands.

Again, so as to ensure the distribution of harvesting operations throughout the season, the maturity of the crops should not conflict.

Lastly, where possible, catch crops should be introduced in the rotation.

Much of the above may appear obvious; much, to the South African farmer, may seem theoretical and impracticable. In justification, however, it may be pointed out that the obvious is too often overlooked, and to the second charge one can only say that rotative farming is already commonly practised by many of our more progressive and successful farmers. Further, the experience of older countries, where extensive farming has been compulsorily abandoned by the force of economic considerations, has shown the necessity for rotating crops.

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[1] "Field Management and Crop Rotation."—Parker.

[2] "The Relation of Different Systems of Crop Rotation to Humus and Associated Plant Food."—Bulletin No. 128, University of Minnesota.

[3] "Soil Fertility and Permanent Agriculture."—Hopkins.

CHAPTER VI.

MAIZE (Zea mays)

PRODUCTION.—Though grown by Europeans only in comparatively recent times, maize production has increased to such an extent that to-day it is the world's highest yielding grain crop. In order of production, the world's average annual cereal production for the period 1906-1910 was as follows :—

Crop.	Quantity.
Maize	113,000,000 tons.
Wheat	107,000,000 ,,
Oats	67,000,000 ,,
Rice	67,000,000 ,,
Rye	46,000,000 ,,
Barley	33,000,000 ,,

For the same years the average Continental production was :—

North America	78·09 per cent.
Europe	15·08 ,,
South America	4·20 ,,
Africa	2·35 ,,
Australia	·28 ,,

The United States of America contribute approximately three-fourths of the world's production. The following indicates the position of the leading countries during 1911-13, the figures representing the average annual production :—

United States	2,725,367,400 bushels.
Austria-Hungary	209,837,600 ,,
Mexico	152,166,200 ,,
Argentina	151,015,000 ,,
Italy	95,696,800 ,,
Roumania	88,163,400 ,,
Egypt	66,058,800 ,,
European Russia	59,831,200 ,,
Union of South Africa (average 1915-17)	33,758,333 ,,

Of these countries, Argentina and South Africa are relatively undeveloped, and as farming becomes more intensive they doubtless will become of much greater importance.

It is of interest to note the percentage of the crop exported from these countries. The United States of America exports only 2·29 per cent. of its crop, while Argentina exports 55·33 per cent. of its maize, and South Africa (1911) 11 per cent. and (1918) 20 per cent. Naturally, in more densely populated countries, where intensive farming is necessarily practised, consumption is high and export low; in fact in the maize belt of America the greater portion of the crop never leaves the farms on which it is grown. While it is anticipated that South Africa in the near future will export both a higher percentage and larger quantities of its maize, when farming assumes a more intensive phase, a smaller percentage is likely to leave our shores.

A curious position is shown when the average yield per acre of these various countries is considered :—

	Average, 1912-14.
Canada	57·1 bushels.
Egypt	30·5 ,,
Argentine	25·1 ,,
Hungary	29·7 ,,
Bulgaria	19·1 ,,
Italy	27·0 ,,
Spain	23·5 ,,
U.S.A.	26·3 ,,
Australia	27·4 ,,
South Africa	14·29 ,,

The low acre yield in the United States of America must be attributed to the fact that a large acreage is cultivated in the drier Western States, where climatic conditions are not so well suited as in the more humid regions. In South Africa, as will be pointed out later, one of the chief contributing causes of low yield per acre is the fact that much of the maize grown is produced in areas unsuited to its growth. Unlike the United States of America, no distinct line of demarcation between the maize and sorghum areas has been definitely formed.

South African Production.—Prior to the Anglo-Boer War sufficient maize was not produced to meet the requirements of local consumption, as is shown by the fact that in 1899 £200,000 worth of maize meal was imported for use on the mines in the Transvaal.

In the rapid development of the country subsequent to that war, maize growing assumed a position of unprecedented importance in our agriculture. New varieties were imported, improved machinery was introduced, up-to-date methods of cultivation were employed, and the then newly-established experimental farms demonstrated how crops could be grown profitably. Added to this, Government itinerant instructors assisted in revolutionising this industry, so that in less than a decade South Africa changed from an importing into an exporting country. In 1907 1,545,266 bushels of maize were exported, and in 1910 Government grades were established and facilities under Government supervision were inaugurated. In this year nearly 6,000,000 bushels were exported, while in 1908 the export had risen to approximately 8,500,000 bushels.

PRODUCTION OF MAIZE, 1904—1919.

Year.	Cape Province Tons.	Natal Tons.	Transvaal Tons.	O.F.S. Tons.	Union Tons.
1904 (General Census)	113,171	78,867	130,366	38,754	261,159
1911 (General Census)	172,786	180,574	331,061	178,829	863,256
1910 (Census of Agriculture)	238,749	144,390	455,391	425,478	1,264,009
1919 (Census of Agriculture)	62,760	74,799	332,186	383,175	802,920*

*Excluding maize produced in Native Locations, etc., which amounted to 292,748 tons.

The leading districts in these Provinces are :—

Transvaal: Potchefstroom, Lichtenburg, Bethal, Heidelberg, Standerton, Middelburg and Pretoria.

Orange Free State: Kroonstad, Bethlehem, Heilbron, Vredefort, Frankfort, Senekal and Winburg.

Natal: Estcourt, Klip River, Ixopo, New Hanover and Umvoti.

Cape Province: Griqualand East and Griqualand West.

In the future, when closer settlement takes place, there is no doubt that in some of the less developed parts of South Africa, *e.g.*, Zululand and North-Eastern Transvaal, maize growing will play an important role.

THE CHIEF CAUSE OF LOW YIELD IN THE UNION.—In the Union the acre-yield of most crops is decidedly below that of most other countries. The average yield of maize per acre is only 7 to 10 bushels (2 to 3 bags), while that of the United States of America ranges from 25 to 30 bushels (7 to 9 bags) per acre. With all crops one is confronted with this disparity, which must be attributed largely to the present extensive phase of farming in South Africa, but probably in the main to uncertain or insufficient rainfall, and often to poor soils. However, these do not account altogether for our low production, as a great many of our progressive farmers obtain returns in good seasons approximating the American average. The following are serious contributing causes:—

(1) General failure in recognising the importance of crop rotations, which must embody a cultivated or hoed crop by which weeds are controlled, a crop to which fertilisers are added (thus preventing the exhaustion of available plant food), and the addition of humus, either by green-manuring or the application of stable and kraal manure.

(2) Poor soil preparation and after cultivation.

(3) Failure to practise seed selection.

(4) The use of varieties unsuited to the locality, *e.g.*, dent maize is too often grown in parts having a relatively low rainfall, where flint varieties would probably be more successful.

(5) Persistence in growing crops unsuited to the natural conditions, *e.g.*, maize is too largely grown for grain in parts having an average annual rainfall of 20 to 24 inches, though sorghums would be infinitely more reliable in these areas, both for silage and grain.

(6) The shortage of satisfactory labour is a very real handicap to crop growing in many sections of the country, and no doubt much of the criticism directed towards the methods of our farmers is really attributable to labour shortage.

(7) Losses due to insect pests and diseases.

When more attention is paid to the shortcomings enumerated above, and when the present acreage under cultivation has inevitably increased, no doubt the production will be tremendously augmented. It is conservatively estimated that only one-third of the suitable land available is planted with this crop. In proof of the fact that various areas can support very much higher yields per acre, it might be stated that in the season 1917-1918 the average yield per acre for the maize grown at Potchefstroom Experimental Farm—over a considerable acreage—was 31·7 bushels (9·6 bags); in 1916-17 Eureka variety yielded 46·8 bushels ($14\frac{1}{2}$ bags); in 1916 the average yield for fifty competitors was 32·1 bushels ($9\frac{3}{4}$ bags), and in 1917 the average for one hundred competitors was 34·6 bushels ($10\frac{1}{2}$ bags); while reasonably authentic yields of 108·9 bushels (33 bags) have been reported. Maize growing is particularly well adapted to South Africa because of the low price of productive land, relatively cheap labour, a long planting season of at least eight consecutive weeks (whereas in the maize belt of the United States the time is only from three to four weeks), and a dry harvesting season which is largely responsible for the phenomenally fine quality of South African maize.

History.—Harshberger states that maize was probably brought into cultivation in Southern Mexico about the beginning of the Christian era. While the cultivation by Europeans of most of the chief cereals ante-dates history, that of maize is of comparatively recent times, *i.e.*, within the last three centuries. In 1492 Columbus found it in common cultivation. Its introduction into Europe, Africa, China and Asia Minor followed shortly after.

The word " maize " is derived from the Haytian word ma'hiz. It is an Arawak word met with in many forms in South America and the West Indies. Mielie comes from the Portuguese word milho. The following are the words used to designate maize in the countries named, viz. :—

South Africa.	Maize, mielie (and wrongly, mealie).
England.	Indian corn.
America.	Indian corn and corn.
Germany.	Turkischer körn.
Sweden.	Koren.

Origin, Description and Classification.—*Biological Origin.*—" The Gramineæ," or grass family, includes most of our common cereals, as maize, oats, wheat and rye. A distinguishing feature of the tribe Madeæ, to which maize belongs, is the separation of its staminate flowers (pollen-bearing) from its pistillate flowers (seed-bearing). Two grasses related to maize and of common occurrence in Mexico—the region in which maize is supposed to have originated—are gama grass (Tripsacum dactyloides) and teosinte (Euchlæna mexicana).

Gama grass is distributed over the southern half of the United States and usually is found on low, rich soil. At a distance a patch of this grass looks very much like maize; while it grows to a height of five to ten feet, the stem is slender and the leaf about half the width of the maize leaf. The plant bears a tassel-like structure at the top and on the lateral branches, closely resembling the maize tassel, except that the seeds are borne on the lower part of each tassel and the pollen on the upper part.

Teosinte, which is sometimes cultivated but does not mature north of Mexico, is more like maize than is gama grass, the plant being larger and the terminal tassel bearing pollen only. The lateral branches of the plant are so shortened that the terminal tassel-like structure is borne in a leaf axil surrounded by a kind of husk as is an ear of maize, and bears only pistillate flowers or seed. It is only a step in the production of an ear of maize, from teosinte, by a development of the central spike of the lateral tassel into an ear.

It is probable that the early progenitor of maize was a grass-like plant having a tassel at the top and a tassel-like structure on long, lateral branches, all tassels bearing perfect flowers. As evolution progressed, the terminal tassel came to produce only pollen, and the side branches only ovules, or seeds. Evolution often results in a greater "division of labour," as in this case. At the same time the lateral branches were shortened or telescoped into the leaf sheaths, these sheaths forming a covering or husk for the ear. Also it is probable that in this evolution the central spike of the tassel developed into an ear. The close relationship of maize and teosinte is proved by the crosses that have been made between the two. In the third or fourth generation after crossing, a peculiar type of corn is secured, identical with a type of maize that has been found growing wild in Mexico (Zea canina), and is supposed by some persons to be the true wild maize and the progenitor of our cultivated maize." ([6])

The maize plant is in many respects typical of the grasses. It belongs to the Gramineæ, and is a member of the Maydeæ, a tribe which is characterised by the separation of the pistillate and staminate flowers. It is monœcious, and is both protandrous and protogynous, protandry being the rule in the chief varieties in South Africa. While self-pollination is common, cross-pollination is usually a factor which later will be shown to have a very marked effect on productivity.

Roots.—The root system is developed as follows:—First the primary root appears, after this the temporary roots develop at the median point between this root and the stem; these serve to maintain the seedling during the early stages. Next whorls of permanent roots are formed just below the surface of the soil, and lastly the " brace " or adventitious roots from the first few nodes above the ground. The function of the latter is to anchor the plant in wet and windy weather.

Stem.—The stem varies in length from about 2 feet to 20 feet, depending chiefly on the varieties, soil and climatic conditions. It is solid, *i.e.*, filled with pith, and divided by nodes, aerial and sub-aerial, 14 to 30 in number.

The internodes on certain parts of the plant are grooved, which seems to be a provision for accommodating the shank or ear branch. When roots or ears arise, they spring from a bud at the base of the groove. This bud is completely enwrapped by the leaf-sheath, which serves to protect it.

Under some conditions, partly dependent on variety, character of season and distance between plants, " suckers," or basal branches, spring from the buds on the main stem near the crown, these suckers afterwards developing independent root systems.[5]

Leaves.—The leaves are long, broad and tapering, very flexible, and to prevent excessive transpiration will roll together during very dry weather.

Kernels.—Various colours are found, *e.g.*, white, yellow, orange, red, purple, black, striped, etc.; the pigment may be found in the seed-coat, aleurone layer, endosperm and even in the embryo.

CLASSIFICATION. –

Order :	Gramineæ.
Tribe :	Maydeæ.
Genus :	Zea.
Species :	Mays.

Montgomery[6] mentions the following groups or agricultural species, and acknowledges his indebtedness to Sturtevant :—

Zea Mays indentata.—Dent or Flat Maize.—Varieties of this group are readily recognised by the dent or hollow at the crown of the kernel. The white starch of the endosperm reaches to the top, while the horny starch is found along the sides. Through the drying and consequent shrinkage of the starch the crown becomes indented in various shapes, from a " dimple " to a " bridge." The ears are usually larger, the rows more numerous—8 to 24—the grain is deeper, less flinty and more angular in shape than that found in the flint group. The dent varieties constitute the bulk of the maize grown in the Union.

Zea Mays indurata.—Flint or Round Maize.—The kernel is round, hard and shallow. The corneous starch surrounds the white starch. In some varieties the former may be very thin, in which case a slight indentation may be found. The cobs are usually slender—8 to 14 inches—and have from 6 to 16 rows. Flint varieties are generally of a shorter maturity and more drought resistant than those belonging to the former group.

Zea Mays amlyacea.—Bread, Soft or Flour Maize.—The kernel is identified by the absence of corneous endosperm and the presence of white starch only. In shape it resembles flint maize, and as the kernel shrinks evenly on maturity, usually no indentation is found. The rows vary from 8 to 14 in number and the length 9 to 12 inches. It is grown in small quantities on many farms in South Africa, chiefly for green mielies for table use, and also for maize flour for porridge. Varieties of bread maize are as a rule comparatively poor yielding and very subject to weevil infestation.

Zea Mays saccharata.—Sugar, Sweet or Table Maize.—A well-defined group of maize recognised by the translucent, horny, shrivelled appearance of the kernel. "Shrinking is probably due to the conversion of starch into glucose. According to East, sweet corns are either dent or flint corns that have failed to convert their sugars into starch." Varieties of this group are grown essentially for culinary purposes, and it is surprising that its superior qualities for table use have not earned for it a greater popularity in South Africa.

Zea Mays everta.—Pop, Kip or Spring Maize.—In these species the ears as well as the grain are small, and the latter contains an abnormal percentage of horny endosperm. When the grain is heated, the moisture contained in the endosperm on expansion causes an explosion which completely everts the kernel, hence the American name, "Pop corn." The ear varies from 2 to 9 inches, and 8 to 16 rows are found. The rice types have sharply pointed kernels, and the pearl is rounded in the manner of flint maize. Profuse stooling is found in this agricultural species and generally a large number of ears are borne by each plant. Little demand for this class of maize is found in South Africa, and consequently very little is grown.

Zea Mays tunicata.—Pod or Dop Maize.—The distinguishing feature of this class is that each kernel is enclosed by glumes; the ear is enclosed by husks. The grains may assume the forms of most of the more commonly occurring types. In no country has this group been of economic importance, and it is of more interest to the botanist than to the agriculturist. The podded condition is now considered to represent a case of imperfect dominance, and that, like the Andalusian fowl, it is unfixable and related to the heterozygous condition.

Zea Mays canina.—Dog Maize.—Of little direct agricultural value, but of considerable interest in that, while it is said to grow wild in Southern Mexico, it can be produced by crossing teosinte (Euchlæna mexicana) and the commonly occurring types of maize. The plant is much branched, having a large number of very small ears, which may be clustered sometimes. These are 2 to 4 inches in length, with 4 to 8 rows.

As the exploitation of the cultivated plants in different parts of the world takes place, a number of new forms are being discovered. Among the outstanding of these the following may be noted :—

Zea Mays japonica.—This has green and white striped leaves with a flint type of grain. Grown ornamentally in gardens.

Zea Mays hirta.—This species occurs in South America, and is distinguished by having very pubescent leaves and sheaths. It is extremely shallow-rooted.

Zea Mays curagua has serrated leaves.

Chinese maize is recognised by having a waxy, not starchy, endosperm. The ear resembles pearl pop maize.

Hopi maize is cultivated by the Hopi Indians. It tillers very freely and will reach the surface when the seed is planted 12 inches in depth in sandy soil, an adaptation which may prove of material advantage in the drier north-western districts of South Africa. The kernel is amylaceous.

Collins[8] reports a type from Bolivia which develops the quality of remaining green for some time after maturity. Hermaphrodite forms are known, these having perfect flowers; the plant has short internodes with broad leaves.

VARIETIES.—Maize, in common with most of the widely grown field crops, has numerous varieties. In 1814 only five distinct varieties were known in North America, while the number to-day is estimated by some to be over a thousand. These have been obtained by the selection of remarkable mutations, by continued selection towards a certain ideal of enthusiastic growers, and by crossing.

It is only within recent years that the leading varieties known in the Union to-day were introduced. Prior to 1899 flint varieties, *e.g.*, Bothma, were the predominant types grown, and dent varieties in many sections were unknown.

The chief dent varieties found in South Africa to-day are :—

White.—Natal White Horsetooth, Ladysmith White, Salisbury White, Hickory King, Hickory Horsetooth (Texas Hickory), Hickory Louisiana, Boone County, Potchefstroom Pearl and Iowa Silver Mine.

Yellow. Natal Yellow Horsetooth, Golden Beauty, Yellow Hogan, Eureka, German Yellow, Chester County Mammoth, Palm's Cornflake (selection of Reid's Yellow Dent), and King of the Earlies (Wiggie).

The following are the chief flint varieties :—

Yellow.—Natal 8-row, Yellow Cango, Cincinnati (Boesman), Will's Gehu (Boesman).

White.—White Cango, American White Flint and Thoroughbred.

Of the bread maize, the Brazilian flour and the Brood mielie are the ones best known ; of sugar maize, Stowell's Evergreen, Country Gentleman and Black Mexican, and of pop maize, both the rice and pearl types are known.

Varieties differ markedly as regards soil and climatic requirements. Iowa Silver Mine does better on relatively sandy soils than most varieties, while Eureka seems to prefer the heavier clay loams. Flint varieties are more successful at high altitudes and in drier regions than dent varieties. Some of the late maturing dent varieties naturally require a long growing season and, incidentally, favourable conditions as regards soil and moisture. From this it must be self-evident that no variety can be expected to be the best variety in all sections of the country. Failure to recognise the suitability of breeds for particular localities has been mainly responsible for a great deal of indifferent production.

Some varieties will mature in 80 days; others take up to 200 days to reach maturity. Under our conditions the period required varies from 90 to 160 days. The factors influencing the length of period are :—

1. The date of planting. If planted late in the season the growth of the crop will take place during the cooler weather,

consequently development is retarded and will naturally take longer than when grown during the hotter months when optimum conditions of light and temperature prevail.

2. The nature of the plant food available. A super-abundance of nitrogen will delay maturity, while a high supply of phosphates will hasten ripening.

3. Altitude. The higher the altitude the shorter the period of maturity.

Date of Planting.—The date of the commencement of the seasonal rains naturally will often govern the period during which crops may be grown; consequently, while the conditions of temperature and light might be fully met in some parts, because of the late commencement of the rainy season, early varieties must necessarily be grown.

The following classification of the varieties according to the period required for maturity must be, on account of what has just been stated, an approximate one :—

(1) *Very Late Varieties.*—These take more or less five months to mature.

(a) Natal White Horsetooth.
(b) Natal Yellow Horsetooth.
(c) Ladysmith White.
(d) Salisbury White.
(e) Brazilian Flour.
(f) Boone County.
(g) German Yellow.
(h) Hickory King.

(2) *Late Varieties.*—These take approximately 140 to 150 days.

(a) Hickory Horsetooth (Texas Hickory).
(b) Hickory Louisiana.
(c) Golden Beauty.
(d) Yellow Hogan.
(e) Eureka.
(f) Potchefstroom Pearl.

(3) *Medium Varieties.*—This class requires 120 to 140 days.

(a) Iowa Silver Mine.
(b) Chester County Mammoth.
(c) Palin's Cornflake (Reid's Yellow Dent).
(d) Natal 8-row.
(e) Yellow Cango.

(f) American White Flint.
(g) Cincinnati (Large Boesman).

(4) *Early Varieties.*—Requiring from 90 to 120 days.
(a) White Cango.
(b) Will's Gehu (Small Boesman).
(c) King of the Earlies (Wiggie or Minnesota).
(d) Brood Mielie.
(e) Rural Thoroughbred.

The very late varieties are not recommended for the highveld (altitude 5,000 feet and above) on account of the shortness of the growing season. And while some of the late varieties, if planted early, may be suitable in favourable seasons, generally speaking, the medium varieties are to be preferred, and of these the flint breeds are to be recommended.

On the middleveld (altitude 4,000 to 5,000 feet) the late varieties are the most suitable, while on the lowveld (4,000 feet and below), where the rainfall is sufficient, the very late varieties are usually most productive; while when the season is shortened by the late commencement of rains, the late and even the medium sorts may prove the best.

The early varieties find their chief use as catch crops when the main crop has failed through the ravages of cutworms or stalkborers, destruction by hail and drought. In the drier maize-growing areas these breeds are the most successful because of their early maturity, which makes them drought-evading, especially the flints, on account of their low transpiration ratio and general drought resistant qualities.

Climatic and Soil Requirements.—"Maize is a sun-loving crop of tropical origin, but is so flexible in its requirements and so readily adapts itself to its surroundings that it is successfully grown over wide climatic ranges. It does not mature, however, anywhere north of the 50th parallel, although it may be grown for green fodder in favoured localities somewhat further north.

"The great maize regions of the world are areas of continental climate. Except where irrigation is practised, most maize is grown in regions having an annual rainfall of over 20 inches and a summer temperature averaging about 75°. A comparatively small area of the earth's surface is devoted to the intensive cultivation of this crop, as the optimum climatic conditions for maize are found in only a few regions of the world."[9]

In South Africa maize cultivation is restricted to the summer rainfall area. The optimum conditions are found in those parts of this area having a mean temperature from November to February, inclusive, of 65° to 80° and a mean minimum temperature for these months of over 55°. Nevertheless maize is grown profitably in parts having a mean minimum during this period of as low as 50°. It requires a frostless season of 160 to 180 days; an annual precipitation of 30 inches and above; but constitutes an important part of the agriculture in districts with a rainfall as low as 24 inches. Of greater concern, however, is the seasonal distribution, and it is found that maize is most successful in those parts having 12 inches well distributed throughout the months of December, January and February. Maize should have as much sunlight as possible; this is shown by the indifferent results obtained in the mist-belt and in parts experiencing a large number of cloudy days. In this connection it might be mentioned that to obtain the maximum sunlight it is the practice of some farmers to plant maize having the rows running east to west where topographically possible.

Maize grows well on a wide range of soils varying from a light sandy soil, *e.g.*, sandveld in the north-western Free State, to heavy clays (turfs), *e.g.*, Springbok Flats, in favourable seasons. It prefers deep, well-drained, rich, sandy loams and loams well supplied with organic matter. It does better on relatively acid soils than on those whose alkali content (brak soils) is high. In general, calcareous, as well as more or less neutral, soils are best.

CULTURAL METHODS.

Soil Preparation.—A thorough preparation of the seed bed is essential. Methods will naturally vary according to localities and prevailing circumstances. In South Africa, as moisture is the chief limiting factor in agronomic production, all steps for its conservation should be taken. Where possible the land should be ploughed as soon as the previous crop has been removed, and it should be left in a rough condition. This facilitates weathering and leaves the soil in a receptive state for the early spring rains. Prior to planting, this land may have to be cross-ploughed to a lesser depth. In any case the soil should be worked by discing and harrowing into a fine tilth to destroy weeds and to ensure a favourable seedbed. Before planting, the necessity for destroying weed seedlings whose growth has been promoted by the early rains cannot be over-emphasised.

Virgin soil should be ploughed if possible during the latter part of the rainy season, and should be pulverised during the winter so as to get the soil into a fine physical state in which the vegetation should be thoroughly incorporated with the soil, thus assisting decomposition before planting takes place. It must be remembered that the crop is not so much affected by the immediate ploughing as by the previous treatment of the soil. All land previously under cultivation should be ploughed occasionally to a depth of 8 inches and deeper, especially heavy soils, but in dry regions and on very sandy soil this will be required less often. The question of sub-soiling is a vexed one. On the whole, under South African conditions it has not proved a profitable practice. In some parts where the sub-soil is near the surface it may be inadvisable to plough too deeply, for by bringing up the inert sub-soil in too large quantities at a time crops will not thrive. Land of this character is best shallow ploughed, gradually increasing the depth of subsequent ploughing.

PLANTING.—Maize is planted almost entirely by maize planters, the wasteful and inefficient practice of broadcasting the seed having long since been abandoned. The seed is planted 3 to 5 inches below the surface, depending on the nature of the soil, whether heavy or light, in rows 3 to 3½ feet apart, and the seed 12 to 24 inches in the rows. It may also be planted in check rows, where by means of a device attached to the planter the dropping of the seed is regulated for a certain distance in the row. By this means the seed is dropped in hills, two to three seeds per hill, 3 feet by 3 feet apart. The advantage of this method is that cultivation can be done along and across the rows. While this is the system in vogue in America, sufficient experimental evidence has not been obtained to warrant its use under our conditions, except on very weedy lands. Listing is also followed. The lister is essentially a double mouldboard or ridging plough, which converts the lands into a series of small ridges. The seeds are planted in the bottom of the furrows between these ridges. This method of planting is used in the drier areas having sandy soils, and is a cheap method of growing maize, as the ground is not ploughed before planting, though it is usually disced. It is contended that maize planted in this way will resist drought better than that planted in the ordinary way, because when the ridges are broken down by subsequent cultivation the root system is left at a depth unaffected by severe soil moisture fluctuations.

The rate of seeding is affected by the following considerations:—(1) Climatic and soil conditions. The more productive the soil and the more favourable the climate the larger the quantity to be sown per acre. (2) Vigour and size of seed. Less seed of good vitality is used than of that having low vitality; the smaller the grain the less is the quantity required per acre. (3) The variety grown. Some varieties have a tendency to stool, and in these less seed is planted; others are more luxuriant in growth and should, therefore, be more widely spaced.

The rate of planting is governed by the average carrying capacity per acre for the locality in question. It is a factor to be determined by the farmer himself. Too close planting is injurious because it reduces the plant food available for each plant, and in drought each plant may be less able to secure sufficient moisture; it prevents proper weeding and retards photosynthesis. There is no uniform distance suitable for all districts. Generally speaking, 3 feet by 18 inches (9,680 plants per acre) is the best average spacing. This will require 12 to 15 lbs. per acre of the large grained varieties such as Hickory King; about 10 lbs. per acre of the medium sized grain varieties such as Iowa Silver Mine, and of the very small grained breeds, *e.g.*, King of the Earlies, about 6 lbs. per acre. These quantities are those recommended for grain growing. When the crop is grown for silage, 50 per cent. more seed is used. At Potchefstroom the largest tonnage of silage maize was obtained when sown in rows 3 feet apart and 1 foot apart in the row. For fodder 40 to 50 lbs. are broadcasted per acre.

It will be appreciated from what has already been said that the date of planting will necessarily vary in different parts. It must be borne in mind, however, that each variety makes an optimum growth during certain periods in each district, determined by experience.

The beginning of the regular rains is frequently the deciding factor. Consequently only approximate times can be given, and then only for normal seasons and for the varieties commonly sown. On the highveld the bulk of the crop is put in during October; in November in the middleveld, and in December in the lowveld.

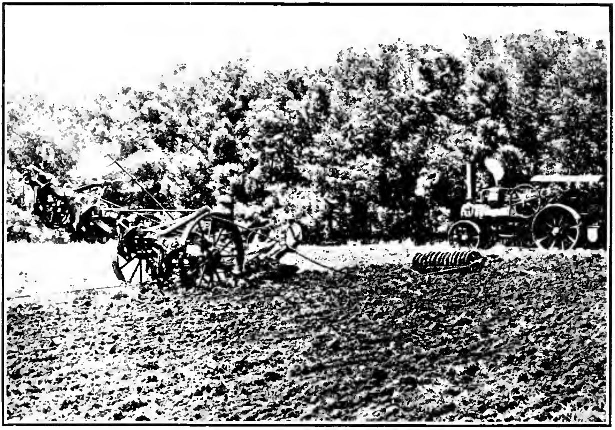
After Cultivation.—On sandy soils the field should be harrowed lightly as soon as the plants have appeared above the surface of the soil, or at such a stage when no likelihood of their being covered completely by the loose soil is possible. If on clay soils shower crusts should have formed before the plants appear, it will be found to be necessary to harrow in order to break the crust to allow the plants to come through and to assist in soil aeration. On normal soils, though, crops should not be harrowed until four leaves are shown; if necessary before this time on account of weeds, the operation is best carried out when the plants are coming through and before the leaves have unfurled. The harrowing may be repeated until the crop is shown to be too severely injured by the operation. During the heat of the day, when the plants are in a wilted condition, harrowing may be safely carried out until the plants are a foot high. The object of this practice is to destroy weed growth at the most susceptible period of the seedling condition; to aerate the soil; to make it more receptive for rain, and to render the plant food more available. On sandy soils the weeder might be used to advantage when the harrow can no longer be employed. The fields should be harrowed across, and not with the rows. After this, cultivators are used between the rows; how often and when to cultivate must be left to the discretion of the grower, who should bear in mind the object of cultivation. As the root systems extend, cultivation must become shallower and must be restricted to the centre of the space between the rows, otherwise injury will be caused by destroying the roots. In drier parts the soil should be left as level as possible and not ridged by the cultivators. Cultivation should cease as soon as the ears are well formed.

MANURING.—While maize may be considered a gross-feeding crop, it requires plenty of available plant food.

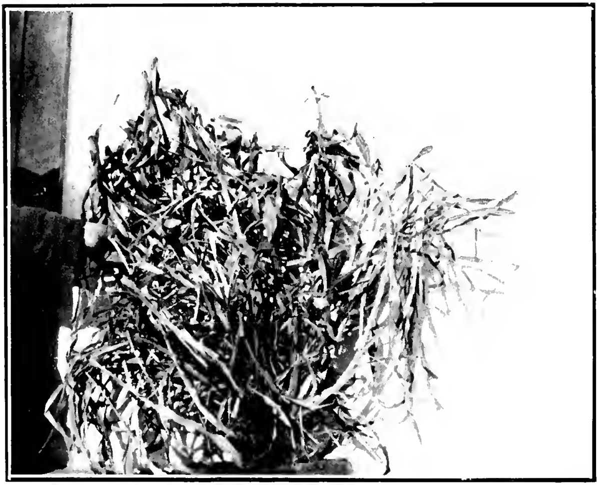
The following table shows the amounts removed from the soil by a good crop of those mentioned :—

	N.	P_2O_5	K_2O
25 bushels maize ...	39·2 lbs.	13·8 lbs.	27·6 lbs.
25 bushels wheat ...	42·5 lbs.	16·6 lbs.	21·0 lbs.
10 tons turnips ...	50·0 lbs.	20·0 lbs.	90·0 lbs.

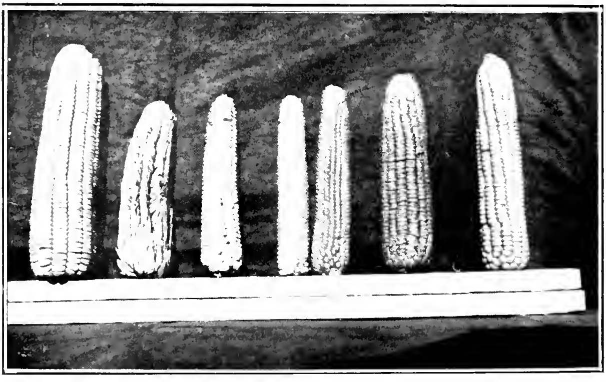
Productive maize soils are almost invariably characterised by a high content of organic matter; where this is deficient as evidenced by the deflocculated and light colour of the soil, it must be remedied by the application of kraal manures or by green-manuring. The addition of artificial nitrogenous fertilisers is not considered necessary, as although maize is a



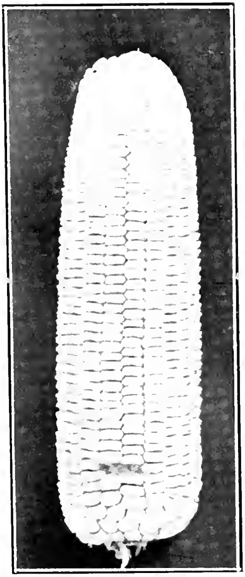
LAND IN GOOD TILTH—STEAM PLOUGHING AT POTCHEFSTROOM EXPERIMENTAL FARM.



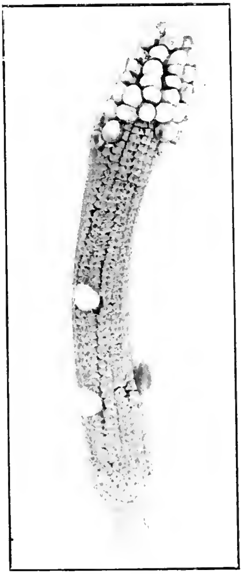
TEOSINTE (EUCHLAENA MEXICANA).



SPECIES OF MAIZE (LEFT TO RIGHT): DENT MAIZE (Z. MAYS INDENTATA); POD MAIZE (Z. MAYS TUNICATA); FLOUR MAIZE (Z. MAYS AMYLACEA); PEARL POP MAIZE (Z. MAYS EVERTA); RICE POP MAIZE (Z. MAYS EVERTA); SUGAR MAIZE (Z. MAYS SACCHARATA); AND FLINT MAIZE (Z. MAYS INDURATA).



EAR OF IOWA SILVER MINE.



EAR OF MAIZE, SHOWING POOR FERTILIZATION.

Plate IV

MAIZE WITH COWPEAS GROWN BETWEEN THE ROWS—TRANSVAAL UNIVERSITY COLLEGE EXPERIMENTAL FARM.

MAIZE WITH COWPEAS GROWN IN THE ROW—TRANSVAAL UNIVERSITY COLLEGE EXPERIMENTAL FARM.

nitrogen-loving crop, its nitrogen requirements are usually fully met by the rapid nitrification which takes place during the South African summers of high temperatures and moist conditions; moreover, under a good cropping system the use of leguminous green manures will further militate against any likely shortage of nitrogen. The application of potassic fertilisers is of doubtful utility, as both analytically and empirically South African maize soils have been shown to contain sufficient available quantities of this element. Almost invariably, however, our soils are found to be lacking lamentably in phosphates, which are absolutely essential for full development, particularly of the grain. Wherever phosphatic fertilisers have been used judiciously good results have accrued, except under abnormal conditions. The use of lime in maize production is of doubtful value, chiefly on the score of economy. Experiments in the Transvaal have not shown an increase commensurate with the cost of applying lime. No doubt on certain acid soils it might be profitably employed. The use of phosphatic fertilisers is in fact becoming popular among our maize growers. The following experiment at Koedoespoort during the years 1910-13 indicates the wisdom of using fertilisers under our conditions.[10]

Plot.	Manurial Treatment per acre.		Yield per acre.		Two years increase due to fertilizer.	Cost of Fertilizer.	Profit per acre for 2 years.
	10-11	11-12	10-11	11-12			
8	Nil.	Nil.	662	484	—	—	—
5	400 lbs. Basic Slag.	Nil.	1,106	2,220	2,287	£1 0 0	£4 2 11
13	400 lbs. Bone Meal.	Nil.	1,612	1,734	2,200	£1 8 0	£4 11 0
4	200 lbs. Superphosphate.	200 lbs. Superphosphate.	813	1,822	1,594	£1 1 0	£2 10 10
11	400 lbs. Basic Slag.	Nil.	1,497	2,433	2,784	£1 0 0	£5 5 4

The maize was valued at 9s. per bag. This soil was originally low in lime and available phosphate, and moderate in nitrogen and potash, hence the increase for basic slag and bone meal over superphosphate.

Generally speaking, high grade superphosphate applied at the rate of 200 pounds per acre seldom fails to give profitable returns. Experience has shown that the best method of application is by means of the fertiliser attachment, found on most planters, at the time of planting.

Bone dust and basic slag are also used and are to be recommended on acid soils and in damp situations. An application of 200 to 300 pounds per acre is generally advocated. These fertilisers have a residual effect beyond that of superphosphate.

Where available, well-rotted kraal manure at the rate of 6 to 8 tons per acre is to be recommended, and if supplemented by the addition of small dressings of phosphates may be looked on as a fairly complete manure.

ROTATIONS.—There is a decided tendency towards a continuous single-cropping system among the maize farmers in South Africa to-day. In fact the majority are growing this crop continuously on the same land. This pernicious practice is attributable firstly to the extensive phase of farming in the Union, in which larger returns are obtained (often more profitably for the time being) by the simple expedient of cultivating larger acreages of the available comparatively cheap land; secondly, a failure to appreciate the underlying advantages to a permanent agriculture of rotative farming; lastly, the necessity of providing food for the live-stock on maize farms has hitherto not received the attention it merits, as farmers seem satisfied with maize stalks left on the land as the only winter feed for their animals.

Maize rotations will naturally vary with local conditions and the needs of the farmer. The following have proved suitable in many cases, viz. :—

1. 1st Year.—Maize fertilised with bone dust or superphosphate.

   2nd Year.—Maize.

   3rd Year.—Cowpeas (kaffir beans), or velvet beans ploughed down as green manure.

Cowpeas will naturally be used on the highveld and velvet beans on the lowveld. This rotation is suitable for the man growing maize chiefly for grain on relatively poor soils. On more productive soils the same man may employ :—

2. 1st Year.—Maize fertilised with bone dust or superphosphate.

   2nd Year.—Maize manured with available kraal manure.

   3rd Year.—Maize.

4th Year.—Cowpeas (kaffir beans), or velvet beans ploughed down as green manure.

The stock farmer might have recourse to :—

3. 1st Year.—Maize.
2nd Year.—Maize fertilised with bone dust or superphosphate.
3rd Year.—Hay crop—Sudan grass, teff or Boer manna.
4th Year.—Cowpeas cut for hay or to increase the protein content of the maize silage.

All kraal manure in this case must be returned to the soil, chiefly to maintain the humus content.

4. For the stock farmer in areas of good rainfall :—

Maize planted in rows four feet apart with a light dressing of phosphatic fertilisers each year. When cultivation has been carried on sufficiently long to control early weeds, cowpeas (kaffir beans) are planted in between the rows, either by straddling the maize rows before the plants are too high or by use of a single row planter. The maize may either be harvested and the animals turned into the field, or the American plan followed, in which the animals are turned in without harvesting the maize. This is recommended particularly where cattle and pigs are to be fattened and also for dairy cows. Some farmers mix the cowpea-seed with the fertiliser, in which case the cowpeas grow in the same row as the maize.

5. For the maize and potato farmer :—
1st Year.—Maize.
2nd Year.—Maize fertilised with bone dust or superphosphate.
3rd Year.—Cowpeas ploughed down as green manure.
4th Year.—Potatoes heavily manured with kraal manure, plus superphosphate.

6. For the cotton farmer :—
1st year.—Maize fertilised with bone dust or superphosphate.
2nd Year.—Cotton.
3rd Year.—Kaffir beans (cowpeas), peanuts or velvet beans.

Lastly, for those growing maize and peanuts the following five-year rotation :—

1st Year.—Maize fertilised with bone dust or superphosphate.

2nd Year.—Peanuts (monkey nuts).
3rd Year.—Maize fertilised with bone dust or superphosphate.
4th Year.—Cowpeas.
5th Year.—Maize.

In this rotation, suited to middleveld and lowveld conditions, three-fifths of the land would be under maize.

Irrigation.—It is the habit of many farmers to grow maize as a summer crop on irrigable land, a practice not to be advocated, as this expensive land would be better utilised for the growing of more remunerative crops.

Harvesting.—(1) *For Grain.*—Harvesting usually commences early in June, and, as the winter is one of little rain, may be delayed until August. By this time the grain is well dried out and the moisture content is low. Generally speaking, maize is not ready for harvesting until the ears droop, at which stage they are easily snapped off, and, if necessary, can be shelled straight away. The ears are thrown into bags or baskets, emptied then into wagons, carted and piled in heaps on floors (made of loose timber or stones), and shelled, without the previous removal of the husks. It is then bagged or stored in bins or tanks in bulk while waiting to be marketed.

The above is the method commonly in vogue among our maize farmers. Some of the more progressive farmers have adopted the more economical American method of harvesting. The plants are cut by hand or by means of sledges, or preferably maize binders, and stooked or shocked, then left to stand in the field for 6 to 8 weeks. The stage at which the maize is cut is indicated as soon as the kernels assume the hard glazed stage. If cut at this period, maturity is completed in the stook.

The stooks are carted off the land, the ears removed and placed in piles ready for threshing, and the stover is stacked ready for winter use. The stooks should not be made too large; about 20 to an acre is usual. Each stook is best bound near the summit with binding twine. The task for one man is about an acre a day, but three men with a maize binder will cut and stook about 10 acres per diem.

The advantages of this method are that the maize is cut at a stage when it has attained the highest yield of grain combined with a relatively high nutritive value of stover, better maintained than if subjected to leaching and weathering; the leaves, the most valuable part of the stover, are preserved instead of a large percentage being lost through wind and tramping; it is of assistance in controlling the stalk-borer; earlier winter ploughing is made possible, and the quantity for winter feeding is better regulated. When fully mature, ears infected with *Diplodea zeæ* often fall to the ground, and when eaten by cattle give rise to a disease, which in Natal has caused severe losses. These losses would be obviated by this method of harvesting.

(2) *For Silage.*—Ensilage is the process through which green and succulent materials are preserved by placing them in airtight chambers, where, through fermentation, putrefaction is checked and the mass caused to retain practically all its nutritive value and palatability. Maize should be cut when fairly mature and containing a large percentage of moisture (about 75 per cent). The starch and the sugars as well as the total weight increase towards maturity.

The stage at which the crop should be harvested is indicated by the following experiment.[11]

Date.	Stage of Maturity.	Percentage Starch and Sugar in free Extract.	Pounds of starch and sugar produced per acre.
August 15 ..	Ears beginning to form	25·1	358·5
August 28 ..	A few roasting ears.	40·5	1,172
September 4 ..	All roasting ears.	42·7	1,545
September 12 ..	Some ears glazing.	42·2	1,764
September 21 ..	All ears glazed.	50·3	2,244

The use of very immature material was at first advocated, but subsequently the silage from mature maize was found to be better in quality and to give a larger quantity per acre. Silage to keep well, though, must pack closely, and as nearly as possible all air must be excluded. "Maize too mature cannot pack closely enough, though sprinkling with water and careful tramping will allow of the ensilaging of maize even when more than half the ears might be considered ripe. As a general rule, when the husks have mostly turned yellow and the kernels are glazing is the proper time, the leaves and stem will still contain a certain amount of chlorophyll."

Late maturing dent varieties, *e.g.*, Natal White Horsetooth and Potchefstroom Pearl, will give the largest tonnage per acre, and are therefore chiefly grown for this purpose;

however, flint varieties, although giving smaller yields, furnish silage of better quality.

The average yield in South Africa is from eight to twelve tons per acre.

In the Union three methods of ensilaging maize are in vogue—namely, in above-ground (airtight chambers), silos usually built of concrete or stone, pit silos, or by stacking.

The above-ground silos are much the least wasteful, but the initial cost of erection has limited them from coming into general use. These are generally 20 to 30 feet in height and 10 to 15 feet in diameter. The maize is run through a cutter regulated to cut it into lengths of about an inch or so. It is elevated by a blower and delivered into the silo, where a man sees that it is evenly distributed and well compacted, particularly the part next to the walls.

Pit silos are inexpensive in construction and therefore to-day are the most popular. In these the ground, located in a well-drained situation, is excavated, leaving somewhat sloping sides 10 to 12 feet in depth and of varying capacity. The maize is either put in whole with the stem ends nearest the walls or it may preferably be passed through a cutter. When properly settled, a layer of grass covered with a foot or two of earth is used as a covering. When starting to feed, the pit should be opened from the side and the silage cut vertically.

Stacking, when done by those competent, is a fairly efficient and inexpensive method. Here the whole maize is built with the stem ends outwards into circular stacks 20 to 25 feet in diameter and 12 to 15 feet in height. When built, the whole is covered with straw and weighted down by a layer of heavy stones. The sides are trimmed down to present an even surface.

The underlying principle in all these is the exclusion of air and to have sufficient depth to ensure enough pressure.

The average weight of a cubic foot of silage is about 40 lbs., of which approximately one quarter is dry matter.

It is estimated that the cost of production of a ton of silage is about 15s. under Transvaal conditions.

The advantages of ensilaging maize are chiefly :—

(1) Low cost of production.

(2) Succulent feed is furnished for any desired season.

(3) Palatability.

(4) Larger tonnage from maize than other crops.

(5) Nutrients are more economically preserved than when dried and cured as fodder.

(3) *For Fodder.*—The crop is cut by mower or by hand when in the flowering stage, raked into windrows when thoroughly wilted, cocked later, and, when thoroughly cured and dried out, is stacked. Maize fodder is likely to play a more important part in stock farming in the Union than hitherto. It is heavy yielding and few areas suffer under conditions so severe that maize could not be grown for this purpose.

MARKETING.—The quality of South African maize is second to none in the world to-day, as is evidenced by the prices obtained on European markets. The dry harvesting season is responsible for the extremely low moisture content of our export maize. The maximum percentage of moisture allowed by Government graders in maize for export is $12\frac{1}{2}$ per cent., and no difficulty is experienced in conforming to this regulation.

At present most of the maize for overseas is shipped from Durban. A special tariff is in force on the South African Railways and Government graders control the export at the ports.

The recognised Government grades, which experience has shown are not too severe for the industry, follow :—

MAIZE GRADES.

Grade Marks to be shown on bags.	Class.	Description.
1.	Flat White No. 1	To be sound, dry, plump and well cleaned, with a maximum of 1 per cent. of yellow, discoloured and defective grain.
2.	Flat White No. 2	To be sound, dry and reasonably clean, and contain not more than 8 per cent. defective or other coloured grain, or both. Berries may be of irregular size.
3.	Flat White No. 3	To be sound, dry and reasonably clean, and contain not more than 13 per cent. of defective or other coloured grain, or both. Berries may be of irregular size and shape.

4. Flat Yellow	To be sound, dry, and reasonably clean, and contain not more than 9 per cent. of defective and other coloured grain, or both. Berries may be of irregular size and shape.
5. Round White	To be sound, dry, and reasonably clean, and contain not more than 9 per cent. of defective and other coloured grain, or both. Berries may be of irregular size.
6. Round Yellow	To be sound, dry, and reasonably clean, and contain not more than 9 per cent. of defective or other coloured grain, or both. Berries may be of irregular size.
7. Mixed	To be sound, dry, and reasonably clean, and contain not more than 10 per cent. of defective grain.
8. No grade	To include all maize which cannot be classed in a higher grade, but to be in dry condition and fit for shipment.

MAIZE MEAL.

M.1. White Maize Flour	To be milled from South African-grown white maize, Govern ment standard maize; grades Nos. 1 and 2 as set forth in Regulation 1.
M.2. Granulated White Maize Meal	To be milled from South African-grown white maize, Government standard maize, grades Nos 1, 2 and 5, as set forth in Regulation 1.
M.3. Ordinary straight-milled white maize meal	To be milled from South African-grown maize, Government standard maize grades Nos. 1, 2, 3 and 5, as set forth in Regulation 1. (Mesh 18 to 32.)

M.4. Ordinary straight-milled yellow maize meal	To be milled from South African-grown yellow maize, Government standard maize grades Nos. 4 and 6, as set forth in Regulation 1. (Mesh 18 to 32.)
M.5. Mixed maize meal	To be milled from South African-grown white maize and yellow maize, Government standard maize grades Nos. 1 to 7, as set forth in Regulation 1. (Mesh 18 to 32.)

As maize is the staple food of the South African natives, a good local market is always assured, particularly in the mining areas, where white varieties are in great demand. At present maize is sold for local consumption in bags of 203 pounds gross weight.

Under the Government's scheme, port elevators are to be erected at Durban and Capetown, with country elevators in the principal areas of production. With their inauguration, long since overdue, a vast saving in handling the crop will be effected; bags will be dispensed with to a great extent, wastage will be reduced to a minimum, transportation will be facilitated, a great impetus will be given to the industry, the producer will receive a larger share of the profits, buying and selling will be simplified, and the export trade better regulated.

MAIZE IMPROVEMENT.

Seed Selection.—Probably one of the weakest links in the chain of maize producton in the Union is the general failure to practise seed selection. Farmers as yet do not sufficiently appreciate the value of good seed. The general procedure is to utilise the largest separates from behind the sheller. While this may be considered to a very limited extent as a form of mass selection, it must be obvious that a great proportion of these large kernels may originate from indifferent ears, and must, of course, give rise to indifferent results when used as seed. Certain growers select their seed ears from the crop after harvesting. While a better practice than the preceding one, it is by no means wholly desirable, as the plants on which these ears have been borne have not been taken into consideration. Consequently, favourable environment factors, *e.g.*, wide spacing, and so forth, may overshadow productive plants of desirable qualities, obscured to a certain extent by the effect of closer competition and more severe conditions of plant food and soil moisture. In short, hereditary qualities do not receive their due value. The average maize farmer should select his seed from the crop as it stands in the field.

Ears only from those plants growing in full competition with their neighbours should be chosen. These plants should be selected for vigour and robustness, for early or late maturity, freedom from disease, drought-resistance, and other desirable qualities; moreover, the ears of these plants should conform to the ideal sought for. The selection of these plants should take place as soon as the earliest ears mature, at which time both the plant and ear can be considered. The ears, however, should not be taken until fully mature. In the selection of ears the points to be judged are those enumerated in the following score-card—viz.:—

	Points to be considered.	Maximum score.	
1.	Indentation	5	General appearance.
2.	Kernel composition	5	
3.	Kernel characteristics	10	
4.	Shank attachments	5	
5.	Tips of ears	5	
6.	Butts	5	
7.	Lustre or polish	10	
8.	Sulci (space between rows)	5	
9.	Freedom from diseased symptoms	5	
10.	Length of ear	5	Particularly as regards breed characteristics.
11.	Shape of grain	10	
12.	Length of grain	5	
13.	Shape of ear and straightness of rows	10	
14.	Uniformity of cobs and grain	10	
15.	Colour of grain and cob	5	
	Total	100	

Brief Explanation of Points.

(1) *Indentation.*—Various indentations characterise the different dent breeds. However, an excessively chaffy condition indicates imperfect maturity often due to disease.

(2) *Kernel Composition.*—This also varies with the variety, but within the variety preference should be given to those showing the most horny starch, as this tends to give maize of a high protein content and of high weight per bushel; and, moreover, white starchy seed is often the result of disease and poor ripening.

(3) *Kernel Characteristics.*—Healthy, well-matured ears usually have thick, plump, bright and clean kernels, having well-developed embryos.

(4) *Shank Attachments.*—Hitherto these have been trimmed away for show purposes. They should be left, however, as found when broken off the plant. Ears with shanks diseased, shown by a pink or brown discolouration and in a shredded condition (*i.e.*, the parenchymatous cells of the pith have become disintegrated by the action of disease organisms and the fibrovacular bundles are left intact, giving a sringy appearance) should be discriminated against, as well as those having shanks too slender or too thick.

(5) *Tips of Ears.*—The tips should show no signs of discolouration or injury from weather, insects, birds, etc., as these are usually those not well covered by the husks. Well filled tips, while due largely to favourable weather at time of fertilisation, should be favoured.

(6) *Butts or Ears.*—These should not be unduly " swollen " or compressed, and should also be well filled, a condition governed to a great extent by weather conditions.

(7) *Lustre or Polish.*—Vigour, healthy development and complete maturity are almost invariably associated with a bright, polished, oily appearance. Those lacking lustre and having a dull appearance should be scored against, since they too often give rise to poor, unproductive and diseased plants.

8. *Sulci.*—Within the variety the space between the rows should not be too wide nor too narrow. It is possible that too great a width may indicate low yielding strains, while grain excessively crowded may be found on cobs lacking vigour.

(9) *Freedom from Diseased Symptoms.*—Discolouration near the tip of the kernel may denote disease, and any other evidence of disease should be discriminated against. A brownish discolouration near the tip of large white flat kernels is often found in maize which has matured late in the season when the night temperatures are apt to be very low. This discolouration is probably due to the condensation of moisture

by the low temperatures with a subsequent oxidation of the testa during the comparatively high temperatures of the day. This should be taken as evidence of disease.

(10) *Length of Ears.*—This will depend on the variety and climatic conditions. Within limits, having regard to the fact that length is directly correlated with late maturity, it should conform to the requirements of the breed and the area in which it is grown.

(11) *Shape of Grain.*—This should be typical of the variety.

(12) *Length of Grain.*—Depth of grain should be favoured. It must be borne in mind, though, that often the deeper the grain the later the maturity, and that variation in environment may cause variation in depth.

(13) *Shape of Ears and Straightness of Rows.*—These should be typical of the variety; cylindrical ears are to be given preference, although high yielding strains are often found to have tapering ears. A too pronounced tapering gives grain lacking in uniformity, since those near the tip are considerably shallower than those near the butt. Crooked rows are undesirable, since the greater the fault in this respect the more irregular the kernels; and, moreover, repeated selection for crookedness has shown crookedness to be of a cumulative character, in that the rows may be eventually lost.

(14) *Uniformity of Cobs and Grain.*—Uniformity is an indication of purity. A lack of uniformity in shape, colour, size and general appearance should be severely cut.

(15) *Colour of Grain and Cob.*—This should be typical of the breed. Variation of colour in the grain may indicate crossing, in which case the hybrid kernels may often be found at the extremities of the ear. Ears showing cross-fertilisation should not be used for seed.

General Remarks on Show Maize.—While the value of shows, particularly in a rapidly-developing country, serves as a rallying point to those interested, and gives an impetus to the industry as a whole, the value of the exhibits for seed may often be doubtful, since the production of show maize may be accomplished by special treatment, liberal manuring, wide spacing, etc., of what may be relatively poor maize. However, on the whole, show maize may be taken as being above the average, and farmers taking the trouble to exhibit are usually those who practise some form of useful selection. Fancy points, having no direct bearing on utility, are too often over-emphasised to the detriment of inherent productive qualities. Dealing with this, Hays and Garber comment as follows :—" Maize shows have accomplished much in teaching growers the characteristics of various standard varieties. They have, however, over-emphasised the value of ear type as a means of maize improvement. Much work has been carried on with the view of determining the relation between various ear and plant characters and ability to give high yields. In general, no single character has been found to be so closely related with yielding ability as to be of much value from the standpoint of selection. This seems reasonable when we realise that yield is the final result of many growth characters. Too close uniformity of type probably tends to reduce yield, for we have learned that self-fertilisation in maize causes a marked decrease in growth vigour as compared with cross-fertilisation." Extensive experiments conducted in Ohio, in which the yields from long and short ears, cylindrical and tapering ears, ears having bare and filled tips, etc., were compared, showed no appreciable gain in favour of any of these characters.

The specialised maize-breeder, working chiefly at experimental stations, pursues more technical methods to improve maize, and usually resorts to the ear-to-row method of selection or combines the best qualities of various strains through hybridisation.

THE EAR-TO-ROW METHOD.—The first step to take is to label the most desirable parent plants in the field to be selected from. It is wise to select at least 100 plants; care being taken to select robust plants growing in full competition with other plants and having no environmental advantage. When mature the desirable ears are selected, of which probably 75 per cent. will be discarded. Each ear is labelled and described. Half of the grain from each is now planted in separate rows, the remnant being carefully stored until the following season. A test of this nature must be made in duplicate, having every fifth row as a check. Beginning with a check, every fifth row throughout the test will be planted as a check. Each series will thus contain 32 rows and the whole test 64 rows. For the checks use good seed taken from the shelled grain of the general crop. Rows twenty-two yards long with the plants every eighteen inches will be found a useful length. Care must be taken to have the same number of plants in each row.

When mature the rows are harvested separately, the good and bad ears separated and weighed. If in both series an ear is high yielding, it may be taken for granted, with reasonable certainty, that the parent ear was of a productive strain. The highest yielding ears are then taken and planted in an isolated field, and from this field seed is obtained for the general crop the succeeding year.

Cross-breeding takes place in the breeding plot; fresh blood being introduced from various sources into the ear-row test each year, and, while the breeding may be narrowed down by the introduction of ears from other breeders into the ear-row test of the sixth and subsequent years, a sufficiently heterozygotic condition is established to counteract any possibility of a loss of vigour due to the in-breeding of normally cross-fertilised plants. The ear-to-row series need not be isolated, but the fields used to increase the seed from the productive ears should be kept apart from other maize. The ear-to-row test should be continued, each year ears being selected from other reliable breeders of the same variety in the same locality. As a means of isolating high yielding strains the ear-to-row test is very much discredited by some, chiefly because it is said that the results are masked by the xenial effect caused by crossing. Nevertheless, in varieties where no continued selection has been practised, this method will undoubtedly assist in procuring some of the most productive strains.

Shull's Pure-Line Method in Maize-Breeding.—Before devising the above method, Shull's previous experiments had led him to conclude, firstly, "that in an ordinary field of maize the individuals are generally very complex hybrids; secondly, that the deterioration which takes place as a result of self-fertilisation is due to the gradual reduction of the strain to a homozygous condition, and, thirdly, that the object, of the maize-breeder should not be to find the best pure-line, but to find and maintain the best hybrid combination."

The process may be considered under two heads: (i) Finding the best pure-lines, and (ii) the practical use of the pure-lines in the production of seed maize.

(i) In finding the best pure-lines it will be necessary to make as many self-fertilisations as practicable, and to continue these year after year until the homozygous state is nearly or quite attained. Then all possible crosses are to be made among these different pure strains, and the F1 plants coming from each such cross are to be grown in the form of an ear-to-row test; each row being the product of a different cross. These cross-bred rows are then studied with regard to yield and the possession of other desirable qualities.

(ii) After having found the right pair of pure strains for the attainment of any desired results in the way of yield and quality the method of producing seed maize for the general crop is a very simple, though somewhat costly, process.

Two isolated plots will be necessary, plots 1 and 2.

In plot 1 will be grown year after year only that pure strain which investigation has proved to be the best mother-strain for the attainment of the desired end. Thus, if it has been found that cross C.X.H. gives the desired result, plot 1 will be occupied by strain C. This will require no attention from the breeder's point of view, except that any exceptionally vigorous or aberrant individuals should be eliminated, as such plants may be safely assumed to be the result of foreign pollinations.

In plot 2, strain C and strain H are to be planted in alternate rows, and all of strain C is to be detasseled at the appropriate time. All the grain gathered from the detasseled rows will be seed maize for the general field crop, and that gathered from the tasseled rows will be pure-bred; strain H to be used again the following year in the same way. Here again in pure strain H all exceptionally vigorous or aberrant individuals should be discarded as being probably due to the entrance of foreign pollen.

Maize Composition.—Composition of the various parts of the maize plant. Water—free basis (15).

Part.	No. of	Analysis. Per cent. Ash.	Per cent. Protein.	Per cent. Fibre.	Extract. Per cent. N. Free.	Per cent. Fat.
Fodder .	35	4·7	7·8	24·7	60·1	2·8
Leaves .	17	7·9	8·6	30·6	51·0	1·9
Husks .	16	3·5	5·0	32·2	57·9	1·4
Stalks .	15	3·6	5·9	34·8	64·1	1·6
Stover .	60	5·7	6·4	33·0	53·2	1·7
Grain .	208	1·7	11·7	2·4	78·1	6·1

From the above it will be seen that the nutritive ratio of the most concentrated part, the grain, is approximately

1 :10·5, while those of the other parts are considerably wider. The necessity therefore of supplementing a maize ration with material of a higher protein content is apparent.

" In well-developed maize," says Montgomery, " planted at proper distances for maximum yield, the weight of shelled maize will be almost equal to the weight of stalk. Increasing the rate of planting has very little effect on the composition of either grain or stalk, but as the proportion of stalk to grain increases, it is evident that the analysis of the whole plant will show a decreased percentage of protein and fat, and an increased percentage of fibre. The total protein per acre will increase. Silage from very thickly planted maize will not be so rich in percentage of protein and fat, but the total yield per acre will be greater."

Experienced farmers have long maintained that yellow flint maize has a higher nutritive value than dent maize, and while the ordinary chemical analysis has shown little difference in favour of the former, recent investigations in the United States of America ascribe the higher feeding value to the superior vitamine content found in the flint types.

Any account of the maize composition, however brief, would be incomplete without some reference to the research work done in selecting high and low protein maize at Illinois University.[16]

The maize kernel was mechanically divided into tip-cap, hulls, horny glutenous part (aleurone layer), horny starchy, white starchy part and embryo. Analyses of these parts from a number of kernels showed that those having a high protein content could be separated by inspection from those having a low protein content, and those containing a high percentage of oil could be separated from those having a low percentage of oil.

Analysed, these parts showed that the increase in protein in high protein maize over that low in protein occurs almost entirely in the horny part of the kernel. 75 per cent. of the total ash and 80 to 84 per cent. of the oil are contained in the grain.

Continued selection, guided by the analysis of these parts, eventually separated strains having the following widely-different composition :—

	Protein. per cent.	Oil per cent.	Ash per cent.	Carbos per cent.
Low protein ears ...	6·71	4·21	1·37	87·71
High protein ears .	14·44	4·93	1·56	79·06
Low oil ears	9·98	2·52	1·44	86·07
High oil ears	11·31	7·00	1·55	80·14

It is interesting to note that eventually a marked positive correlation was found to exist between the high protein ears and those having a high percentage of oil.

Uses of the Maize Crop.—While in the United States of America most of the grain produced is fed to live stock, in South Africa the greater part of the grain not exported is used for human consumption. It is eaten in a great many forms by Europeans and is the staple food of the South African natives. As has been stated, its use as silage is rapidly increasing, and the stover forms an important part of the winter feed for stock.

Numerous other uses are made of the crop—the husks are used for making matting, hats, filling for mattresses and horse-collars; the stalks and pith provide cellulose and maize-pith packing; the cobs are used in making tobacco pipes and for fuel, and from the grain, starch, glucose, dextrine, maize oil, glycerine, sugar and alcohol are obtained. Pop-maize is used in the manufacture of confectionery; green sweet, flint, dent, and flour ears are used roasted or boiled in most South African households; maize meal is made into porridge; in America into johnny-cake, and during the late war a certain amount was used with wheat flour in making bread. For a detailed discussion on the uses of this crop the reader is advised to consult "Maize: Its History, Cultivation, Handling and Uses," by J. Burtt-Davy, as well as his articles, "Maize as a Raw Material for Manufacture," published in Vol. V. of the *South African Journal of Industries*.

Maize Pests.—(1) *Insects*.—Those most commonly and often causing considerable damage are :—

> Cut-worms (Agrotis and Euxoa spp.), Stalk-borer (Bussiola fusca), Ear-worm (Chloridea obsolete), Army Worm (Laphygma exempta), Weevil (Calandra oryzæ), Angoumois Grain Moth (Gelechia cerealella), and Locusts (Locustana pordalina).

Cut-worms are best controlled by winter ploughing and by poisoned bait scattered over the infested land; the stalk-borer by growing catch-crops early in the season, winter ploughing, and by the American plan of harvesting; and the granary pests by fumigation with carbon bisulphide.

(2) *Other Animals.*—There are a number of animals which cause damage to this crop, such as: Baboons, Cape monkey, ground squirrels, porcupines, crows, springhares, partridges and pheasants. Systematic shooting and poisoning are fairly effective measures in dealing with these.

(3) *Diseases.*—The most common diseases are: *Brown Rust of Maize* (Puccinia maydis), alternate host Oxalis corniculata. Although bad in certain seasons and in limited localities, it has not proved a serious menace so far. Certain varieties are more resistant than others, *e.g.*, vigorous growing varieties, like Potchefstroom Pearl, etc. *Maize Smut or Brand* (Sorosporium reilianum), common in all parts of the world where maize is grown. Prevention should be aimed at. Use new seed from smut-free fields, and where possible burn all affected maize early, and avoid using fresh manure from animals fed with affected plants. *Ear-rot of Maize* (Diplodea zeæ), very common in South Africa, and is the source of a disease causing paralysis in cattle.

The American plan of harvesting should be followed to guard against this disease, which is most common on fallen cobs. Rotate crops, and where possible burn old affected plants or bury very deeply by ploughing.

Leaf Scorch or Maize Blight (Helminthosporium turcicum) occurs, but is of little economic importance.

WEEDS.—*Perennial.*—Cynodon dactylon (Quick), Cyperus rotundus, or escultentus (Vintjes), Convolvulus arvensis (Bindweed), and Rumex acetosella (Sheeps' Sorrel).

Annuals.—Amaranthus paniculatus (Pigweed), Bidens pilosa and leucantha (Black-jack), the grasses Chloris virgata and Panicum lævifolium, Datura stramonium and tatula (Stinkblaar), Physalis minima (Wild Gooseberry), Tagetes minuta (Khaki-bos).

Parasitic.—Striga lutea (Witchweed or Rooibloom) is controlled by growing a host plant such as Sudan or teff grasses, which can be harvested when the parasite is in bloom; after this the land is ploughed before the weed has a chance to seed. This is probably one of the worst weed pests of the maize crop in the Union.

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CHAPTER VII

SORGHUMS

History.—Piper says sorghums were grown in China in 2200 B.C. Whether this is correct or not, it is certain that sorghums were grown for grain in very ancient times. Their culture by Europeans is of comparatively recent date. In 1853, Wray collected sixteen varieties in Natal for the United States Government, which were the first to be imported into the United States.

To-day sorghums play a very important part in the agriculture of the dry Western States of America, and the success of these crops there has stimulated their culture in other parts of the world, including South Africa.

Production.—The acreage devoted to kaffir corn in the Union in 1911 was 166,597, while in 1918 it had risen to 233,105 acres. No figures are available of the world's production. In the United States the crop is limited to the dry semi-arid States of Kansas, Oklahoma, Colorado, etc. The following figures show the increasing importance of sorghums in those States, and the area cultivated in India.

Kansas.	1901.	1913.	India.
Kaffir ...	618,816 acres.	1,403,731 acres.	30,000,000 acres.
Milo ...	5,988 ,,	229,534 ,,	

The sorghums, being more drought resistant, are gradually taking the place of maize in all parts of the world where the moisture is not sufficient for the latter. They would be grown more extensively in South Africa were it not for the depredations of birds.

Origin, Description, and Classification.—The progenitor of those having rootstocks is supposed to be *Andropogon halepensis*, while that of the chief agricultural sorghums is held to be *Andropogon sorghum*. The cultivated sorghums are thought to have originated in Africa. Tunis and Sudan grasses are annuals, and because these do not have rootstocks and cross readily with kaffir corn and Milo they are considered to be closely allied to the original wild form.

The panicle varies considerably from the small, compact type in which the rachis is almost as long as the panicle to the Broom-corn type, in which the rachis is only one-fifth the length of the branches.

Seeds.—The shape of the seed varies from round in the Kaffir, Kowliang, and Shallu groups, to somewhat pear-shaped in certain of the sweet sorghums, fairly flattened in Milo, and decidedly flat in the Durras. The astringency of the dark coated varieties is due to the presence of small amounts of tannin. The distribution of horny starch and starchy endosperm somewhat resembles maize, in that the soft starch is surrounded by horny starch.[9]

The United States Department of Agriculture has analysed the kaffir kernel on similar lines to those employed in the analysis of the maize kernel at Illinois University. Except for the high ether extract found in the bran of kaffir the analyses are very similar, viz. :—

COMPARISON OF KAFFIR AND MAIZE SEPARATIONS.

Material.	Kernel. per cent.	Ash. per cent.	Ether Extract per cent.	Protein. per cent.	Carbos. per cent.
Maize Hulls ...	7·39	0·79	0·89	3·96	94·36
Kaffir Bran	6·1	2·0	6·8	4·8	86·4
Horny endosperm—					
Maize	55·59	·44	1·15	11·85	86·56
Kaffir	48·9	·3	·7	14·5	84·5
Starchy endosperm—					
Maize	25·49	·26	·24	7·84	91·66
Kaffir	35·0	·3	·8	11·66	87·3
Germ—					
Maize	11·53	9·90	34·84	19·80	35·46
Kaffir	10·0	13·20	31·5	19·3	36·0

DISTRIBUTION OF CONSTITUENTS.

Material.	Whole Kaffir.	Ash.	Ether Extract.	Crude Protein.	Crude Fibre.	N.F. Extract.
Germ ...	10·0	77·9	75·2	15·5	19·1	4·1
Bran ...	6·1	7·2	9·9	2·3	49·7	5·5
Starchy Endosperm	35·0	6·2	6·7	28·4	14·1	38·4
Horny Endosperm	48·9	8·7	8·2	53·8	17·1	52·0

"The results of this study show that corresponding parts of the kaffir and maize kernels resemble each other in composition and appearance, and lead us to believe that if kaffir were handled in a manner similar to that used in the preparation of maize products, kaffir products might be substituted for the corresponding maize products."

The colour of the seed varies considerably with the varieties, white, black, red, and yellow being the most common colours.

Stems.—The stems vary from 4 to 15 feet, and from $\frac{3}{4}$ to 2 inches in thickness. They may be juicy or dry; in the former the juice is easily extracted by crushing or chewing—the difference in actual water content is small. Those having very juicy pith are the canes or forage sorghums, the grain sorghums having a pith less juicy and not sweet.

Tillers.—Appear as in maize, being governed largely by spacing, temperature, soil fertility, variety and soil moisture.

Branches.—With very thin planting, branching may occur beginning from latent buds, that of the topmost node being the one always to develop first. Because the heads on these branches mature later than those on the main branch, they are undesirable, and planting should be thick enough to inhibit this tendency.

Leaves.—These are short and broad, coarse in texture, roll together in an erect fashion, which apparently protects them from hot winds and protracted drought. The most drought-resistant kinds are the most scanty-leaved.

Roots.—These feed more in the surface soil than maize.

The most outstanding characteristic of the sorghums is their drought resistance, which is attributed to the resistance of the leaves to dry, hot, and windy weather; the non-saccharine sorghums being more resistant than the forage or saccharine kinds. Their capacity to remain almost dormant during drought, and then to continue growth immediately with the improvement of the weather, enables the crop to withstand drought better than maize, which, if once severely checked, will never entirely recover.

In the early stages, sorghums are slower growing than maize.

Sorghums are perfect-flowered, and are usually self-fertilised, although cross-fertilisation is very common, and crosses between the most widely differing types occur quite frequently.

Sorghum Types, based on Economic Uses.

(1) Saccharine sorghums.
(2) Non-saccharine sorghums.
(3) Broom-corns.
(4) Forage sorghums :—Sudan, Tunis, Johnson.

(1) *Saccharine Sorghums* (*Soet Riets*).—Those having an abundant sweet juice. Previously cultivated for syrup, but now principally as a forage plant and for silage.—I. Cane or Sorgo.

(2) *Non-Saccharine Sorghums.*

(*a*) Pith contains scanty juice, which varies from slightly sweet in some varieties to semi-acid in others. Grown principally for the grain, but has also forage value.—II. Kaffir. III. Milo.

(*b*) Pith Dry.

(i.) Grown principally for the grain and forage. II. Kaffir. VI. Durra. IV. Shallu. V. Kowliang. VII. Feterita.

(ii.) Grown for the panicle (brush); little value as forage.—VII. Broom-corn.

In South Africa, the principal varieties grown belong almost entirely to the Kaffir type, namely: Blackhull Kaffir Corn, Whitehull Kaffir Corn (both these have white seeds), and Red Kaffir Corn.

Varieties from all the other groups have been grown from seed distributed by the Government, but have not been generally adopted. The local demand is chiefly for the natives on the mines, who prefer the white-seeded varieties.

Saccharine Sorghums.—These are usually low yielders of grain, and are grown principally for forage or for silage. They are generally tall, slender, leafy, with pyriform seeds. Early Amber, Orange and Sumac, Planter's Friend, Sugar Drip, are varieties which have been tried in the Union and have given good results.

Sudan Grass and Tunis Grass are also forage sorghums, usually looked upon as grasses.

Non-Saccharine Sorghums.—Comparatively heavy seed-yielding, and stocky in growth. In the Kaffir Group the heads are erect, long, and cylindrical obovate seeds. In the Durra Group the inflorescence is thick, compact, ovate and pendant large flattened seeds (Yellow Milo, Durra and Feterita).

Broom-Corn Group.—The varieties in this group have wide-spreading panicles.

General Notes on Varieties.—Of the saccharine sorghums, Early Amber Cane is the earliest and one of the most prolific yielders of forage.

Sudan Grass is dealt with fully in the chapter on Grasses.

Of the non-saccharine sorghums Milo and Kowliang, Feterita, and Dwarf Negari, are the earliest, the latter maturing in some localities from 85 to 95 days. Milo is one of the most drought-resistant and heaviest seed-yielding varieties. It is immune from kernel and head smut, and is three weeks earlier than Kaffir. It is of very little use as forage. Most milos have recurved necks.

Kaffir.—Is later in maturing; a heavy seed yielder, and fairly valuable for forage or ensilage. The grain is smaller than the Milos or Durras, but is less liable to shatter.

Shallu.—Somewhat resembles Broom-corn in having open panicles. It is grown chiefly for grain, but has a fair forage value.

Feterita.—Matures about a week earlier than Milo; is a very heavy yielder of seed, but has a too strong tendency to branch.

Durras.—Are better adapted for grain production than the Kaffirs, but are not so well suited for forage purposes. They have large flat kernels, and are nearly all goose-necked.

BOTANICAL CLASSIFICATION. (6)

Order.—*Gramineæ.*

Tribe.—*Andropogoneæ.*

Genus.—*Andropogan.*

Species.—*A. Sorghum var. vulgare.*

Ball has suggested the following classification as a key to the principal groups of sorghum :—

I.—Pith juicy.

(A) Juice abundant and very sweet.

(1) Internodes elongated; sheaths scarcely overlapping; leaves 12—15 (except in Amber varieties); spikelets elliptic-oval to obovate, 2·5 to 3·5 mm. wide; seeds, reddish-brown.—I. Sorgo.

(B) Juice scanty, slightly sweet to sub-acid.

(1) Internodes short; sheaths strongly overlapping; leaves 12—15, peduncles erect; panicles cylindrical; spikelets obovate; 3 to 4 mm. wide; lemmas awnless.—II. Kaffir.

(2) Internodes medium; sheaths scarcely overlapping; leaves 8—11; peduncles mostly inclined; often recurved; panicles ovate; spikelets broadly obovate; 4·5 to 6 m.m. wide; lemmas awned.—VII. Milo.

II.—Pith dry.

(A) Panicle lax, 2·5-7 dm. long; peduncles erect; spikelets elliptic-oval or obovate, 2·5 to 3·5 mm. wide; lemmas awned.

(1) Panicle 4-7 dm. long; rachis less than one-fifth as long as the panicle.

(*a*) Panicle umbelliform, the branches greatly elongated, the tips drooping; seeds reddish, included.—III. Broom-corn.

(2) Panicle 2·5-4 dm. long; rachis more than two-thirds as long as the panicle.

(*a*) Panicle conical, the branches strongly drooping; glumes at maturity spreading involute; seeds white, brown, or somewhat buff.—IV. Shallu.

(*b*) Panicle oval or obovate, the branches spreading; glumes at maturity appressed, not involute; seeds white, brown or reddish.—V. Kowliang.

(B) Panicle compact, 1-2·5 dm. long; peduncles erect or recurved; rachis more than two-thirds as long as the panicle.

(1) Spikelets elliptic, oval or obovate, 2·5 to 3·5 mm. wide; lemmas awned.—V. Kowliang.

(2) Spikelets broadly obovate; 4·5 to 6 mm. wide.

(*a*) Glumes grey or greenish; not wrinkled; densely pubescent; lemmas awned or awnless; seeds strongly flattened.—VI. Durra.

(*b*) Glumes deep brown or black, transversely wrinkled, thinly pubescent; lemmas awned; seeds slightly flattened.—VII. Milo.

Climate.—Sorghums do best in a rather dry, hot climate, but do not do too well at high altitudes where the nights are cool.

While maize and sorghums both prefer climates having plenty of sunshine and warmth, they differ in that the developed sorghums of to-day prefer less humid conditions than maize. No doubt some of the tall-growing tropical forms require very humid conditions for their growth, and the broom-corns as well as some of the saccharine sorghums do well under conditions preferred by maize rather than those must suitable for the non-saccharine kinds. In the United States of America the average annual rainfall for the Grain Sorghum belt is about 20 inches, varying in different parts from 15 to 25 inches, the majority of which falls in the growing season, and the evaporation is from 35 to 55 inches.

They are extremely sensitive to frosts, but their water requirement is less than that of maize.

Soils.—In general, soils suitable for maize are suitable for sorghums, although good forage crops are grown on soils too poor for maize. They are supposed to be much more alkali-resistant than maize. Being comparatively surface feeders, they have the reputation of being very exhaustive of soil fertility. In reality this is not so, since suitable rotations will maintain the yield.

In semi-arid parts the soils are usually very poor in humus, consequently to increase the water-holding and water-absorbing capacity of the soil rotations should be judiciously planned to increase or maintain the humus content when economically possible.

Soil Preparation.—This is very similar to that required by maize, but as the seedlings are less vigorous than those of maize the surface should be reduced to a finer tilth. Deep ploughing in sorghum areas is not always advisable, as it may result in excessive desiccation of the soil and subsoil, which is in most cases harmful. The object should be to keep the soil free from weeds, and in a receptive condition for rain. Ploughing and leaving the ground rough until just before planting is sufficient. Just previous to planting the ground should be worked down into a moderately fine tilth. On some soils, though, deep ploughing has proved necessary.

Very sandy soils are common in the sorghum areas, and on these care should be exercised to prevent blowing. Humus is particularly important, and every means of incorporating it economically should be resorted to. If free from weeds, the soil should be left undisturbed as long as possible. On these soils American experience indicates that listing is preferable to ploughing, as the soil is disturbed less.

Seed.—This weighs 54 to 62 pounds per bushel. When a variety has been found suitable to a particular part that variety should be adhered to, and selection should be made from the desirable plants before the whole crop is harvested. As the seed of sorghums grown under uncertain conditions may vary considerably in size, care should be taken not to discard a variety on that account. This may necessitate the adjustment of the planting plates accordingly, in order to obtain a correct spacing.

ROTATIONS.—While it may pay a maize farmer to have a third or fourth of his land down to cowpeas, it may be unprofitable for a farmer growing grain sorghums to do the same unless his farming is also largely devoted to stock-farming. Green-manuring in arid parts, while extremely important, has been found to be very costly. The yield per acre is small, consequently extensive methods are more profitable. However, if cowpeas or similar crops can be fed on or off the land, and the manure returned to the soil, as a policy of permanent agriculture it will pay to do so. On very sandy soils the effect of green-manuring in binding the soil will often compensate the farmer for his extra expenditure. Fertilisers should be employed very cautiously and not until experimented with on a small scale. These soils are often extremely poor in phosphates and, where deficient, small dressings of 100 to 200 pounds of superphosphate per acre may pay. Phosphorus has a tendency to promote vigorous root-growth, and in doing so enables the plant to feed over wider areas. Thus a better use of the available moisture and plant food is afforded. In comparison with most soils, those in sorghum areas are comparatively rich in plant food, and the necessity for applying fertilisers is not so urgent as in more humid parts.

PLANTING.

DATE OF PLANTING.—Their early growth is very tardy, particularly in cool weather, consequently they are usually planted somewhat later than maize. In South Africa the date of planting is usually governed by the seasonal rainfall. The Kaffir corns may be planted from the latter part of October to the end of December, while Milo, Feterita, and Kowliang Negari may be planted up to the middle of January. Sorghums for forage or ensilage may be sown up to the latter part of January. Late sown sorghums are often badly attacked by aphids.

As in all crops, the rate of planting depends on the fertility of the soil, the climatic conditions, the vitality of the seed, and the purpose for which the crop is grown.

For forage, planting must be much thicker than for grain or silage. For grain, the rows should be 3 to 3 feet 6 inches apart, and the plants 4 to 8 inches in the rows. This requires from $1\frac{1}{2}$ to 5 pounds of seed. For forage, though, the rows may be 2 feet 6 inches and 3 inches in the row.

If broadcasted for forage, about 20 to 30 pounds of seed is required.

Failures in obtaining good stands are frequently caused by planting too deeply. Planting must be shallower than for maize, about one to two inches, according to the condition and type of soil, seems to be the best depth.

The best implement for planting is the maize planter, most of which are now supplied with suitable plates. If these are not obtainable, the holes in the ordinary planter plates should be filled with lead, and new holes of desirable size bored through these lead fillings. Before use, the planter should always be adjusted and tested on a hard road or suitable place, to see that the correct distances of planting have been arranged.

After Cultivation.—Harrow once the plants are well rooted. After this the ordinary maize cultivation should follow to break light shower crusts and to keep the land free of weeds.

Harvesting.

Time of Harvesting.—*The Grain Sorghums* should be harvested when fully matured. If, however, the crop is to be used for ensilage, harvesting should take place in the soft dough stage, as ripe seeds in silage are apt to pass through animals undigested. The best method is to shock the whole plant, as in maize; when cured and thoroughly dried the heads are taken off and run through the ordinary grain-thresher. Some farmers in South Africa send boys down the rows with clippers, to slip off the heads into bags. These heads are then thrown into heaps or stored ready for threshing. The seed is very liable to overheat, particularly when slightly immature or damp. If stored in bins or tanks it must be carefully watched, and if any evidence of overheating is shown, the seed must be thoroughly ventilated by shovelling, etc.

A good average yield in South Africa is about 15 to 25 bushels.

For Silage.—Extensive experiments in Kansas have shown sorghum ensilage to be practically equal to maize silage from a feeding point of view. The saccharine sorghums do not seem quite so valuable as kaffir. On account of their succulency they should be cut at a later stage of maturity (when the seed is comparatively hard), otherwise sour silage may result. The average yield is from six to eight tons per acre.

For Forage.—Sowing is usually heavy, 20 to 30 pounds broadcasted or drilled with seed-drills. If planted in rows with a maize planter about 15 pounds per acre are required. The latter method is to be preferred in South Africa. For forage purposes saccharine sorghums should be used. It is somewhat difficult to cure; bundles should be placed in small stooks at first, and left until thoroughly cured before being stacked. If broadcasted, it may be treated as ordinary hay, care being taken that the hay is fairly dry before being cocked. The average yield is two to five tons per acre.

COMPARISONS BETWEEN SORGHUMS AND MAIZE.—Sorghums will produce good crops more reliably than maize in parts where maize, owing to a lack of moisture, is uncertain. Good practice is adopted in parts of the Lichtenburg District, where the annual rainfall is about 22 inches, but of an erratic nature, in planting half the land to maize and half to sorghums. In the years when maize fails as a grain crop it can be used for silage, and the sorghums can then be relied upon to produce a fair yield of grain. This is the practice adopted over large parts of the Western States of America, bordering on the Maize Belt. In parts of the Union having less than 20 inches of rain, sorghums should undoubtedly supplant maize altogether.

COMPARISON OF YIELDS OF MAIZE AND KAFFIR AT STILLWATER, OKLA.

Crop.	1909.	1910.	1911.	1912.	1913.	Average
Kaffir	34·0	19·0	45·5	48·0	28·0	34·9 bushels.
Maize	2·5	00·0	00·0	1·5	1·0	1·0 do.

The superiority of the yield of the sorghum at this semi-arid station is largely due to the fact that sorghums can remain dormant during periods of drought, while maize is practically ruined when badly checked in growth.

The composition of the grain has been shown to be practically the same as that of maize, the digestibility being slightly lower. The storage and harvesting of the sorghums is more difficult than maize.

Sorghums, if checked in growth during dry, bright weather, develop poison to a dangerous degree, and pasturing them should be done with caution. When frosted, the aftermath is said to be particularly dangerous. If fed, when cut and wilted, the toxin largely disappears. No cases have been found of prussic-acid poisoning of stock fed on sorghum silage.

Uses.—In South Africa, the grain is used chiefly as food for the natives. In America, it is used mainly as food for stock, being ground before being fed, but its use as a human food is increasing.

In America and Europe, the seed is used extensively as a poultry feed.

Its use as silage and forage has been shown. The saccharine sorghums are used for forage, and seem well adapted for that purpose, as several cuttings can be obtained in one season. In humid parts, Ontario, etc., the sorghums are also used for pasturage, either alone or mixed with millets or oats.

In Asia their uses are most varied, the seed being used as human food and the stems for thatching, building, mats, fuel, rafts, etc.

The cultivation of the saccharine sorghums was really begun in America originally for syrup making, 1,200 pounds of juice being obtained from one ton of cane. Syrup is still made, but the practice is rapidly decreasing. It was also grown for this purpose by the Boer pioneers in the early days.

Broom Corn.—The cultural methods are similar to those described for the grain sorghums. The brush should be bright green, with a short rachis, long, flexible and tough. The distance in rows, two to four inches, is much closer than for milo or kaffir. The crop is harvested quite green, or soon after the full bloom stage. The heads are threshed a few days after harvesting, after which the brushes are cured and dried and then baled. The seed may be used as a stock food, but on account of its immaturity and the adhering glumes, is not nearly as valuable as that of the grain sorghums.

Several varieties have been grown in the Union, and factories at different centres for the manufacture of brooms have been in operation for many years. Probably owing to the labour entailed, and lack of experience, the manufacturers have found great difficulty in getting farmers to go in for broom-corn culture, and consequently the brush is imported from America. At present the demand for brush exceeds the supply, prices varying from £40 to £80 per ton.

Improvement.—Probably no crop in South Africa has been so neglected. Little or no selection has taken place, varieties have not been properly identified or appreciated, and their place as a dry-land farming crop has not been sufficiently recognised (except by natives).

"There are certain definite characteristics that are required in the grain sorghums. Chief among these are even height, early maturity, dwarf stature, well shaped and fairly compact heads, erect heads, freedom from stooling and branching, good exsertion of the head from the upper leaf sheath."[4]

The head to row method is the best means of seeing the merits of the respective strains. As they cross easily, heads must be bagged before flowers open.

While leafiness with total yield should be aimed at in the forage sorghums, in the true grain-sorghums the yield of seed, drought resistance, and early maturity, seem to be correlated with an absence of leafiness.

SCORE CARD FOR GRAIN SORGHUMS.

HEAD SAMPLES.

Points.	Value.	Score.
Uniformity of Heads and Kernels	20	—
Shape of Heads	10	—
Size of Heads	5	—
Arrangement of Spikelets	20	—
Shape of Kernels	5	—
Size of Kernels	5	—
Colour of Kernels and Glumes	5	—
Freedom from Shattering	5	—
Exsertion	10	—
Market Condition	15	—
Total ...	100	—

GRAIN SAMPLES.

Uniformity in Size and Colour	20	—
Shape and Size of Kernels	20	—
Market Condition	35	—
Weight per Bushel	25	—
Total ...	100	—

NOTES ON SCORE CARD (Head Exhibits).

Uniformity.—The heads should be similar in size, shape and colour.

Shape and Size.—True to standard of perfection for the variety.

Arrangement of Spikelets.—The spikelets and seed-stems should be close together in the common types of the grain sorghums, except in Shallu and White Kowliang. A compact head indicates a high percentage of grain. The spikelets should be close together, pedicles short, and the branches of the panicle thickly covered with seed, both on the inside and outside. Low yielding or light heads have few or no grains on the inside of the branches, and on the lower half of the branches. The joints of the main spikes or seed-stems should be short. Short-jointed main stems, five or more joints in number, indicate a large number of rows of spikelets, giving a high-yielding head. The head must not be too compact, however, as drying will not take place easily.

Shape and Size of Kernels.—Should be true to variety.

Colour of Kernels.—Must conform to type.

Freedom from Shattering.—Shallu, Feterita, and Jerusalem Corn, are usually bad in this respect. The heads should be shaken, and if many kernels drop out the head should be discriminated against.

Exsertion.—The head should be free of the boot or upper leaf sheaths. If the lower spikelets are not filled out or are mouldy, poor exsertion is indicated, and such heads are inferior for seed purposes.

Market Condition.—There should be no sign of decay, disease (smut), or immaturity.

Grain Exhibits.

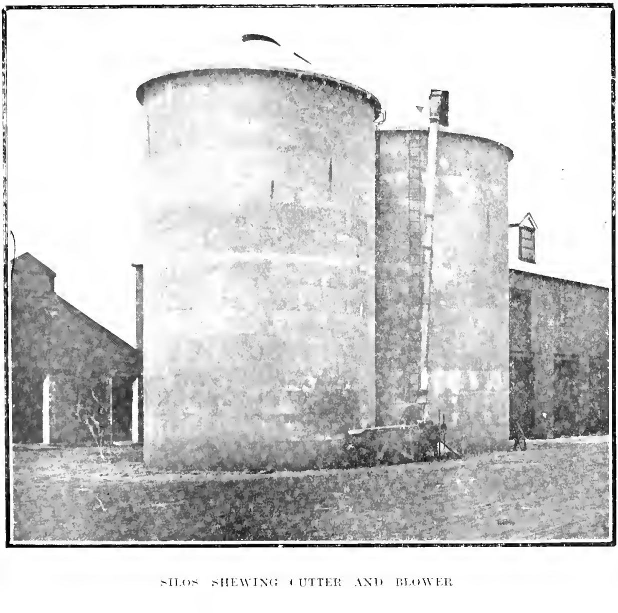
Uniformity in Size and Colour.—Uniformity in these denotes trueness to type, careful selection, and evenness of maturity, and also grain that will store well.

Shape and Size of Kernels.—These should be true to type, and in the variety the larger the grain the better.

Market Condition.—The sample should be free from dirt, mustiness, foreign matter and disease.

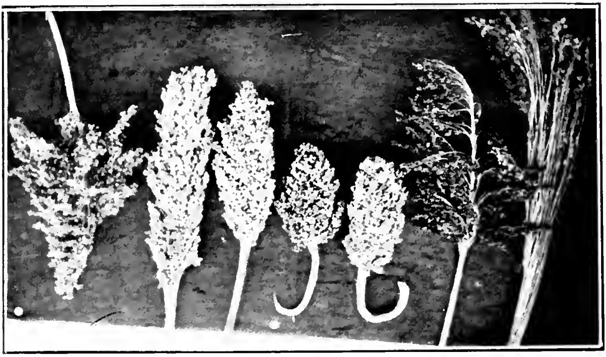
Weight per Bushel.—No official standard has been set; 56 pounds is the usual weight for Kaffir; some varieties are lighter. Preference should be given to the heavier strains in the variety.

Shelling Percentage.—Kaffir and Milo heads should give 77 to 84 per cent. of grain respectively.

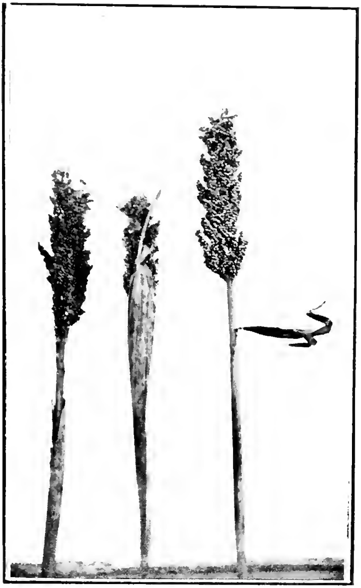


SILOS SHEWING CUTTER AND BLOWER

PLATE VI



TYPES OF SORGHUMS (LEFT TO RIGHT): SHALLU, WHITE KAFFIR CORN, FETERITA, WHITE MILO, WHITE DURRA, EARLY AMBER SACCHARINE SORGHUM AND BROOM CORN.



HEADS OF KAFFIR-CORN (LEFT TO RIGHT): HEAD SHOWING POOR EXSERTION (UPPER LEAF SHEATH REMOVED); HEAD SHOWING POOR EXSERTION; HEAD SHOWING GOOD EXSERTION.

Plate VIII

PLANT OF FETERITA, SHOWING UNDESIRABLE BRANCHING DUE TO TOO WIDE SPACING IN THE ROW.

Diseases and Pests.—(1) Kernel Smut (*Sphacelotheca sorghi*). In Kernel Smut only the individual grains are affected, the head being only slightly changed in appearance. The disease can be controlled by the use of formalin.

(2) Head Smut (*Sphacelotheca reiliana*).—Head Smut resembles maize smut to some extent; the entire head is destroyed. On exsertion, the head is found to be composed of a mass of spores covered with a whitish membrane. The ontogeny of the organism is not properly understood, and no satisfactory treatment has been found. Care should be taken to get uninfected seed.

Red Spot or Blight (*Bacillus sorghi*).—Red spots appear on stems and leaves, causing the latter to die prematurely. Seldom serious; certain strains are more resistant than others.

Sorghum Midge (*Diplosis sorghicola*).—Egg laid in flower and ovary destroyed by larvæ. No treatment known; somewhat rare. Early varieties in America are less susceptible to severe injury.

Rooi Bloom (*Striga lutea*).—Is parasitic, and should be treated as in maize.

Sorghum Aphis (*Heuning Dow*).—This insect has proved serious to late-sown sorghums, especially in the Lowveld.

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[5] "Better Grain Sorghum Crops."—U.S.D. of Agri. Bulletin 448.
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[16] United States Department of Agriculture No. 634, 1918.

CHAPTER VIII.

THE POTATO

HISTORY.—The natural habitat lies in the highlands of Chile and Peru, whence (at the time of the Spanish conquest of Peru in 1533-1535) it was taken to Spain. It was grown in Europe for some time before its introduction from Virginia into England by Sir Walter Raleigh, who, in 1585 or 1586, cultivated potatoes on his estate in Cork, Ireland. It rapidly became one of the world's principal articles of diet, and, on account of its intimate association with the history of the latter country, it is often spoken of as the Irish Potato. The following are some interesting figures of production in bushels :

	Average total production for 1911-13.	Average yield per acre 1904-13.
Germany	1,698,826,000	200·7
European Russia ...	1,258,120,333	106·4
Austria-Hungary ...	642,149,000	134·35
France	499,523,666	130·2
United States	348,303,000	96·5
United Kingdom ...	259,482,666	210·0

About 90 per cent. of the total production is grown in Europe. The average Australian and African production for 1908-12 was ·26 per cent. and ·09 per cent., respectively, of the world's production. The potato crop's average position for 1908-1912 among the world's crops is given by Gilbert as follows—viz. :[1]—

	Million tons.
Potatoes	161·0
Maize	128·38
Wheat	106·0
Oats	65·6
Rice	55·6
Rye	57·0
Barley	33·41

During 1917-18 the Union of South Africa planted 110,185 acres, obtaining 234,538,000 pounds, or an average of about one ton per acre. The census for 1911 showed an average of one and a half tons per acre. Under intelligent management and in favourable localities, yields of four and a half tons (60 bags) are not uncommon.

The table which follows, compiled from the 1919-20 agricultural census returns, shows the total number of bags of potatoes growing in each Province of the Union. For purposes of comparison the total production in bags of the two chief cereal crops is also given :—

Crops.	Cape.	Natal.	Transvaal.	O.F.S.	Total.
Potatoes.. ..	291,000	134,920	521,870	303,130	1,250,920
Wheat	1,118,500	4,560	285,050	130,610	1,538,720
Maize	502,800	1,442,540	3,923,000	3,500,740	9,369,080

From the above it is evident that the potato ranks only third in importance among the crops produced in the Union, and it is likely to remain so, as our present market for this crop is confined to the local trade, which is limited.

Below is given the two highest producing districts in each Province and the quantity produced by each of them :—

Province.	District.	Quantity produced in bags.
Cape	Humansdorp	20,880
	Stellenbosch	18,240
Natal	Newcastle	24,455
	Estcourt	17,220
O.F.S.	Thaba 'Nchu	87,380
	Ladybrand	47,550
Transvaal	Bethal	140,790
	Middelburg	47,550

The bulk of this production is obtained without irrigation. The crop is well suited to those areas of high altitude in the regions of summer rainfall.

There is no doubt that large areas of suitable land for the cultivation of potatoes are still available in the Transvaal and Orange Free State. In these Provinces the production is rapidly increasing.

Description and Classification.—Of the large number of Solanum species only six are tuber-bearing, and of these S. tuberosum (the common or Irish potato) is the only one of agricultural importance to-day. The roots are fibrous, the tubers being formed at the ends of rhizomes. "When growing under natural conditions the tubers are relatively small, close to the surface of the soil or may be upon it. The production of small green tubers on the haulm in the áxils of the leaves of the potato is not infrequent, and affords an interesting proof of the true morphological nature of the underground shoots and tubers. This phenomenon follows injury to the phloem in the lower part of the stem, which prevents the downward flow of the elaborated sap." Seeds are produced on the upright stems in smooth berries, perfectly globose and under an inch in diameter. The varieties of cultivated potatoes to-day vary in the formation of berries, and in some cases, owing to the production of non-viable pollen and general incompatability, and also adverse climatic conditions, some strains rarely form berries. In some cases even the formation of inflorescences is suppressed. Self-fertilisation rarely, if ever, occurs. When sown the seeds produce plants bearing small tubers the first year, which reach normal size in about three years. Since potatoes are normally propagated vegetatively their purity is comparatively constant. Unlike the artichoke tubers, that of the potato never bears roots. The view is held by some that the formation of tubers is associated with the presence of certain fungi, and that in reality the potato tuber is a gall produced by a micro-organism.

Potatoes are classified[2] into agricultural groups according to the colour and shape of the tuber, sprouts and flowers.

Shape of Tuber.—Round, oblong, and long, either flattened or round. Those tapering at one end are said to be spindled when compared with uniform potatoes.

Colour of Skin.—This may be white, cream-white, flesh-coloured, pink, rose, red, bluish, mottled and russet brown.

Colour of Sprouts.—" The colour of sprouts is very important in determining the main groups of varieties. The colour is determined by germinating the potato in the dark, and as soon as the sprouts appear, they are examined usually with a magnifying glass. The sprout is tipped with minute scales or leaflets, which may be either coloured or white. Also the base of sprouts may be either coloured or white. The usual colours are white, cream-white, pink rose, rose-lilac, magenta, lilac, violet, or deep violet."—Montgomery.[2]

COLOUR OF FLOWERS.—These may be white, rose, rose-lilac, rose-purple, purple and violet.

The depth and number of eyes vary considerably in the different strains. Those having shallow and few eyes are most sought after.

CLASSIFICATION ACCORDING TO MATURITY.—The following are the principal varieties grown in the Union—viz. :—

Early, about 90 days : Epicure, Early Rose and Early King.

Medium—90 to 110 days : Flourball, Factor, Arran Chief and Arran Comrade.

Late—110 to 130 days : Up-to-date, Five Towers and Scottish Triumph.

New varieties, as the old sorts become less popular, are constantly being introduced, *e.g.*, Kerr's Pink, King Edward VII., etc.

STRUCTURE AND COMPOSITION OF THE TUBER.—Four distinct zones are found in the tuber. "The outer skin is the coloured portion and may be completely separated from the part underneath. The cortical or fibro-vascular layer lies next, and is easily distinguished by the separating line of vascular bundles. In the interior the inner medullary layer appears like an undeveloped stem branching out towards the eyes."

Composition of the different zones of the potato tuber :—

Variety.	Zone.	Water.	Starch.	Total nitrogenous matter.
Geante	Cortical	72·74	21·14	1·91
	Out. Med.	74·33	19·78	1·88
	In. Med.	81·72	12·30	2·14
Czarine	Cortical	72·92	22·45	1·84
	Out. Med.	78·87	15·64	2·17
	In. Med.	84·48	10·50	2·11
Sancisse	Cortical	78·72	14·38	2·22
	Out. Med.	79·12	13·47	2·39
	In. Med.	80·73	12·31	2·62

The water and nitrogen contents increase from the outer to the inner zones, while the starch content decreases.[4]

The average composition of the potato is very similar to that of the soft wheats, and is composed as follows :—

	Per cent.
Water	75 to 80
Starch	16 to 20
Protein	2 to 3
Ash	1
Fat	Trace.
Fibre	Trace.

The zones :

Epidermis	2·5
Cortical layer	8·5
Inner medullary and Outer medullary	89

The starch granule is characteristically marked with eccentric rings, and is relatively large in size.

Good potatoes may be judged with the aid of the following score-card of the New York State Potato Association :—

Points to be considered—	Conformity Varietal type.	Conformity Market demands.
(1) Uniformity	20	20
(2) Blemishes and diseases	15	20
(3) Shape	15	15
(4) Size	10	15
(5) Quality of the flesh	10	10
(6) Depth and frequency of eyes	15	10
(7) Colour and texture of skin	15	10
	100	100
Total		200

The requirements for "seed" tubers must, naturally, vary somewhat from those required in marketing, and in a score-card of this nature the combined requirements are well met.

(1) *Uniformity.*—The tubers should be uniform in general appearance, *e.g.*, shape, size, colour, etc.

(2) *Blemishes and Diseases.*—There should be no evidence of disease, insect depredations or injury due to rough handling.

(3) and (4) *Shape and Size.*—Should be typical of the variety. On the whole, those varieties in best demand are those oval-flat or round-flat in shape, and medium in size. A spherical tuber if sufficiently large to be desirable is so thick that in cooking the exterior is likely to become overdone before the interior is properly cooked.

(5) *Quality of Flesh.*—Must be typical of the variety, fine-textured, light in colour, free from excess moisture and from hollow or dark spots. East[4] says : " The cortical layer, below the first few layers of cells, which are removed with the skin, shows a remarkably larger amount of starch in the cells than does the internal medullary layer. The starch content of the external medullary layer is also greater than that of the internal. The grains of starch in the cortical and external medullary layers, besides existing in greater numbers per cell, are generally of larger average size. The paucity of starch in the internal medullary layer causes the cells to be only partially filled with the cooked starch, and the cell walls are scarcely ever ruptured. In the cortical layer, on the other hand, the amount of starch is such that in the swelling due to cooking the cells are filled completely, and many of them ruptured, causing the mealy appearance so much desired by the consumer.

" It is quite evident, then, that potatoes having, so far as possible, a homogenous flesh, and containing as large an amount as possible of cortical and outer medullary layers in proportion to inner medullary layers, should be of the finest quality."

It must be remembered that the quality may vary according to the manner of use in the different countries. English-speaking people prefer a potato when boiled to be soft and mealy, while the French, who usually fry their potatoes in deep fat, prefer one which, when boiled, gives a relatively firm and soggy appearance.

(6) *Depth and Frequency of Eyes.*—Trueness to variety is necessary. The market demands few and shallow eyes in order that wastage due to peeling may be at a minimum.

(7) *Colour and Texture of Skin.*—This should be typical of the breed—the market wants a thin, tough, smooth or netted skin.

CLIMATE.—For optimum growth cool and moist conditions are required. In South Africa conditions corresponding to those of the plant's natural habitat have proved the most suitable, consequently those districts in high altitudes, of a cool and moist climate, are fast becoming the leading potato districts *e.g.*, Thaba 'Nchu and Bethal. The requirements of climate are largely met by the time of planting, hence the main crop in the Union is often planted in November or December, so that the time of tuber development is towards the cooler part of summer and in the autumn. The early crop (grown only under irrigation) is planted in August and lifted in November before the hotter summer weather commences.

Soil and Manurial Requirements.

Soil.—The ideal soil appears to be a well-drained, deep, friable, rich loam, containing an abundant supply of well-decayed organic matter. The crop requires a light, porous, open soil, for the following reasons:—

(1) The root system is weak and small compared with that of a plant like maize, and is especially weak in penetrating heavy soils.

(2) The crop is easier to plant, cultivate, and to dig.

(3) The tubers develop more freely, are smoother and more regular in shape.

(4) Fertilisers and manures are more effective.

Relatively heavy soils in which large quantities of organic matter have been incorporated, provided they are well drained, may be, contrary to popular belief, very productive.

Potatoes follow a green manure better than most crops, and do well on virgin land, provided a fine seed-bed is prepared. It is a crop well suited to follow on land after lucerne is ploughed down.

It is never a profitable crop on poor soils, as, being a surface feeder and short-lived, it requires a soil in a high state of productivity.

On average farm soils the following manurial applications have been found to give good results—viz., 10 to 12 tons well-rotted kraal manure, and in addition 300 lbs. superphosphate or 400 lbs. bone dust; the manure should be ploughed under before planting and in sufficient time to ensure thorough decomposition. The superphosphate, or bone dust, should be applied in the rows at the time of planting. Where no kraal manure is available, 200 lbs. guano, with 200 lbs. of bone dust, and 100 lbs. of superphosphate, in all 500-600 lbs. per acre, have given satisfactory results.

The potato is a potash-loving plant; but in most South African soils this element of plant food is usually found in sufficient quantities to supply the needs of the crop.

The experience at the different experiment stations in the Union has been that a combination of kraal manure with mineral fertilisers has given much better results than either alone. The organic matter seems essential for successful potato propagation.

It will be noted from the following experiments[8] that complete mineral fertilisers (Plot 16) gave no better result than eight tons of kraal manure per acre by itself. The best yield was obtained from 400 lbs. superphosphate, 400 lbs. of wood ash, and 4 tons kraal manure; and the next best with kraal manure and superphosphate alone. It would be as well when wood ash is not available to use in its place 80-150 lbs. of sulphate of potash.

Co-operative fertiliser experiments at Zeerust (1920-1921):—

Plot No.	Fertiliser used	Rate per acre	Yield per acre lbs.	bags.
1.	Superphosphate ...	400 lbs.	2,420	16·1
2.	do. ...	600 lbs.	2,783	18·3
3.	Kraal manure ...	4 tons	2,783	18·4
4.	Control ...	No treatment	1,936	12·9
5.	Kraal manure ...	8 tons	3,388	22·5
6.	Superphosphate ...	400 lbs.	2,904	19·3
	Wood ash ...	400 lbs.		
7.	Superphosphate ...	400 lbs.	4,598	30·6
	Kraal manure ...	4 tons		
8.	Control ...	No treatment	1,936	12·9
9.	Superphosphate ...	400 lbs.		
	Wood ash ...	400 lbs.	5,082	33·8
	Kraal manure ...	4 tons		
10.	Wood ash ...	400 lbs.	3,872	25·8
	Kraal manure ...	4 tons		
11.	Wood ash ...	600 lbs.	2,420	16·1
12.	Control ...	No treatment	1,815	12·1
13.	Wood ash ...	400 lbs.	1,694	11·2
14.	Sodium nitrate ...	100 lbs.	2,178	14·5
15.	Sulphate of potash ...	100 lbs.	2,178	14·5
16.	Superphosphate ...	400 lbs.		
	Sulphate of potash ...	100 lbs.	3,388	22·5
	Nitrate of soda ...	100 lbs.		
17.	Control ...	No treatment	1,875½	12·5

Lime or manures giving an alkaline reaction should not be used immediately before planting, as soil conditions will then favour the development of Scab (*Actinomyces chromogenus*).

CULTURAL METHODS.—The potato responds to good soil treatment better than most field crops. Initial ploughing should be deep and thorough as the plant requires a deep, mellow and moist seed-bed. Just prior to planting, the field should be either cross-ploughed, disced or cultivated in order to loosen the soil and to establish a fine tilth.

PLANTING.—There are at least two methods in vogue in the Union, namely, the " ridge " and the " flat " system. In the former system the tubers are planted in furrows or drills, previously drawn with a ridging plough after the seed-bed has been prepared. In the latter method they are planted between the second and third share or disc of a three-furrow plough, or else in the second furrow of a two-furrow plough, followed by a single-furrow plough to cover up the seed.

Most of the seed is planted by hand, as machines have proved unsatisfactory so far. The sets are placed either slightly to the right in the furrow where the trek animals cannot trample on them, or else they are dropped in the furrow between the hind oxen and the plough, or, better still, from the seat of the plough between the second and third share or disc of a three-furrow plough.

The " ridge " system is recommended under irrigation and where the crop is likely to experience a wet season. In the former case ridging facilitates water-leading, and prevents encrustation of the soil next to the plant, and in the second it affords drainage.

On dry-lands the " flat " or level system will, in most cases, prove to be the most useful and profitable one, as it will assist in conserving moisture.

QUANTITY PER ACRE.—The quantity required will vary with the size of the sets and the spacing. About 1,000 lbs. (6 to 7 bags) of tubers the size of a hen's egg (2 to 2½ ozs. in weight) is the average amount planted.

The " seed " should be sound, free from disease and sprouted, or at least showing signs of germination.

If a moist condition of the soil is assured large tubers may be cut to about the above weight to economise in " seed." They should be cut to have, as far as possible, two to three eyes per piece, and the cut surfaces should be covered with gypsum or calcium carbonate (ordinary lime) or clean wood-ash, forming a crust over the surface. The object of this is to prevent undue desiccation. Cut seed should be planted soon after cutting, and should not be left exposed or planted in dry ground. Experiments at Grootvlei and Tweespruit, O.F.S. (1906-1908),[5] showed a marked increase of whole over cut tubers, when the same spacing was used in planting.

SEED TUBERS.—Where seed has been held dormant it is good practice to place the seed in a light warm place to sprout. This should be done some time before planting—a uniform standard is obtained in this way, because potatoes of retarded germination can be discarded, and only those planted which have started to sprout. The shoots should not be allowed to grow too long.

The great difficulty in South Africa at present is to procure seed of the proper maturity at the different times of planting, as it is almost impossible to secure places of low enough temperature to ensure dormant tubers. Seed lifted during the winter months start sprouting with the advent of warm spring weather, and as this is not used for the main crop until November and December, it is found hard to retard the growth until then. With the prevailing high temperatures of September and October this is by no means easy of accomplishment. Some farmers are successful in doing the lifting as late as possible, about the end of July (in some places in October) and then placing them in mounds. These mounds are made by having the tubers in long piles covered with a thick layer of grass, which, in turn, is covered with about a foot of soil, care being taken to chose a cool, well-drained site, and to provide good ventilation by having holes through the covering, which are usually kept fairly open with bundles of grass. In this method the pile should be examined from time to time to see that the tubers are not decaying.

In storage the temperature should be kept as low as possible (in South Africa), the humidity of the air in the storage place should not be high nor too dry, and the supply of air (oxygen) should be limited.

Where small amounts of seed are handled greening is possibly the best method. Here the tubers are placed one layer thick in shallow crates, which are placed in a well-ventilated situation in strong light. In this manner they may be kept sound for several months while they produce short, stubby sprouts and turn a slight greenish colour. Very few sprouts are broken off during planting.

Immature tubers produce more vigorous plants than those fully matured, hence it is the custom in some countries to dig tubers before maturity, or to allow the crop to ripen prematurely by withholding water; or to plant late and to allow the crop to be frosted before maturity. Tubers not fully matured are easily bruised in handling, and the germination is apt to be slow and irregular. However, with careful handling, storage, and if sprouted as described, excellent crops are obtained, as will be seen from the following experiment conducted at the Ontario Agricultural College :—

Seed obtained from planting of:	Average of six varieties.
May 31st	192·37 bushels per acre.
June 14th	194·80 ,, ,,
June 28th	201·84 ,, ,,
July 12th	219·46 ,, ,,

The farmer, under irrigation growing both early and main crops, experiences difficulty in getting the seed lifted in November and December to sprout in time for January planting. While germination may be hastened by placing the tubers in a warm, moist situation (a covering of moistened stable manure is often of assistance), this method is not always successful. Potatoes are grown in the Low Veld—*e.g.*, Koedoes River and Barberton—in time to be lifted in October and ready for the main crop planting in December and January, and these could be used for seed by the farmers on the High Veld.

ROTATIONS.—As previously stated, potatoes follow green manure better than most crops, as the comparatively loose soil produced is suited to their growth.

Below are some suggested rotations :—

(1) *Without Irrigation*—dry lands.
- 1st year—Maize.
- 2nd year—Maize, with an application of phosphates.
- 3rd year—Cowpeas (kaffir beans), ploughed under.
- 4th year—Potatoes, manured as previously recommended.

If an excess of nitrogen is indicated by too much top growth at the expense of tuber formation, then the potatoes should receive only a light phosphatic dressing without the kraal manure, or the crop of cowpeas might be eliminated in the rotation or used for hay.

(2) *Under Irrigation*—two-year rotation.

1st year—Winter crop: wheat with a dressing of phosphates.
Summer crop: cowpeas ploughed under.

2nd year—Winter crop: wheat, with a dressing of phosphates.
Summer crop: potatoes with kraal manure.

(3) Seven to nine years' rotation: lucerne, followed by potatoes, followed by wheat, having a dressing of phosphates; land then to be re-sown to lucerne.

PLANTING.—Under irrigation, two crops are grown in one year, the spring-planted crop for the summer and autumn; and the summer-planted crop for the winter and spring markets.

The early crop is planted from June to September according to the climatic conditions of the locality; in the Low Veld, where litle frost is experienced, the crop is planted in June and July; in the High Veld and Middle Veld in August, or as soon as the danger of late frosts is over.

For the summer crop, planting takes place in December and January.

Without irrigation the date of planting will vary with the commencement of the seasonal rains for the locality and the condition of the stored seed tubers, usually from September to January.

For the spring planting the early varieties are used, and medium and late varieties for the main crop.

The tendency in South Africa is to plant much too closely. The rows should be three to three and one-half feet apart, and the tubers 12 to 18 inches in the rows. In moist climates, or under irrigation, on rich soils, a much closer spacing is used.

The tubers should be planted four to six inches below the surface, depending on the nature of the soil.

Planting machines, under South African conditions of labour, have not proved satisfactory, and the crop is mostly put in by hand.

AFTER CULTIVATION.—Before the plants appear above ground, it is often necessary and advisable to harrow the field to destroy weed growth and to break any crusts which might have formed. This may be repeated while the plants are still small and unlikely to be injured. Cultivation to keep the ground loose and to destroy weeds should start soon afterwards, getting shallower as the roots spread, and must be continued until after flowering.

Under irrigation, and to a less marked extent on dry lands, the crop should now be ridged (earthed up) to check tubermoth injury, and to prevent the soil cracking, which is undesirable, for when exposed to light the tubers assume a greenish colour.

Potatoes respond to heavy irrigation, provided this is well distributed, better than any field crop. Experience has shown that where possible water should not be applied during the extreme heat of the day, as this practice seems to predispose the plants to disease. Wide fluctuations in the soil moisture should be avoided, as malformed tubers are common if the growth is interrupted. Heavy irrigation should be avoided also during the early growth of the crop.

HARVESTING.—The main crop should be dug when thoroughly mature, *i.e.*, when the skin is firm, the tops have dried and the tubers separate easily from the rhizomes. Tuber development and starch storage are most rapid during the last month of growth, and continue as long as the tops are green.

In areas of dry winters, having relatively low temperatures, the potatoes are often left in the soil and are lifted only when required. On the High Veld they may be left in the soil until August.

The early crop is often harvested before maturity, as the loss in yield is counter-balanced by the high price obtained for new potatoes. The early crop seldom yields as heavily as the main crop.

If the vines are frosted before maturity the tubers should be left in the ground for some time to enable the skin to harden.

The crop is usually lifted by hand, double mouldboard plough, or potato digger. The latter implement is coming into more general usage, although some difficulty has been found in South Africa in hard, dry ground to get the digger to dig deeply enough.

In the Union, potatoes are sold in bags 153 pounds gross. Unfortunately, grading is little practised. Medium-sized potatoes are preferred to those very large, and no discrimination with regard to colour is shown. Prices fluctuate from a few shillings to a few pounds per bag, depending chiefly on the season. The best prices are obtained from July to October.

Uses.—Apart from their use as human food and to a certain degree as stock food, potatoes are used in the production of starch, alcohol, glucose and syrup. Potato flour is used largely in European countries as an ingredient in flour for bread-making.

Potato Improvement.—No discussion on this topic would be complete without a survey of the chief factors involved in the question of degeneracy in potatoes. It is the experience of capable growers, in some localities widely differing from the natural habitat of the potato, *e.g.*, of high temperatures, of low rainfall, and often at low altitudes, that the importation of seed tubers is necessary because of the depreciated productivity of old strains.

There are many factors contributing to this state of affairs; chief among these are :—

(1) The prevailing method of selecting the culls and small tubers to be used for " seed " purposes.—In this method hills of low productivity, and, although not apparent, often diseased, receive disproportionate representation in the succeeding crop, consequently there is a constant tendency for the crop to decrease in yield—colloquially " to run out." To counteract this tendency, hill-selection should be practised to obtain the high yielding biotypes (strains). The procedure is to select healthy and vigorous plants in the growing crop, and when dug to take the most productive and desirable hills for propagation in a breeding plot. This is multiplied by succeeding plantings until sufficient seed tubers from these high yielding hills are secured to plant the main crop. Hill-selection should always continue from the main crop, and the breeding and multiplying plots maintained.

That the yielding capacity of the hills in the same variety differ widely is shown in the following experiments—viz. :

Ontario Agricultural College.

Davies Warrior Selections.	Average for three years.
No. 5	243·4 bushels per acre
2	216·3 ,, ,,
1	190·8 ,, ,,
8	136·2 ,, ,,

Cornell University.		Average for five years in bushels per acre.
1.	Low-yielding strain	67
	High-yielding strain	251
2.	Low-yielding strain	100
	High-yielding strain	203
3.	Low-yielding strain	80
	High-yielding strain	171

(2) Degeneracy is attributed by Stewart and East to be due largely to diseases carried in the tuber. The organisms have not been isolated, and some of these diseases may be physiological, exhibiting themselves under unfavourable conditions. Typical of these are those disorders knowns as Mozaic Disease, Spindling Sprout and Curly Leaf.

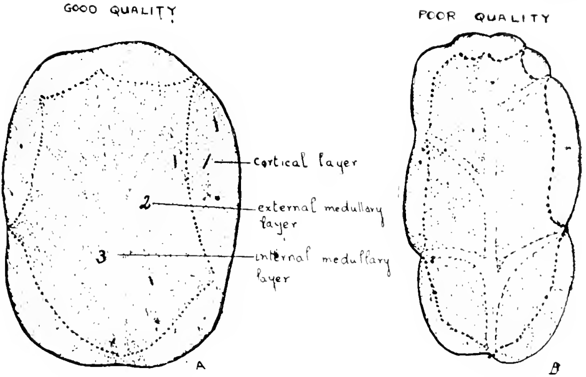
(3) It has been suggested that the continual asexual propagation may be the cause of this degeneracy, since the vigour due to heterosis cannot manifest itself. East, however, maintains that this view is unproven.

There is no doubt, however, that this so-called degeneracy can be checked to some extent by hill selection. In localities well suited to that plant, the productivity is often maintained without recourse to any special form of selection. For instance, in Ontario, where the climate is favourable, Zavitz has grown five varieties in a variety test for 25 years without employing any method of selection; these varieties have given a slight increase during the period of the trial.

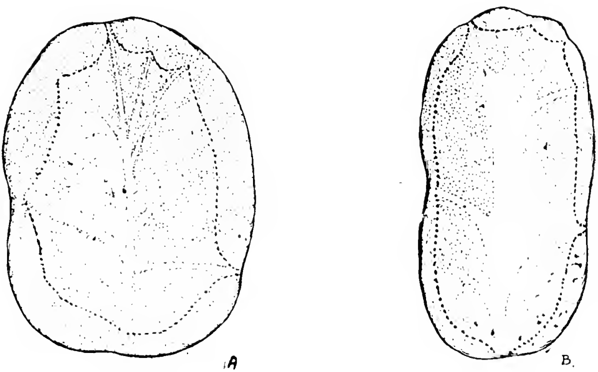
Emerson[6] has shown that by mulching potatoes with about 4 to 6 inches of straw, and thus modifying the moisture and temperature of the soil, the productivity of varieties was maintained. In this method the field from which seed potatoes for the following year are to be obtained is mulched with straw after planting and no subsequent cultivation given.

Improvement by hybridisation is slow, laborious and uncertain, and should be undertaken only by those having the time and means at their disposal. The chief obstacles are in getting crosses to take, and the time required to test the yielding capacity of the hybrids. Improved varieties have, however, been produced in this way.

Mutations do occur, and if of some outstanding peculiarity are naturally selected by breeders and growers, and often good new varieties may be found.



A. POTATO OF GOOD QUALITY, SHOWING FEW AND SHALLOW EYES.
B. POTATO OF POOR QUALITY, SHOWING NUMEROUS DEEP-SET EYES.



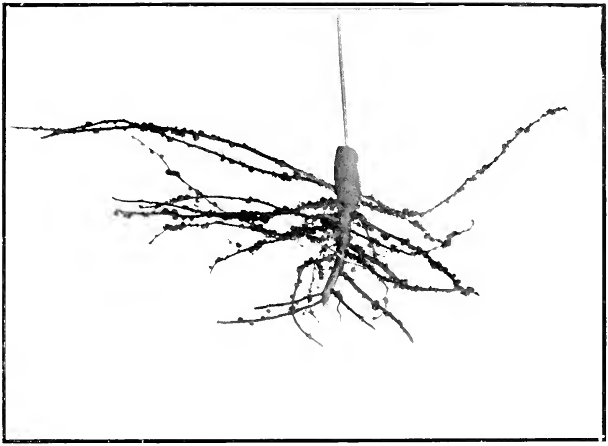
AMOUNT OF INTERNAL MEDULLA AND CORTEX.

A. GOOD.
B. BAD.

Plate X

POTATOES IN RIDGES BEING CULTIVATED—POTCHEFSTROOM EXPERIMENTAL STATION. (COURTESY UNION DEPARTMENT OF AGRICULTURE).

LUCERNE PLANT SHEWING CROWN AND STRONG ROOTING SYSTEM.

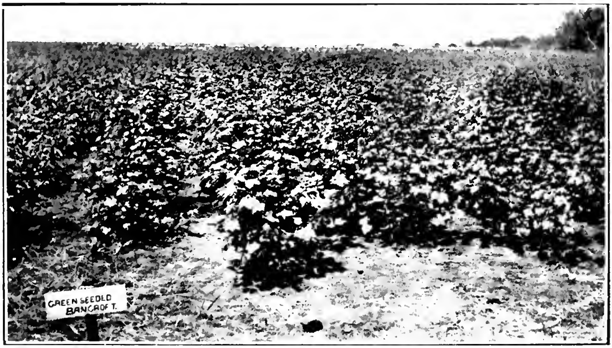


COWPEA ROOTS, SHOWING NODULES.

SOYBEANS.

PLATE XII

COWPEAS IN CENTRE WITH SOYBEANS ON LEFT AND RIGHT.



GREEN-SEEDED BANCROFT COTTON AT RUSTENBURG EXP. STATION.
(COURTESY J. DU P. OOSTHUIZEN).

East says that yield is correlated with flat shape of tuber, number of haulms and length of growing season; that round-flat tubers are richest in starch; that a netted skin is usually associated with high quality; and that heavy fruit production is associated with small tuber formation.

In South Africa much might be done by the selection of heat-resistant strains.

Diseases and Other Pests.—The potato is subject to numerous diseases, and as it is a widely-grown and important crop a considerable amount of attention has been focussed on these by phytopathologists. Among the more important fungous and bacterial diseases in the Union are the following—viz., Bacterial Wilt, or Vrot-pootje (*Bacillus solanacearum*), Potato Scab (*Actinomyces chromogenus*), Early Blight (*Macrosporium solani*) Late Blight (*Phytopthora infestans*), Rhizoctonia Disease (*Corticum vagum var solani*), Potato Rot (*Nectria solani*), and Wart Disease (*Synchitrium endobioticum*). The last-named has just lately been discovered by Mr. Puttick in Natal.[7]

Internal Brown Fleck is often met with in the Union, and at present the casual organism (if any) has not been isolated.

Remedial Measures.—A good system of crop rotation is probably one of the best preventive measures, and the selection of resistant strains is an avenue which might be further explored.

It must be remembered that while a number of these diseases is limited to a specific host, others have alternate hosts—*e.g.*, *Macrosporium solani* is also parasitic on *Datura stramonium* (Stinkblaar), consequently, weed control is of special importance. The use of disinfectants is growing in South Africa, and, no doubt, assists materially in the control of some of these diseases—*e.g.*, Scab. The potatoes are soaked in a formalin solution, one pint to 30 gallons of water, for one hour; or two ounces of corrosive sublimate to 16 gallons of water for three hours. Seed tubers should never be cut before treating same for the prevention of scab.

Spraying with fungicides to control vine diseases is at present uncommon in the Union, but may become more popular as farming becomes more intensive. Bordeaux Mixture, together with lead arsenate or Paris Green is chiefly used as a fungicide and insecticide.

Insects and Other Pests.—The Cut-worm (*Euxoa spp.* and *Agrotis spp.*), Tuber Moth (*Phthorimæa operculella Lell*), Millepeds and Eel-worm (*Heterodera radicicola*) cause considerable damage. Thorough cultivation, rotative cropping and the avoidance of soils poorly drained are preventive measures. Of the larger animals, the Porcupine and Wild-Boar prove serious pests in certain localities.

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[3] "Productive Farm Crops."—Montgomery.

[4] Study of the Factors Influencing the Improvement of Potatoes."—Illinois Bulletin 127.—East.

[5] Annual Reports, Department of Agriculture, O.F.S.

[6] Bulletin 146, University of Nebraska.

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[8] "Potato Culture."—L. J. Bosman; Union Agricultural Journal, July, 1922.

CHAPTER IX

LUCERNE

History and Production.—Lucerne is probably the first plant to have been cultivated solely as a forage plant, and until recently was the only crop cultivated for this purpose by Asiatics.

The natural habitat of *Medicago sativa* is along the coast of the Mediterranean, and, as far as is known, it was first cultivated in this region. According to Pliny, it was brought from Media to Greece in the year 470 B.C.

The United States of America imported it from Chili in 1854. It is now more extensively grown in North America, where it is known by its Arabic name, " alfalfa," than in any continent. It is one of the most important of the world's forage crops, being cultivated extensively in the United States of America, Canada, Russia, South-Eastern Europe, France, Argentine, Australia, and South Africa.

It was probably introduced into South Africa about 1860, and soon assumed an important position in South African agriculture, particularly when, at a later date, the ostrich came into domestication. In fact, the chief impetus to its cultivation was its generally recognised value as a feed for ostriches. However, to-day, its outstanding nutritive and high-yielding qualities have made it one of the most valued and widely grown of the hay crops in the country. It is limited in the Union to irrigable land of a suitable nature.

It is safe to say that there is no other plant at present known which will furnish so much valuable forage for so long a term of years without re-seeding. A field at Glen Lynden, Bedford, planted forty years ago, was still producing good crops in 1921.

Description and Classification.—Lucerne is a perennial legume, making its chief growth in summer, and attaining a height of $1\frac{1}{2}$ to 3 feet. When cut or grazed down, new stems arise from buds at the crown, and increase in number with the age of the plant. It is characterised by its exceedingly deep and well-developed tap-root, which often penetrates to considerable depth, fifty feet and more. The more or less kidney-shaped seeds are borne in special racemes springing from the axils of the leaves. In the ordinary varieties under cultivation, purple is the characteristic colour of the flowers, and root-stocks are almost entirely absent.

The places of origin of the medicagos are Europe and Asia. The genus *Medicago* contains a large number of species. Among the annuals the only ones of any agricultural importance, and then not in the Union, are the Burr Clovers, the chief of which is *M. lupulina* (Black Medick or Yellow Trefoil). Three species belonging to the perennials are of great agricultural value, namely, the *H. sativa*, *M. falcata*, and by hybridisation of these two, *M. media*. The plant *M. sativa var. gaetula* may prove of economic value because of its tendency to produce rhizomes.

Medicago sativa.—Nearly all varieties in common cultivation belong to this species. It is purple-flowered, has a very pronounced tap-root, and produces numerous upright stems. The plant in general is less bushy than in *M. falcata*. In *M. falcata* the seed is carried in spiral pods.

Medicago falcata.—This species is yellow-flowered, with sickle-shaped pods. It also has numerous stems, but the plant is usually more decumbent and the stems are finer than those of *sativa* or *media*. It shows a tendency to have its crown partially buried, and a few plants have been found with rhizomes. The rooting system is more branched, and the tap-root less developed. It is found in the natural state in Siberia, and, consequently will stand extraordinary low killing temperatures, and is very drought resistant. It is not ordinarily high yielding.

Medicago media.—This species has variegated flowers with spiral pods. In growth it resembles *sativa*, but is hardier and more resistant to drought and cold—qualities it owes to its *falcata* parent. Most varieties of supposedly the *sativa* type will be found to have some *media* characteristics. In cold, dry climates, varieties such as Grimms', Sand or Variegated, which are distinctly *media*, thrive better than varieties of *sativa*, such as Arabian or Peruvian.

Medicago sativa var. gaetula.—This species was imported from Tunis to the United States. It is peculiar in having abundant rhizomes up to $3\frac{1}{2}$ feet in length. The hybrid from this sub-species and *sativa* gives promise of making excellent grazing lucernes, "giving a dense matted growth, a single plant covering a surface of several square feet, and presenting much the same general appearance as White Clover (*T. repens*)."

Varieties.

Provence or Common.—Is a variety imported from Provence, France. It is the best known and most commonly grown variety in the Union. A small percentage of the flowers are sometimes found to be variegated, but the great majority are purple. It is generally classed as belonging to the species *sativa*. The crowns are fairly close to the ground, and the stems are not quite so erect as in some of the other varieties—*e.g.*, Peruvian.

Hunter's River and Tamworth.—These are named after the districts where the seed is produced in Australia. There is practically no difference between these varieties, and both probably originated from seed imported from Provence, as they closely resemble the Provence variety. Under South African conditions, however, they are slightly earlier in starting their spring growth, and are said to be somewhat heavier yielding. Their cultivation is, in fact, becoming popular in the Union, and would become more so were it not that the imported seed costs several shillings per pound as opposed to less than a shilling for locally grown seed.

Turkestan.—In appearance is very much like Provence, and in America has given good results in cold, semi-arid parts. In South Africa, however, it has not yielded as well as the latter variety, and is slower in growth.

Arabian.—Is a very hairy variety, with large leaflets. It is of very rapid growth and relatively short-lived. In California it has given up to twelve cuttings. However, by the third year the stand starts to become sparse, and is generally ploughed down by the fourth year. It is a very erect variety, with exposed crowns, easily injured by close grazing. Being more frost-resistant, it commences growth earlier than Provence.

Peruvian.—Is similar to Arabian, and its marked pubescence gives it a bluish appearance. The crowns are very exposed, and the stems strikingly erect though somewhat coarse. The leaflets are large; like Arabian, it has a long growing season and short life; lacks hardiness, and is easily injured by grazing.

Chinese.—Introduced comparatively recently; has not yet come into general use. A *sativa* variety, having somewhat hairy leaves. Vigorous, early and late growth, and apparently long lived. Excellent results are reported from the Grootfointein Agricultural School.

Variegated, Sand or Grimms'.—Is undoubtedly a cross between *sativa* and *falcata*. The flowers are white, cream, yellow, bluish-green, smoky-green and purple. It is slightly decumbent in habit, especially when widely spaced, but is more cold and drought resistant than Provence; this is probably due to its tendency to produce root-stocks. The crowns are fairly sunken in the ground. It has not been tried to any extent in South Africa, but may be of decided value, as it is well adapted for grazing as well as for hay.

Yellow, Sickle or Siberian (*M. falcata*).—Is very decumbent, crowns sunken in the ground; occasionally produces rhizomes. It is relatively low-yielding, and shatters its seed almost as soon as mature. It is very hardy, for which reason it is extremely valuable as a parent in crosses. It is grown to a considerable extent in Siberia, but except in an experimental way has not been grown in the United States, Australia, or South Africa.

Climate.—Lucerne is capable of withstanding great extremes of temperature, and has been known to survive a temperature of 83 deg. F., as well as temperatures much higher than commonly occur in the Union. As far as cold is concerned, there are great differences in the resistance of many varieties, but the lowest temperatures in South Africa would not affect the vitality of any varieties.

It is especially adapted to semi-arid climates. High humidity with high temperatures are detrimental to its growth. Although lucerne will survive periods of excessive dryness, its water requirement is very high; hence if large yields are to be expected, the soil must be such that a large quantity of water is available for the growing plants. It therefore responds more readily to, and will yield heavier crops under irrigation than under humid or dry-land farming conditions.

Soil Conditions.—The heaviest yields of lucerne are obtained on deep, open, alluvial soils, well supplied with lime, and having a water table twelve to thirty feet below the surface. Hence along river banks, where irrigable soils of this nature are found, it is one of the most profitable of crops in the Union.

The seedlings are very sensitive to alkali (brak), but if once established the plants will withstand a larger proportion of alkali salts. Acid (sour) soils are always poor lucerne soils, and it is questionable whether the crop can be grown on these soils profitably when liming has to be resorted to.

If the water-table is within four feet of the surface, or if the subsoil is of a heavy, impervious character, or the soil shallow, the crop is rarely successful, as it is exceedingly susceptible to a water-logged condition of the soil.

Lucerne requires a productive soil. Reinecke has found that this crop on land in the Transvaal, with a fair lime content, gave a substantial profit when superphosphate (400 pounds per acre) or kraal manure (twelve tons per acre) was applied. The increases in yield over unmanured land, *i.e.*, 3,672 pounds and 2,792 pounds, were valued at £5 16s. 11d. and £2 4s. 3d. per acre, respectively. Bone meal was not so profitable, and the use of potash fertilisers showed no appreciable gain.

Where kraal manure is employed it should be applied some time before sowing, so as to give it time to decompose thoroughly, and more especially to afford an opportunity of destroying the weeds, the seeds of which are carried in the manure, prior to sowing. It is often advisable either to apply the manure to the previous crop or to fallow the land previous to sowing. Top dressings of 200 pounds of superphosphate each season will prove profitable in most cases. This is best applied early in spring, when active growth has not started, and while the crop is being cultivated.

Seed-Bed.—The land should be in as good a condition as possible, more care being required in its preparation than for the cereals. The early growth of the seedlings is largely devoted to root-development, consequently they are poorly adapted to compete against weeds. The preceding crops, therefore, should be cleaning crops, *i.e.*, cultivated crops. The seedling stage is the most susceptible phase of the crop. Therefore the soil should be compact and in a state of fine tilth. The preparation of the field should commence in ample time to allow the soil to settle and to get rid of weed growth.

For successful lucerne growing it is essential that the land be carefully levelled, particularly with the object of economising in water and labour. The fields should be divided into irrigation beds, with only a moderate fall of, if possible, about six inches every one hundred yards. The beds, where necessary, should be terraced, and so far as possible should follow the contour of the land. Having regard to the slope, texture of the soil and volume of water available, to facilitate mowing, they should be as wide as possible. Usually they are made twenty to forty feet in width. The ground must be firm and, where possible, moist enough to ensure a fair start before the crop receives its first irrigation. To ensure a stand, in some cases irrigation must be resorted to, but to promote deep root growth the fields should be watered as little as possible during the early stages.

Planting.—The best time to sow is in the autumn, before the first frosts, when the most active weed growth is over, and when the soil is kept moist by the late rains. If sown during March, April, or May, the risk of having the young crop destroyed by caterpillars is not so great as in spring, as the crop is well started before winter, and a number of summer weeds are killed by the first frosts.

Planting in spring is sometimes successfully practised on land free from weeds.

This crop is commonly sown broadcast, at the rate of 15 to 20 pounds per acre; thicker seeding is recommended if the land is weedy. The seed is lightly covered with very light harrows, weeders, or a chain harrow. As the seed must not be placed deeper than an inch below the surface, those growers not in possession of any of these implements often resort to covering the seed by dragging branches across the field, or sow it on top of a moving harrow, or may even drive a flock of sheep to and fro to trample the seed into the soil.

The use of a seeder is advisable, as a more even stand is secured and less seed is required, 10 to 15 pounds being used when a drill is employed.

Lucerne is sometimes sown with oats, barley, or field peas, as a nurse crop. This, while a successful practice in more humid countries, is not generally recommended in South Africa, as the seedlings suffer from competition with the more rapid-growing plants of the nurse-crop.

Seeds.—As lucerne is grown only on expensive land, and as preparation of the soil and the seed is costly, great care should be taken in the choice of seed. The following score-card may be used in judging the merits of seed :—

	Possible.
(1) Size and plumpness	20
(2) Brightness, lustre or polish	20
(3) Purity	40
(4) Freedom from dark brown seeds ...	20
Total ...	100

(1) *Size and Plumpness.*—Some strains are smaller-seeded than others, while some are plumper. As in all seeds, however, the plumper and the larger within the variety the better. Immature seed is often very flat and shrunken.

(2) *Brightness, Lustre or Polish.*—This is the chief superficial means we have of distinguishing age and vigour in lucerne seed, and as it loses its vitality fairly rapidly after a few years, especially if poorly stored, it is important that the colour be bright. A dull appearance is easily detected, and invariably indicates age, severe weathering, or bad storage. The seed should have a high polish, be bright yellow in colour, and have an oily appearance.

(3) *Purity.*—The presence and kind of weed seeds must be ascertained. In lucerne, this is of paramount importance, as weeds establish themselves before the crop has made much headway, on account of it having a relatively small growth during the first few months. Weeds are more objectionable in lucerne than in most crops, because the crop usually occupies the ground from five to seven years: consequently, intercrop tillage can very seldom be resorted to. Moreover, weeds can be destroyed in the growing crop only with difficulty, and the value of the hay is much depreciated by their presence. Dodder (*Cussuta spp.*) is the worst weed, and the only impurity for which special laws have been provided to protect the South African grower. The seeds are somewhat smaller than lucerne seed, roundish in shape, and light to dark brown in colour. Weed seeds in lucerne are prevalent largely because some of the seeds of the worst weeds are about the same size and weight as lucerne seed, and consequently are hard to separate by winnowing or screening.

Adulterants, particularly in European seed, are common, and are often difficult to distinguish. Seeds of Black Medick (*M. lupulina*) and Sweet Clover (*Melilotus alba* and *leucantha*) are those most commonly found.

Sticks, stones, and dirt, naturally increase the price actually paid for seed.

(4) *Freedom from Dark Brown Seed.*—With excessive weathering, but particularly with age, the seed assumes a brown colour. The vitality of such seed is low, and often only a very small percentage is viable. If present in large quantities, by no means uncommon, the quantity per acre used should be increased considerably. On the other hand, dark green colour is often a sign of immaturity, especially if the seeds have a tendency to be flat and shrunken as well.

Inoculation.—Crop failures are sometimes due to the absence of certain bacteria (*P. radicicola*) in the soil. The plants grow only a few inches high, turn yellow, and then die. In land sown to lucerne for the first time, in which the plants behave in this way, all other conditions being favourable to its growth, and especially if no nodules are formed on the roots, the seed of subsequent sowing should be inoculated, or soils from established fields in which lucerne is doing well should be strewn over the seed-bed and harrowed in without delay. The nodule bacteria of *Melilotus spp.*, and, it is believed, that of Burr Clover and Yellow Trefoil, are thought to be symbiotic with lucerne as well. It is probable that the nodule bacteria of some wild, commonly occurring legumes in South Africa may suffice for the lucerne plant. On the other hand, it is doubtful whether failures due to this cause often occur in South Africa. The soil method of inoculation is the most practicable. Artificial cultures, generally speaking, have proved unsatisfactory,

Early Treatment.—The young lucerne should not be cut too early unless smothering by weeds is threatened, in which case it should be mowed as low as possible. If it flowers and starts seeding before the winter sets in, it should be mowed, as the young plants must not be allowed to fruit, since this tends to set back the growth. Young lucerne plants should on no account be pastured, and never when the soil is wet.

Irrigation.—Irrigate as little as possible before the plants are well established. Depending somewhat on the rainfall, one irrigation, as soon as the crop is taken off, is usually sufficient. As soon as the soil permits, after this watering, it should be thoroughly cultivated with heavy cultivators, of which several kinds have been introduced, namely, the Martin Cultivator and Roberts' Lucerne King Cultivator. Disc harrows are often used where these latter implements are not available.

If the ground is not weedy, a deep and thorough cultivation before growth starts in spring may be all that is necessary.

Lucerne should not be irrigated with water heavily charged with alkali or silt. The latter tends to pack into a hard, impervious crust, very detrimental to the crop. Over-irrigation may easily occur, especially if the subsoil is of an impervious character, and the crop may be killed if submerged for any length of time.

HARVESTING.—The first cutting of the season is generally the lowest yielding. If the plants are of a retarded and stunted growth, it should be cut, since this often ensures a good second crop.

The crop should be mowed when about 10 to 20 per cent. of the plants are in flower. This stage will be found to correspond with a slight yellowing of the lower leaves, and the appearance of young shoots at the crown. Mowing should not be delayed until these young shoots are long enough to be cut.

As the leaves contain 70 to 80 per cent. of the protein of the whole plant, their preservation is of chief importance. Even with careful management, however, a loss of 10 to 20 per cent. of the leaves will take place. The Kansas Experimental Station cut lucerne in three stages, *i.e.*, when about 10 per cent. in bloom, 50 per cent. in bloom, and in full bloom. That cut when 10 per cent. in bloom was found to be richer in ash, protein, and fat, than that produced by later cuttings, while the crude fibre and the *N*— free extract increase in percentage as the plant matures. Harcourt, at the Ontario Agricultural College, says : " A much larger amount of digestible matter was obtained by cutting when the plants were about one-third in bloom than by cutting two weeks earlier or two weeks later." Mowing, then, at the time recommended gives the most nutritious and least fibrous hay.

After cutting it should be allowed to lie until the leaves wilt, but should then be raked into windrows before they become dry and brittle, and later cocked. In hot weather, cutting in the morning should be avoided—it should be cut in the afternoon, raked and cocked the following morning. Before stacking, the hay should be sufficiently dry to prevent over-heating in the stack. It may be taken as fit for stacking if no moisture exudes when a wisp is rolled and twisted sharply into a rope. The hay should be stacked on boards or stones, and if not stacked in barns should be covered with straw to facilitate the shedding of rain.

If harvested in the right condition and properly cured the hay should have a bright green colour and a pleasant aroma.

YIELDS.—The number of cuttings will vary according to the available moisture, length of growing season, productivity of the soil, and the variety grown. In South Africa, under irrigation, 4 to 9 cuttings, giving in all 3 to 6 tons of hay per acre, are obtained each season, and without irrigation 2 to 5 cuttings, yielding 1 to 2 tons. The highest yields are obtained in the third and fourth seasons, but under favourable conditions good varieties will continue to yield well up to 8 and 12 years.

Generally speaking, the crop is only ploughed up when, through weeds, the stand becomes poor.

COMPOSITION AND USES.

LUCERNE AND HAY.[2-3]

Hay.	Water. %	Ash. %	Protein. %	Fibre. %	N— Free Ext. %	Fat. %
Sudan Grass ...	7.20	5·60	7·94	31·56	45·45	2·25
Lucerne	8·40	7·40	14·30	25·00	42·70	2·20
Millet	7·70	6·00	7·50	27·70	49·00	2·10
Teff	9·02	6·13	5·50	37·35	40·90	1·14

The high percentage of protein indicates the reason why lucerne is so valuable. The protein content is even higher than that found in maize grain, which is nine to ten per cent. As compared with other hay, it is to be noted that lucerne hay contains the smallest fibre content, although this will naturally vary according to the maturity when cut.

Lucerne is used principally for hay for all classes of livestock, but chiefly for dairy cattle and young growing animals. It is also extensively used as a soiling crop, and is often pastured by sheep and ostriches. Its use for pasturage is warranted only under certain circumstances, *e.g.*, stud sheep during drought, and the drier winter and early spring months. Horses, however, injure the plants so much by close grazing that they should never be allowed in the field. With ruminants, bloating is common if care is not exercised. Stock should be allowed in the fields very gradually, the usual practice being to allow them to graze in the fields for about a quarter of an hour the first day, slowly increasing the time each day until eventually they may be allowed in permanently. A young, sappy growth is most dangerous, especially when moist with dew or rain. Hungry or thirsty animals should on no account be allowed to pasture this crop.

It can be ensilaged, but as it is easily made into hay, this is not advocated, unless the weather is such that hay cannot be made.

Place in Rotations.—As the crop occupies the ground for an indefinite period, *i.e.*, so long as it is producing satisfactory yields, it does not fit well into regular rotations. It should be followed preferably by cultivated crops, *e.g.*, potatoes, and then by wheat. Experience shows that lucerne following immediately on land previously down to the same crop is not thrifty, largely due to the difficulty of getting a good seed-bed prepared.

Dry Lands.—When not grown under irrigation, lucerne may be a profitable undertaking, provided a fair rainfall is assured; that it is drilled thinly in rows, two to two and a half feet apart, to allow of cultivation; and that the soil is deep and porous, of good water-holding capacity and calcarious. Where these conditions prevail in South Africa it is surprising that so few farmers have attempted its cultivation without irrigation. On dry lands, if used for pasture, it should be pastured often and fairly closely, as under these circumstances the most economical use is made of the soil moisture.

Characteristics and Improvement.—Piper[1] says:—"Alfalfa owes its highest importance as a forage crop to a combination of characteristics, as follows:—

"(1) Its high nutritive value and palatability.
"(2) Its large total yield where successful.
"(3) Its drought resistance, due largely to its deep roots.
"(4) Its long life."

Such a combination of desirable qualities has led to a vast amount of experimental investigations with alfalfa, perhaps more in the aggregate than has been devoted to any other forage plant.

The wide diversity which exists both in wild and cultivated alfalfas has in recent years stimulated much interest in breeding to secure varieties especially adapted to certain purposes and to special localities. Among the improvements sought by various investigators along this line, the following may be enumerated:—

(1) A higher degree of leafiness combined with erect stems, so as to produce more and better hay.

(2) Better seed production, especially if combined with good hay qualities.

(3) Greater drought resistance.

(4) Greater cold resistance.

(5) Varieties that possess ability to produce seed under humid conditions, so that adapted strains may gradually be developed.

(6) Better pasture varieties, especially such as have rootstocks, so as to withstand pasturing without injury.

(7) Disease resistance.

The characters enumerated are all possessed in varying degrees by different varieties.

Since the plants cross-pollinate naturally a large proportion of lucerne plants are heterozygote. To propagate, selected plants should be enclosed in insect-proof cages to prevent cross-pollination, or increases should be made by cuttings. Either method should be used until sufficient seed has been obtained to sow in an isolated fair-sized plot, which should be situated at some distance from other fields, as crossing is usually accomplished by bees of short-tongued species, *e.g.*, *Megachile* and *Andrena*.

Cage plants must be hand-tripped.

Hybridising lucerne is a relatively easy operation,[4] and Oliver has secured some interesting hybrids, chiefly between *falcata* and *sativa*.[5]

SEED PRODUCTION.—During recent years the production of seed in the Union has increased markedly, particularly in the Cape Province, where the Oudtshoorn District has developed this feature to an important extent. South African seed is sold at a reasonable figure, and with the cleaning methods recently introduced, is of very good quality.

Unlike the South Western States, the plants set seed freely in the Union. The first growth is cut for hay and the subsequent growth allowed to mature seed—400 to 800 pounds per acre is considered a good yield of seed. For seed production a thinner sowing is necessary, and less water should be given.

PESTS AND DISEASES.—Lucerne is, relatively speaking, very free of those causing much damage.

Lucerne Caterpillar (*Colias electra*).—This is a yellow butterfly which, in the larval stage, a smooth green caterpillar, may do considerable damage. If badly threatened, the crop should immediately be cut as short as possible. If under irrigation, flooding is likely to produce disease among the larvæ.

Lucerne Leaf Weevil (*Phytonomous posticus*).—Has caused tremendous damage in the Western States, but so far has not been responsible for any loss in the Union. Cutting as soon as they appear, followed by frequent harrowing, may keep them under control. Close pasturing may also be of assistance.

Eel-Worm (*Tylenchus spp.*).—On low-lying damp ground these worms may prove a serious pest. They are detected by a yellowing of the leaves, stunted growth, and a browning of the tap-root immediately below the crown. A change of crop must be resorted to.

Root-rot (*Ozonium omnivorum*).—Appears on the roots as orange-coloured threads, the diseased plant nearly always dying. The fungus spreads to surrounding plants, and eventually a circle of dead plants will be observed. It does not attack monocotyledons; they should, therefore, be grown in rotations.

The remaining fungous and bacterial diseases, *e.g.*, Leaf-spot (*Pseudopeziza medicaginis*), *Urophlyctis alfalfæ*, etc., while very common, are not of much known economic importance in South Africa.

REFERENCES:

[1] "Forage Plants and Their Culture."—Piper.
[2] Oklahoma Bulletin 103.
[3] Ingle's "Agricultural Chemistry."
[4] "New Methods of Plant Breeding."—U.S.D.A. Bureau of Plant Industry, 167.
[5] "New Alfalfa Varieties for Pasture."—U.S.D.A., Bureau of Plant Industry, 258.

CHAPTER X.

COWPEAS, SOY BEANS AND PEANUTS

COWPEAS, OR KAFFIR BEANS.

The cowpea has been cultivated in Asia and Africa as a food for human beings for a great many centuries. It is really a bean and not a pea. Its natural habitat is Central Africa, and although the kaffir bean (cowpea) has been cultivated in South Africa for a long period the introduction of the better known varieties from America is recent, as is the general use of the cowpea on a large scale. It is the chief legume in the Union which lends itself to rotations with maize as the main crop. The importance of this plant as a forage crop and as a crop to increase the protein content of maize silage is becoming more generally recognised, particualrly in the maize-growing areas.

DESCRIPTION AND CLASSIFICATION.—The cowpea is an annual summer legume of indeterminate growth adapted to very much the same climatic conditions as maize. It is very readily injured by frost, withstands shade to a greater extent than most crops, and will thrive on a wide range of soils, giving a good growth even on fairly acid soils.

There are three cultivated species :—[1]

(1) The Catjang (*Vigna catjang*); (2) the Asparagus bean (*V. sesquipedalis*) and (3) the cowpea (*V. sinensis*). The catjang has small erect pods, with little sub-cylindric seeds, and, like the asparagus bean, is of small economic importance. The asparagus bean has very long inflated pods which on ripening collapse about the kidney-shaped seeds. The cowpea possesses hanging thick-walled pods which preserve their form and contain various shaped seeds. The plant may be bushy, erect or prostrate; maturity varies with the varieties, from seventy to one hundred and twenty days. The seeds are kidney-shaped, or crowder (angular), and the colour of the pods may be creamy, purple or purple streaked, while the seeds may be black, brown,

buff, purple, maroon, pink or white, marbled and speckled. In all cowpeas the embryo is yellowish.

Harvey and Saunders[2] state that the catjang was commonly cultivated for its pods in Cape Colony in 1894. A number of species are found wild in South Africa, some of which when properly exploited may prove of agricultural value.

The varieties most commonly known in South Africa are :—

Kaffir Beans.—As commonly grown and sold, these are a mixture of numerous types. Maturity varies, and generally prostrate forms predominate, though bushy types are also found. These have been grown for many years by the natives, who look upon them as "crop medicine." It is a native custom to grow this crop with their sorghums and millets, and naturally in this practice they have noticed the advantage to the soil. The seed is produced in large quantities in the native territories and is generally cheap.

Erect or Bushy Types.—*Whippoorwill* has subreniform seeds, buff marbled with brown in colour. It is early, taking three and a half months to mature seed, and is a good forage variety.

New Era.—The seeds are small, rhomboidal, buff, dotted with minute blue specks. A very early variety.

Iron possesses buff seeds, rhomboidal, very angular and hard. This variety is resistant to cowpea wilt and root-knot diseases. It matures about the same time as whippoorwill.

Prostrate or Trailing: Wonder or Clay or Unknown.—Has buff coloured seeds, is late, of very heavy growth, and excellent, therefore, for green manure.

In a variety trial at Potchefstroom the following results were obtained :—

Variety.	Maturity in days.	Green fodder per acre.	Seed per acre in pounds.
Iron	101	29,200	520
Whippoorwill ...	101	26,000	440
Black	101	24,000	1,240
Wonderful	101	20,200	1,600
Red Ripper	93	17,600	680
New Era	89	17,200	815

Soil.—The cowpea does well on a wide range of soils, provided they are well drained, but prefers a loam. It is used as a soil renovating crop, and fortunately does surprisingly well on comparatively impoverished soils. The ground should be well prepared.

PLANTING.—The rate of seeding depends largely on the variety grown, whether large or small seeded, and whether grown for seed, hay or green manure. Smaller quantities are used when the seed is drilled and when the crop is to be used for forage and green-manuring; larger quantities when broadcasted and when the crop is to be harvested for seed. Thick seeding hastens maturity.

Sowing must be regulated by the average dates of the occurrence of the last and first frosts. If grown for green-manuring or forage, at least ninety days must be allowed before the first frost. For green-manuring, as the crop is best ploughed under when most succulent and when the soil is still moist, it should be planted in December or early in January so as to be ready for ploughing down in March with the late rains. Frost causes the leaves to drop off very readily, and for forage the crop must be cut, therefore, before being injured in this way. The seed should not be sown until all danger of late frosts is over.

Planting is usually done with an ordinary maize planter fitted with $\frac{3}{8}$ inch plates. The seed should be planted about 2 inches in depth, 6 to 9 inches apart in the rows, and the amount used should be about 15 pounds per acre.

For seed it should be sown in rows 2 to 3 feet apart during November to January; for forage and green-manuring it may be broadcasted or planted in drills 18 inches to 2 feet apart. The erect types may be planted closer than the trailing varieties.

Some of the very late varieties will not mature seed on the highveld no matter how early they are planted.

When sown between the rows of maize, the seed should be planted when the maize is about 2 to 3 feet in height, *i.e.*, a little before the time when the last ordinary cultivation of maize would take place, in this case the last cultivation. This practice, though, is not recommended in areas of small rainfall.

When used between the rows of maize, the latter should be planted in rows 4 to 6 feet apart, and the cowpeas drilled in between these rows, usually about a month to six weeks after the maize has germinated. The seed is sometimes mixed with the maize seed or with the fertiliser and sown with the maize in the same rows. In this way the viney types are supported by the maize. Some growers follow the practice of broadcasting the seed between the rows and covering the seed with the ordinary cultivator. Where moisture is limited, though, the best method seems to be in planting the maize wide apart and drilling the cowpeas in between the maize rows.

After the plants are up, cultivation between the rows should be given, and continued until the plants begin to throw out vines.

HARVESTING.—If used for forage, the crop is cut when the first pods are well formed. In some cases (the erect varieties) the crop may be cut with a mower; if viney, hand-cutting is necessary. Curing the hay is rather difficult on account of the thickness and succulency of the stems. When wilted, it should be cocked, and if necessary the cocks may have to be opened again, but as soon as it has cured thoroughly the hay is stacked.

If the forage is to be used for enriching maize silage, the best practice is to have a separate wagon carrying the freshly cut cowpeas. Small quantities are thrown from this on the cutter as the maize is being cut up. This ensures better distribution of the cowpeas in the silage, as it is a somewhat difficult crop to ensilage alone.

When harvesting for seed the difficulty lies in deciding when to harvest, since the plant is of indeterminate growth; usually the best time is about a fortnight after the first pods ripen. In South Africa the pods are usually picked by hand, and, if so, the field should be gone over two to three times in order to obtain the late maturing pods at the correct maturity. However, if the whole plant is harvested by means of bean harvesters, this must be done when the majority of the pods are mature and before much loss from the early ripening pods occurs. Care must be taken in drying, as overheating quickly spoils the beans.

Threshing with the ordinary grain thresher is possible, although a large percentage of seed is usually cracked. This may be obviated to a certain extent by lowering the number of revolutions per minute and removing the teeth of the concave. Until more specialised machinery is introduced, tramping out the seed with animals or beating with flails is likely to be preferred in this country to utilising the ordinary threshing machines.

If the crop is to be used as a green manure it will be found advisable to cut the vines by means of sharp and weighted disc harrows, so as to enable easier ploughing under. Disc ploughs are often used for turning in the crop. The aftermath will often give sufficient growth for a good green-manuring crop if the hay is cut early.

MIXTURES.—For hay, Sudan grass and cowpeas promise to be an excellent mixture. The former give support to the latter, the Sudan grass matures late enough to ensure good growth of the cowpeas, and the hay is cured more easily than if the latter were sown alone. Millets are usually too early for this purpose.

USES.—The seed is used for human consumption, and when ground may be used as a concentrate for feeding to stock.

The plants are grown for forage and silage, but chiefly as a green-manuring crop.

IMPROVEMENT.—Piper[3] is of opinion that improvement should be directed along the following lines :—

"(1) Size and vigour.
(2) Habit, especially erectness and height.
(3) Prolificness.
(4) Disease resistance.
(5) Weevil resistance in seed.
(6) Ability to retain leaves late in the season.
(7) Time of maturity or life period.
(8) Evenness of maturity.

"The ideal forage cowpea would seem to be one that is tall, vigorous, bushy in habit, leafy, the leaves persisting late; prolific, the pods well filled and held well above the ground, the seeds hard and therefore rather small, and immune from or resistant to serious diseases. (On the highveld earlier maturing varieties are wanted.) For planting in maize, a strong vining habit is an additional desideratum. Fortunately some varieties are half bushy when planted alone, but sufficiently vining where a support is available.

"Where cowpeas are to be used as a human food or to be pastured by hogs, the yield of pods and seeds is most important, the erectness of the plant being of secondary consideration."

In South Africa much remains to be done in separating the varieties of kaffir-beans and in exploiting the untried indigenous species.

As smothering crops, cowpeas and buckwheat are among the most effective. The cowpea will choke out all low growing weeds, but is not successful against tall growing ones like Khaki-Bos (*Tagetes minuta*).

COMPOSITION AND FEEDING VALUE.[3]

	Nutritive ratio.
Cowpea silage	1 :7·2
Cowpea hay	1 :7·2
Cowpea grain	1 :3·4

Cowpeas make excellent feed for all live stock. The hay is said to equal wheat bran for producing milk.

ROTATIONS.—Being a quick growing summer crop, it is well adapted as a green-manuring for forage crop with cereals as a winter crop. If used in this way it should be ploughed down as early as possible to ensure fairly complete decomposition and to prevent too open a condition of the soil for the cereals. The following results were obtained for wheat at Potchefstroom Experimental Farm, viz. :—

	1916.	1917.	1918
Cowpeas cut for forage, followed by wheat ...	1,400 lbs.	1,380 lbs.	1,240 lbs.
Maize followed by wheat	800 lbs.	520 lbs.	540 lbs.

In the above experiment, even after the above-ground parts of the plant were removed, the residual effect of cowpeas on winter cereals was clearly shown.

DISEASES AND PESTS.

Cowpea Wilt (*Fusarium spp.*).—These organisms attack the roots. Wilt resistant varieties, *e.g.*, Iron, should be used, or a change of crop is advised.

Root-Knot.—This is caused by a nematode (*Heterodera radicicola*). The iron variety is said to be immune, and, if unobtainable, a wide rotation should be adopted.

Weevils (*Pachymerus chinensis and quadrimaculatus*).—These lay their eggs on the pods in the field or on the seed in storage. As the life cycle is only 18 to 30 days, the damage increases with storage unless steps are taken to ensure their destruction. If the seed is placed in containers, *e.g.*, galvanised bins or tanks, they may be fumigated with carbon-bisulphide, care being taken to aerate the seed soon afterwards, otherwise its vitality may be impaired.

The Bean Fly (*Agromyzia phaseolii*) may be serious, particularly in late plantings. Eggs are laid on the stem near the surface of the ground, and on hatching the larvæ invade the tissue and eventually pupate in the stem, causing the plant to die prematurely, or to be stunted. Early planting is advocated.

REFERENCES:

[1] "Agricultural Values of Cowpeas and Their Immediately Related Species."—Piper.
[2] "Flora Capensis."—Harvey and Saunders.
[3] Ohio Bulletin No. 237.

SOY BEANS (*Soja max*).

The soy bean in South Africa is not as important a crop as the cowpea. It seems adapted to a more intensive phase of farming than prevails in this country. Most varieties shed their seeds a few days after maturity and the leaves fall very early. Chiefly for these reasons cowpeas are usually grown in the Union instead of soy beans.

History.—It has been cultivated for many centuries in the East, particularly in Manchuria, China and Japan, where it is grown largely as human food and for the oil extracted from the seed. A large quantity of the seed is exported from Manchuria to Europe and America, where it is crushed, the bean cake being used as a feeding concentrate and the oil for industrial purposes, generally in the manufacture of explosives. In America it is grown principally as a green-manuring crop, for fodder and for the grain. A number of varieties were imported into the Orange Free State as early as 1901, grown on the experimental farms and then distributed among the farmers. The difficulty of harvesting the seed, because of its tendency to shatter when mature, has no doubt retarded its popularity.

Description.—It is one of the most productive as regards seed of any legume adapted to temperate climates. The flowers are small, white or purple, borne on short axillary racemes. The pods are short, 1 to 3 inches long, usually compressed, and bear two to four seeds each. The number of pods per plant varies from thirty to four hundred. They may be grey, tawny or black, and always very pubescent. The colour of the seed, which in shape is globose to elliptical, may be yellow, green, brown or black. The embryo may be yellow or green. It is a summer annual, determinate in growth, *i.e.*, the whole plant reaches maturity as the pods ripen, and no further growth takes place. The whole plant is somewhat hairy, the stems upright, well defined, somewhat woody and from 6 inches to 6 feet in height. The leaves turn yellow as the pods mature, and have all fallen by the time the pods have ripened.

Since the uses of the soy bean and cowpea are agronomically much the same in South Africa, the following comparison may be of value in differentiating between them :—

Soy beans are determinate in growth, while cowpeas are indeterminate; the former will stand slight frosts, the latter cannot. Soy beans are said to be more drought resistant than cowpeas. Soy bean seed has a nutritive ratio of nearly 1 :2, cowpea seed 1 :3·4. Soy beans have a fat content of 14·6 per cent., as compared with 1 per cent. in the cowpeas. With few exceptions they show no tendency to vine, while all cowpeas are viney to a greater or less degree. Soy beans are heavier seed yielders. Unlike that of the cowpea, its seed is immune to the attacks of weevil.

VARIETIES.—All the known varieties belong to one species, *Soja max.* Those grown in South Africa have all been imported in comparatively recent years. The best known are :—Mammoth, Ito San, Hollybrook and Green.

Ito San.—Early, erect, purple flowers, seeds yellow with a brown spot round the hilum, slender stems, good for hay, matures in about 100 days.

Mammoth.—Tall, late variety, bushy, white flowers, grey pubescence and yellow seeds. Too late for the highveld.

Hollybrook.—Fifteen to twenty days earlier than Mammoth, seeds yellow, pubescence grey, plants not so tall as Mammoth.

Green.—Medium early, pods burst and shatter seeds very early, seeds green, ellipsoidal, plants comparatively short.

CULTURAL METHODS.—Like cowpeas, about twenty to sixty pounds are required, the amount depending on the variety and whether drilled or broadcasted. The smaller varieties like Ito San should be drilled 24 inches apart, while the large, vigorous growing varieties like Mammoth should be planted 36 inches apart. They should not be planted deeper than 1 to 2 inches. Their growth during cool weather is very tardy, consequently while they can be sown earlier than cowpeas, being more frost resistant, there is very little advantage in doing so.

When cut for fodder they should be reaped when the pods are quite green, but well formed. For this purpose they must be harvested early, as the stems become very woody and the protein decreases as maturity advances. The yield of hay varies from 1 to 4 tons. Harvesting is easier than in the case of cowpeas, because the plants do not intertwine.

Judgment is required in harvesting for seed on account of the shattering habit of most varieties when fully mature. For this reason the crop when harvested for seed should be moved as little as possible. Since most of the leaves have fallen by the time the seeds are matured, very little preliminary drying is necessary before stacking.

They are threshed by adjusting the ordinary grain thresher, by stock tramping, or by the use of the flail.

Yields of 15 to 30 bushels (4 to 8 bags) per acre are considered good.

COMPOSITION: SHOWING PERCENTAGE OF DIGESTIBLE NUTRIENTS.

Name of Feed.	Percentage Dry Matter.	Protein.	Carbo-hydrates.	Fat.
Soybeans (grain) ..	88·3	29·1	23·3	14·6
Cowpeas (grain) ..	85·4	16·8	54·9	1·1
Maize (grain)	89·4	7·8	66·8	4·3
Wheat (bran)	88·1	11·9	42·0	2·5
Soybean (hay) ..	88·2	10·6	40·9	1·2
Cowpea (hay)	89·5	9·2	39·3	1·3
Lucerne (hay)	91·9	10·5	40·5	·9

GENERAL.—While used for much the same purposes in rotations as cowpeas, soy beans should be considered more from their value as seed, while cowpeas, being relatively smaller yielders of seed, are of greater importance from a point of view of hay and green-manuring. Soy beans are, however, more resistant to frost and drought and will furnish good crops even on thin acid soils.

In South Africa failures are often reported on land on which soy beans have not been previously grown, and while this is no doubt frequently due to imported seed which has remained on seedsmen's hands for a number of years and is consequently of low vitality, it is not unlikely that these failures may be due to an absence of soy bean nodular bacteria. Should the latter be the case, a small quantity of soil, on which soy beans have grown well, might be broadcasted and harrowed in at the time of seeding.

The high prices obtained for soy bean seed will attract greater attention in South Africa as farming becomes more intensive. Only yellow seeded varieties are shipped from Manchuria to Europe, and as European buyers are accustomed to purchasing these, it will probably pay to grow varieties with yellow seeds.

In storage the seed is apt to overheat, but this can be easily obviated by providing good ventilation.

USES.—The crop may be grown for hay, silage, green-manuring or for seed. The seed may be used for human consumption. Soy bean cake, the residue after the extraction of the oil, is one of the most valuable and nitrogenous of concentrates. The oil is used for a variety of purposes, *e.g.*, manufacture of high explosives, linoleum, salad oil, margarine, india-rubber substitutes, soap, and a great many other commodities.

IMPROVEMENT.—The chief direction of investigation should be focussed on obtaining varieties of early maturity which retain their leaves and do not shatter the seed.

DISEASES AND PESTS.—The soy bean is, comparatively speaking, little troubled with these. The seeds are rarely attacked by weevils. A fly, *Agromyzia sp.*, is known to cause damage to the growing plant, but is seldom serious. Root-knot, caused by a nematode (*Heterodera radicicola*), may cause considerable damage, and a wilt disease due to a *Fusarium* is at times also troublesome.

REFERENCES:

[1] Purdue University Bulletin, 172.
[2] "The Soy Bean: History, Varieties and Field Studies."—U.S.A. Department of Agriculture, Bureau Plant Industry.—Piper and Morse.

THE PEANUT, GROUNDNUT, OR MONKEY-NUT.

The peanut (*Arachis hypogæa*) is an annual legume which is being increasingly grown in all parts of the world suitable for its cultivation. Its chief value lies in the high nutritive value of the whole plant, and in the quantity of excellent oil contained in the seed.

De Candolle[1] believed it to be a native of Brazil and that it was carried from there by slave ships to Guinea, whence it is supposed to have spread over Africa to Asia, Europe and America. It has been an important crop in the Southern States for a great many years. In South Africa it had not been cultivated by Europeans to any extent until recent years, although it has been grown by the natives for a considerable period.

The United States of America plant nearly two million acres per annum of this crop, while India and West Africa each export nearly £5,000,000 worth of nuts annually. In the Union in 1911 1,384 acres were planted to peanuts, and in 1917 6,557 acres, an increase which has not diminished during the last few years. The average yield in the Union is about 1,000 pounds per acre. The Transvaal produces nearly three times as much as the rest of the Union. It is a crop fast becoming an important one in the lowveld of the Transvaal and Natal, particularly in the Zoutpansberg, Waterberg and Barberton districts, where climate, soil and labour conditions are favourable. It can also be grown successfully in parts of the middleveld, *e.g.*, Western Transvaal and Western Free State.

Prices paid during the Great War have given a decided impetus to the industry. At present local factories are being supplied with nuts grown locally, but the greater part is imported from Mozambique.

It is a crop likely to play a more important role than hitherto in South African agriculture, since large areas of land well suited to its cultivation, in parts where labour is cheap and easily procurable, can still be obtained at relatively low prices.

Being a legume, its value to the soil should not be overlooked.

Description.—It is a summer annual somewhat resembling some of the clovers in appearance, except that instead of being tri-foliate, it has four leaflets. In the running varieties the plant is decumbent, and in the bushy types fairly erect. The flowers are yellow and sessile. After the ovules are fertilised the peduncle elongates, bends downwards carrying the sharp pointed ovary below the surface of the ground, where it matures. If the ovary is unable to penetrate the soil, as is often found on soils liable to form crusts, it withers and naturally fails to mature.

The pod is large, oblong, reticulated and indehiscent, having one to several ovate seeds. The shell is the pericarp, and the thin reddish membrance surrounding each seed is the testa.

Types.

(1) Large-podded—
  " Bush " or " bunch," *e.g.*, Virginia Bunch.
  " Running," *e.g.*, Virginia Runner.

(2) Small-podded—
  " Bush " or " bunch," *e.g.*, Spanish.
  " Running," *e.g.*, North Carolina and African.

Virginia Bunch is the variety most commonly grown in the Union. The Kaffir has brittle peduncles, consequently nuts have a tendency to remain in the ground. Spanish is nearly a month earlier than the other varieties.

Composition of Peanuts and Other Products (Montgomery):

	Percentage. Protein.	Percentage. Carbos.	Percentage. Fats.
Peanut hay	10·12	42·46	2· 4
Peanut whole plant .	13·18	36·40	15·21
Peanut kernels ...	24·26	16·18	42·50
Maize meal	9·10	66·68	4· 5

Seed from the following varieties grown in South Africa showed an oil content of moisture-free peas as given below :—

Spanish Bunch	50·05	per cent.
Tennessee Red	49·27	,,
North Carolina	49·96	,,

Improvement.—Very little breeding work has been done with the peanut. Selection of high-yielding plants with tough peduncles will improve most varieties.

Climatic and Soil Requirements.—It is essentially a tropical and sub-tropical summer annual legume, and is therefore very susceptible to frost. It requires a comparatively long growing season varying in the time needed to reach maturity from $3\frac{1}{2}$ to 5 months. It does well in areas suitable for citrus, tobacco and cotton. Although moderately drought-resistant, it requires a fair rainfall, with plenty of warm, bright weather. While it is limited to a great extent by the seasonal distribution of rain, the peanut is not likely to be a profitable crop in those areas in South Africa with a high evaporation and a precipitation less than 22 inches per annum.

The crop will grow on any good agricultural soil, but it succeeds best on open, sandy loams, because the highest market quality, *i.e.*, bright shells, is obtained on these. Moreover, these soils are more easily kept in a loose, friable condition necessary for "pegging," and lifting the crop is less laborious. The crop is, however, often profitably grown on heavier types of soil, *e.g.*, on the Springbok Flats. The surfaces of heavy red soils are more difficult to keep friable and frequently stain the pods.

Peanuts thrive best on calcareous soils, but will also give good yields on those of a somewhat acid character.

Soil Preparation.—The seed-bed should be deep and well pulverised. As peanuts cannot be closely cultivated after flowering, they should be planted only on lands free from weeds, and in rotations they should, therefore, follow such crops as maize, potatoes and cotton. It is better to use kraal manure on the preceding crops, as too much nitrogen retards the formation of nuts. Phosphatic manures such as bonedust or superphosphate, at the rate of 150 to 250 pounds per acre, may be used to advantage on South African soils, and should be applied at the time of planting.

Planting.—Erect varieties like Spanish should be planted in rows 30 inches apart, while in the spreading varieties the rows should be 36 inches apart. The seed should be planted 6 to 12 inches in the row, depending on the fertility of the soil, the variety, moisture limitations and so forth. Whole or shelled seed may be planted to a depth of 1 to 3 inches; the general practice is to use shelled seed, as it is more economical and gives a more uniform germination and stand. During dry weather pods decompose very slowly, consequently germination is often delayed and irregular. About two bushels of pods or thirty to forty pounds of shelled seed are required per acre. Care should be exercised in shelling the nuts for seed, since the vitality is easily impaired when the seed coat is damaged. A seed drill, planting one row at a time, called the "Planters' Friend," is in most common use. A large portion of the crop at present is planted by hand, and the maize planter with special plates is also employed.

November seems to be the best month for planting, but in some localities where the growing season is a long one, planting may be continued until the end of January.

Cultivation.—The crop should not be harrowed as in the case of young maize. The ordinary maize cultivators should be used, and as the season advances and the plants commence to flower, cultivation should be so arranged that the soil is banked up against the plants. Broad tooth cultivators will be found best for banking, although a number of farmers employ a double mouldboard plough for this purpose. Once pegging has commenced, cultivation must be restricted to the centre of the space between the rows, and the plants must not be disturbed.

Harvesting.—It is a somewhat difficult crop to harvest, and for this reason is largely restricted to areas having plenty of cheap labour. The plants should be lifted just before the pods about the base of the plant become detached. At this stage the leaves assume a yellowish colour, and the majority of the nuts will have reached maturity. As the leaves are very nutritious and make very good hay, the crop should be harvested before the leaves are lost by frost.

In the Transvaal lifting is done mostly by hand. A better method is found in barring the rows, *i.e.*, throwing a furrow away from each side of the plants, so that they remain on a narrow ridge and can be more easily lifted by hand, or by a special implement somewhat like a potato digger, which unearths them. The peanut plough cuts the taproot of the plant well below the crop of nuts, and in varieties like Virginia Bunch, in which the peduncles are tough, the whole plant is thrown out with the nuts adhering. Another method is to remove the mouldboard from a turn-plough and run the share under the row on each side at depth so regulated as not to sever the pods from the branches, the side from which the mouldboard has been removed being kept next to the row. The plants are then stacked on poles, the nuts inside and off the ground, until dry, or simply cocked. They are then stacked, hand picked when thoroughly dried, and bagged. The remainder of the plants is then stacked for feed.

If left in the ground too long, particularly during wet weather, the seed in the pods is apt to germinate.

Harvesting conditions in South Africa are usually very advantageous, since the crop is lifted after the rainy season is over.

Yields.—A bag contains 70 lbs. of pea-nuts and fifteen bags to the acre is considered a fair yield in the Transvaal, although yields up to twenty-five bags are not uncommon.

At the Experimental Farm, Potchefstroom, the following yields were obtained :—

Variety.	Yield of Nuts per acre in pounds.
Virginia Bunch	1,500
Tennessee Red	1,400
South African variety	1,360
Spanish	1,160

Uses.—As a fodder, the stems and leaves are highly nutritious and readily eaten by stock even when very dry. In the Southern States of America pigs are often fattened by pasturing off the crops and allowing them to root out the nuts.

The chief use is made of the seeds and their products as human food. They are eaten, roasted, used in confectionery;

the extracted oil is employed as a salad oil, and the crushed cake is a valuable concentrate for dairy cows. Peanut butter, made from the ground peas, or nuts with or without the addition of oil, is a palatable and nutritious article of human food and is rapidly growing in popularity.

PESTS.—Leafspot (*Cercospora personata*) may be troublesome during very wet spells, but is seldom serious. It causes the wilting of the plant and premature ripening of the crop.

The crop has few insect pests. The cutworm sometimes does some harm. The nuts are also subject to attack from weevils if kept too long, and a certain root aphis occasionally attacks the plant.

REFERENCE:

[1] De Condolle.—" Origin of Cultivated Plants."

CHAPTER XI.

COTTON

Introductory.—Records seem to show that cotton was first used in India, whence its use spread to China. The Chinese cultivated cotton extensively during the 6th century. It is known to have existed in Egypt at a very early date, but apparently its cultivation was not general there until comparatively recent times. During the 10th and 11th centuries the Moors introduced cotton into the European countries of the Mediterranean. With regard to the Americas, Burkett[1] states that Cortez sent Charles V. exquisite cotton fabrics dyed in various colours, and he quotes Handy as follows: "Everywhere between the parallels 40° north latitude and 40° south latitude, with the exception of our present American 'Cotton Belt,' cotton, either in its wild or cultivated state, was known and used at the date of the settlement of America."

Cotton growing was started in South Africa as early as 1846 by Dr. Adams, of the American Mission. At Amanzimtoti, Natal, it gave good results, neighbouring farmers were impressed with the experiment, and four years later 6½ tons of lint were exported. However, on account of the economic difficulties of the times, the cultivation was discontinued. At a later date the American Civil War cut off the principal source of cotton, consequently the high prices offered for the small quantity available from other sources stimulated its cultivation in other parts of the world, and in 1863 Natal produced 3,414 pounds of lint. By 1883 cotton growing in South Africa had again practically ceased. In 1907 its cultivation was revived, and since then the acreage devoted to cotton in South Africa has increased markedly.

Cotton is the most important of all fibre crops, and provides the major part of our clothing. Silk, flax, and even wool are being rapidly superseded by cotton. The crop is easily grown, the cloth readily manufactured and the finished product is cheap; moreover, the industry furnishes a great many useful by-products. Of no small account is the fact that its imperishable nature renders it proof against depreciation in storage.

PRODUCTION.—The demand has been increasing rapidly during recent years, and this has stimulated production. The reasons for this increase are :—

(1) Of the clothing actually worn to-day, nine-tenths of the raw material is estimated to be cotton. The spread of civilisation has had as a concomitant the use of better clothing, so that to-day many races originally partially clothed are clothed; in consequence, there is an increased demand for more and for better clothing.

(2) Cotton has lately been shown to be a successful substitute for other raw materials, with the result that articles previously made of linen or silk are now made from cotton.

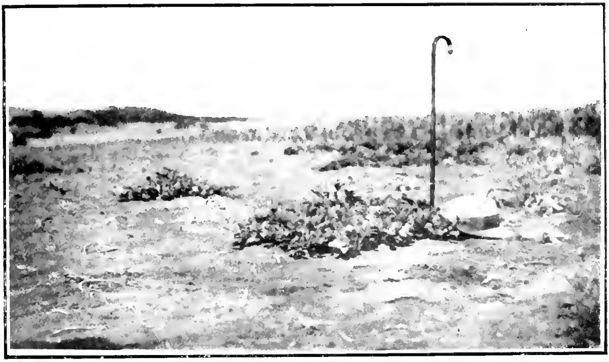
(3) New uses are being discovered daily, *e.g.*, webbing for motor car tyres, yacht sails, etc.

(4) Lastly, there has been an extraordinary improvement in the quality of cotton fabrics. At one time " cotton " was a term of contempt applied to cheap and obviously inferior goods, whereas to-day some of the finest materials are made from cotton, and their value is well recognised.

The production of cotton is confined to warm countries having an average frostless season of 200 days or more. At present 97 per cent. of the world's cotton is produced in the Northern Hemisphere, and 95 per cent. is grown south of the 37th parallel of latitude. Since 1830 the production of cotton has centred in the southern part of North America, where to-day 60 to 65 per cent. of the total crop of the world is produced.

The world's crop for 1916-17 was obtained as follows :—

North America	12,500,000 bales.
India	4,500,000 ,,
Egypt	1,200,000 ,,
Russia	1,500,000 ,,
China	2,000,000 ,,
Other countries	1,200,000 ,,



PEANUT PLANT, RUNNER TYPE.

PEANUT PLANTS OF ERECT TYPE (NEXT STICK).

PICKING COTTON, RUSTENBURG EXP. STATION. (COURTESY J. DU P. OOSTHUIZEN, ESQ.)

TOBACCO SEED-BEDS BRITISH SOUTH AFRICA COMPANY'S MARANDELLAS ESTATE. (COURTESY H. W. TAYLOR ESQ.)

FIELD OF TURKISH TOBACCO—RHODESIA RANCHING CO., DARWENDALE.
(COURTESY H. W. TAYLOR, ESQ.).

JOINER TOBACCO SHEWING THE INFLORESCENCES OF SELECTED PLANTS COVERED WITH MANILLA BAGS, RUSTENBURG EXP. STATION.
(COURTESY J. DU P. OOSTHUIZEN).

PLATE XVI

CONVEYING VIRGINIA TOBACCO (WHOLE PLANT METHOD) FROM THE FIELD—RUSTENBURG EXPERIMENTAL STATION. (COURTESY OF J. DU P. OOSTHUIZEN, ESQ.).

TURKISH TOBACCO ON CURING RACKS—"GREAT B" FARM, MAYOR DIST., RHODESIA.
(COURTESY H. W. TAYLOR, ESQ.).

The North American crop is rapidly decreasing, owing largely to the ravages of the Mexican Boll Weevil; moreover, the local consumption in America is increasing, and consequently the over-plus absorbed by Lancashire is decreasing. It is safe to conclude, therefore, that the development of cotton growing in some of the other countries is likely to assume an important aspect in the near future. Among these countries the Union is likely to play no mean role; firstly, because of the relative cheapness of land in suitable areas; secondly, labour is plentiful in the cotton districts; thirdly, the harvesting season, being a dry one, is very advantageous, and, lastly, there are close on 2,000,000 acres of land on which cotton should be a profitable crop.

South African Production.—While the Union's production is low at present—in 1919 only 2,838 bales of 500 pounds each were produced—it should not be taken as an index of the country's potentialities. The production has remained low hitherto for the following reasons :—

(1) Impure seed has been used, giving a staple lacking in uniformity, and consequently in no demand.

(2) Farmers, generally conservative, have been slow in gaining experience of cotton growing, and in organising the industry.

(3) Large tracts of suitable areas have been poorly served by railways, and some parts have been unduly classed as too malarious for European occupation.

(4) Grading has been neglected.

The handicaps mentioned are now being overcome, and competent judges hold that cotton production in the near future will rival that of maize in importance.

At present the census returns given for the various districts should not be regarded as the relative possibilities of the respective districts, but should be looked upon as the amount of experimental evidence at present available as to the suitability of the particular districts for cotton growing. Physical conditions are suitable for cotton in the greater part of the lowveld of the Transvaal, Swaziland, Zululand and Natal.

Classification of Cotton Produced in Various Countries.[2]—The cotton produced in the various countries may be broadly classified according to quality and spinning capabilities as follows :—

1. The best cotton of all is the true Sea Island, grown on the islands (hence the name) off Charleston, South Carolina, and also in the West Indies. The total quantity of these crops is very small, but their value is very high on account of their marvellous spinning qualities. The use of the fine yarns made from this cotton is confined to the very highest grades of fabrics and the finest sewing cottons.

2. Next to these come certain grades of Sea Island grown in Georgia and Florida, which are of excellent quality, though not so superfine as the real "Islands." In this class must be included the best Egyptian grades, which are second only to the finest Sea Islands in quality and spinning capabilities. They are also extraordinarily strong, which has given them certain special uses of their own where strength and fineness are essential.

3. In the next grade may be placed the ordinary varieties of Egyptian cotton and the best varieties of American long staple Upland cotton, which for many purposes have proved themselves as good as ordinary Brown Egyptian. Peruvian, as well as some of the best African cottons, comes very close to this class.

4. The great bulk of the world's cotton supply, however, consists of the ordinary American Upland crop. Of about the same quality is the cotton from Brazil, West Africa, Russia, Asia Minor and some Indian cotton. Some Chinese cotton may also be included in this grade.

5. The greater part of the Indian crop is in a grade by itself, of a very short, staple and of inferior quality. It is little used in Lancashire, but is largely employed in the local mills in India, Japan and also in most of the Continental spinning countries. Similar to the Indian crop in quality are certain of the native varieties of Russian cotton. Finally, the great unknown of the cotton trade—the Chinese crop—is probably on the whole of Indian quality.

Description and Varieties.—Cotton belongs to the Malvaceae and to the genus Gossypium. The classification of the cottons into species has led to a great deal of controversy. However, the varieties with which South Africa is at present concerned are the Upland varieties (*G. hirsutum*) and the Egyptian and Sea Island types (*G. barbadense*). Broadly, the chief differences between these two species is that *barbadense* is taller, of more slender growth, with small pointed bolls, and later in maturity. The seed is usually naked, while that of *hirsutum* is generally fuzzy. The flowers of *hirsutum* are white, turning red on the second day of blooming, but yellow with a purple-red spot at the base of each petal in *barbadense*. The fibre of *hirsutum* measures from $\frac{3}{4}$ to $1\frac{1}{2}$ inches in length, while that of *barbadense* from $1\frac{1}{2}$ to 2 inches.

Under cultivation, cotton is treated as if it were a summer annual, the seed being planted annually. Annual planting may be avoided by ratooning, *i.e.*, cutting off the crop close to the ground and allowing the aftermath the next season to provide the crop. Ratooning is condemned because insect pests are favoured by the practice and, moreover, experiments have shown it to result in very much depreciated yields.

There are two sorts of branches in the cotton plant[3]: "(a) Vegetative branches or 'limbs,' and (b) fruiting branches. There are two buds at the base of each leaf. One of these is a true axillary bud, the other one extra-axillary. Vegetative branches or limbs may arise from either axillary or extra-axillary buds. Normal fruiting branches arise only from extra-axillary buds. It frequently happens that both fruiting and vegetative branches arise at one node, that is, both the extra-axillary and the true axillary buds develop. Ordinarily, however, only one bud at a node develops. The axillary buds usually develop into branches at only a few nodes on the lower part of the main stem. The accompanying extra-laterals remain dormant. On the other hand, the upper true axillary buds normally fail to develop, while each of their accompanying extra-laterals forms a fruiting branch. Hence, in most cultivated cotton varieties no fruiting branches occur on the lower part of the main stem.

"Vegetative and fruiting branches differ from each other in more ways than origin. The former makes a small angle with the stem from which they arise, while fruiting branches are more horizontal. Vegetative branches produce no flower buds, while fruiting branches bear a flower bud opposite each leaf. Vegetative branches are frequently as long as the main axis, while fruiting branches are much shorter. The basal internode of fruiting branches is usually longer than the others. The difference in length is much more pronounced in Egyptian cotton than in Upland cotton. The internodes of vegetative branches are about equal in length. Vegetative branches may form both fruiting and secondary vegetative branches, but fruiting branches seldom bear secondary fruiting branches or vegetative branches. Cottons with short-jointed fruiting branches are more productive and usually earlier than those with fewer and longer internodes."

The seeds of cotton are borne in a leathery capsule, which when mature is called a " boll." The " boll " may be subglobose, oval or ovate-acuminate. Three to four " locks " are found in Sea Island and Egyptian types and four to five in Upland kinds.

FIBRE.—There are generally two kinds of fibre on the seed—(a) long hairs, lint or commercial fibre (staple), and (b) short hairs or fuzz. The latter may be white, green or brown. Some varieties produce no fuzz, and in these the seed is naked when ginned. About one-third of seed cotton is lint.

With regard to the fibre, Balls[4] comments as follows :— " The development of the fibre begins before fertilisation is accomplished, by radial growth of a large number of the epidermal cells of the seed coat. These cells differ in no respect from their neighbours, and it seems possible that the density of the coating may be determined by the external conditions during a day or two after flowering. Possibly irregularity in length may arise from distribution of the normal simultaneous ' sprouting ' of these cells over several days.

"The young fibre at once assumes its final diameter, which is about twice that of the unaltered cell. It remains unicellular throughout its career, and is always covered by the cuticle which protected the original cell. The familiar heading which follows treatment with ammonical copper hydroxide is simply due to constriction of the swelling cellulose by the cuticular remains. For the first day the nucleus lies at the tip of the swelling, but after the third day it takes its place in the middle of the cell axis, and there remains, either slung in cytoplasmic bridles or at one side. The cytoplasm, of course, lines the whole cell wall, and appears to remain alive until the boll cracks.

" The growth of the fibre is at first confined to linear extension. In fact it seems that the boll attains almost to its full size before any secondary thickening of the fibre wall begins. By this time the fibre has reached to rather more than its final ripe length. This period embraces about half the total maturation period, being some 25 days. The final length is, of course, constitutional, and can only be deflected from this constitutional basis to a relatively slight extent. Even seeds which have not been fertilised and consist of empty, undeveloped seed-coats alone, possess hairs of nearly normal length, though abnormally weak. Mean lint-lengths is an inherited character. The final attainment of the lint cell in the matter of length is effected by intercalary growth, the form of the tip and the base being determined at an early stage. The cessation of this growth is thus the result of internal constitution, though environmental changes exercise a limited effect. Probably linear extension has ceased before thickening of the wall commences. It is this thickening which determines the strength of the individual fibre. The strength of the commercial sample depends not only on thickness, but also on uniformity of strength as between different fibres. Moreover, commercial strength does not merely result from the thickness of the cell wall, but also from the uniformity of that thickness over the whole length of the cell, and possibly is also affected by the texture of the thickening layers.

"Concentric layers of cellulose probably delimited from night to night are laid down on the interior of the delicate cellulose-cuticle wall until a certain thickness is reached. This disposition is not uniform, but results in the formation of simple pits at intervals, elongated obliquely.

"In consequence of this thickening we find that fibres devoid of secondary thickening show no twisting when extricated from the unripe boll and dried, while fibres taken from a boll which is nearly ripe exhibit rapid and uniform twisting as they dry, owing to the closure of the solid portions of the cell wall into the minute spaces formerly occupied by the pits."

Morgan states: "If the fibre is mature, examination will show it to be somewhat flattened and irregularly twisted. It is claimed that the number of twists varies from 300-500 to an inch. The amount of twist in the cotton fibre is very important in determining its spinning qualities, and hence its value. The degree of twisting is to a large extent determined by the stage of maturity of the fibre. The immature fibres, on drying, form almost flat, structureless ribbons, with very little twist. The strength of the cotton fibre varies according to its ripeness and fineness. From 2·5 to 15 grams represent its breaking strength. The cotton fibre in proportion to its size is stronger than jute or flax and is three times as strong as wool. It is surpassed in strength by the fibre of hemp, Manila hemp and silk.

"Length of lint varies with the variety and to a certain extent with soil fertility. Some strains produce lint of the same length on all parts of the seed-coat. Most kinds, however, make shorter hairs at the micropylar end, *i.e.*, the base or pointed end of the seed. This is probably due to the slower growth and later starting of the fibres on the base of the seed. In the Upland cotton there is, in addition to the fibre proper, an ' under-fleece ' (called fuzz or linters) which is very short, as a result of the failure of a number of cuticular cells to elongate.

" Commercially, cotton contains lint from bolls of various ages, and this affects length, the length of lint being correlated to a certain extent with length of boll maturation."

Cotton fibre is prevented from readily absorbing moisture by an oily covering of each fibre which is said to make up about 2 per cent. of the fibre. Absorbent cotton represents cotton from which this oily protection has been removed by treatment with chemicals. The oily covering must be removed before the yarn can be dyed.

The characters which determine quality of lint are :—

(1) Length of fibre.

(2) Uniformity in length.

(3) Strength of fibre.

(4) Colour and cleanliness of fibre.

Cotton lint should have a rich, bright, creamy colour and should be free from trash and dirt.

Kapok.—" This is a soft cotton-like down growing in the seed pods of the silk-cotton trees, *Ceiba pentendra* and *grandiflora* and *Bombox malabaricum*, native in the tropics of both hemispheres. Although abundant in many parts of the tropics, nearly all the kapok of commerce comes from the Dutch East Indies and Ceylon. The pods are collected from the wild trees and the down separated from the outer covering, and from most of the seeds, and packed for shipment. It is too short and brittle for spinning, but it is very light, fluffy and elastic, making an excellent substitute for feathers for cushions, pillows and mattresses, and it is also used in place of cork and hair in life-preservers."[10]

VARIETIES IN SOUTH AFRICA.—Although the production in the Union is at present small, a large number of varieties have been tried and a great many are still grown. The more important of these are the following :—

(a) *Improved Bancroft.*—This variety is now giving excellent results, especially in the Rustenburg area. The bolls are large and pointed; the seeds sparsely covered with white fuzz, often naked; the lint is $1\frac{1}{8}$ to $1^3/_{16}$ inches in length; requires 195 to 200 days to reach full maturity.

(b) *Zululand Hybrid*, said to be a cross between Sea Island and Nyasaland Upland, is very similar to improved Bancroft, and is very favourably spoken of in Vryheid and Zululand.

(c) *Russell's Big Boll* matures in about 200 days; has large seed covered with green fuzz, and produces lint approximately an inch in length.

(d) *Griffin* is prolific bearing, with numerous small bolls to which the cotton clings tightly. It is earlier than improved Bancroft and the lint is probably a little better than that of Russell's Big Boll. It is grown to a certain extent in Barberton and Weenen districts.

(e) *Nyasaland Upland* has large, branched open trees, light foliage, rather small round bolls; seeds small and fuzzy; lint 1 to $1\frac{1}{8}$ inches.

(f) *Sunflower, Cook's Long Staple and Allen's* all produce lint approximately $1\frac{1}{4}$ inches, and require a relatively long growing season.

(g) *King* is a very early hardy variety. The lint is short, $\frac{3}{4}$ inch, and coarse; consequently its cultivation is not advocated.

(h) *Uganda* has line averaging from 1 to $1^1/_{16}$ inches, is good yielding, but so far has not been able to replace any of the better varieties.

It is possible that in parts having a long growing season and where irrigation can supplement the rainfall, some Egyptian and perhaps some Sea Island types may be profitably grown.

Few of the varieties grown at present are pure, and as uniformity in cotton is more important than in most crops, no pains should be spared to isolate pure strains of the different varieties. This leads to a consideration of the next point.

Seed Selection.—Probably in no other direction in the cotton industry in South Africa can greater progress be made than by seed selection. All the varieties grown at present contain a number of strains both good and indifferent. While a good deal of pure line work might well be left to the qualified plant breeder, the farmer can do a good deal to improve his crop. Once he is assured that the variety he is growing is the most suitable one for his locality, he should proceed to select the best plants, having regard to yield, length and strength of staple, number of bolls, storm resistance, early maturity, uniformity and disease resistance. A certain percentage of cross-pollination takes place between plants situated close to one another. Consequently varieties should be kept widely separated. Hybrids are often abnormal in vigour of growth, therefore in selecting plants it is well not to select those showing abnormal growth. Once a desirable type has been obtained, the grower might proceed in two ways. Firstly, he might grow half the seed from each plant in a row test, and if the progeny is uniform and thus pure to type, he should grow the remaining seed in an isolated plot. The seed from this should be increased by growing it in an isolated plot until sufficient seed is procured to plant the acreage required for the main crop. In the second method he might practice a rough form of mass selection, *i.e.*, select a number of desirable plants each year, the seed from which he would plant separately until he had sufficient from this to grow his general crop.

Climatic Requirements.—Burkett[1] states these to be as follows :—" A relatively high temperature ; a long growing season ; a moderate and well distributed rainfall throughout the growing season ; a small amount of rain at the maturing period ; a great deal of sunshine." In South Africa these conditions are well met in many areas of low altitude in the Transvaal, Swaziland, Zululand and Natal.

A comparison of the temperatures prevailing in our potential cotton areas with those found in the American cotton belt show a distinct advantage to the South African cotton grower, since the extremes are not so great as those of the American cotton belt.

An examination of the minimum temperatures occurring in our cotton parts indicate a frostless season sufficiently long for cotton. In some areas unusually early frosts, which tend to limit the crop, may occur in April.

The following records, the average of a number of years, show the average of the minimum and maximum temperatures obtaining at the places mentioned. It must be noted that the altitude of the towns Zeerust and Rustenburg is considerably higher than the suitable areas for cotton of Marico and Rustenburg districts :—

Recorded at	Altitude.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Barberton .. TRANSVAAL.	2,900 ft.	68·9	69·7	71·6	74·1	72·3	70·8	67·4
Bushbuckridge .. LYDENBURG, TVL.	2,800 ft.	69·2	70·8	72·9	73·0	72·6	71·4	67·3
Zeerust .. .. TRANSVAAL.	3,900 ft.	69·0	71·2	73·4	74·2	72·6	69·4	63·4
Rustenburg .. TRANSVAAL.	3,800 ft.	69·3	70·6	72·6	73·2	70·5	68·7	63·4
Bremersdorp .. SWAZILAND.	2,000 ft.	68·0	69·8	73·3	73·4	72·4	70·5	66·6
Mabisa .. .. ZULULAND.	800 ft.	67·5	68·9	71·2	74·0	72·8	70·7	69·5
Mtumzini .. .. ZULULAND.	43 ft.	68·4	69·4	70·4	70·8	71·4	71·1	68·4
Weenen .. .. NATAL.	2,840 ft.	69·2	73·3	76·2	77·2	75·8	72·2	67·0

All the districts mentioned have an average summer rainfall of over 18 inches, which, if reasonably distributed, is adequate for the cotton crop. In some, however, the commencement of the rainy season may be delayed, and where this state of affairs is apt to occur, winter ploughing should be practised so that full advantage can be taken of the first rains to commence planting. If this is done, the available growing period will generally be found to be sufficiently long for profitable cotton cultivation. Cotton is grown only in the summer rainfall area of South Africa, consequently harvesting synchronises with the cessation of the rainy season, and practically no cotton is damaged by excessive moisture after the bolls open. That cotton is infinitely more drought-resistant than maize should not be overlooked. It is often a successful crop in areas where moisture conditions are too adverse for maize.

Mists are a rare occurrence in our cotton districts, and the requirements of cotton for sunshine are amply met.

SOIL REQUIREMENTS. Productive maize soils are generally good cotton soils. Good loam soils, having a texture permitting of the free movement of soil moisture, are the best for the crop. Clay soils, if the drainage is good, when properly manipulated often give excellent results. Cotton is remarkably resistant to alkali, in which respect it differs fundamentally from maize.

CULTURAL METHODS.

SOIL PREPARATION.—While winter ploughing should be practised in order that full advantage may be taken of the relatively short growing season, it should be undertaken for the purpose of insect pest control as well. Just prior to planting, the soil should be worked down into a fairly fine condition.

MANURIAL REQUIREMENTS.—The cotton crop is less of a drain on the soil than any of the ordinary South African field crops.

PLANT FOODS REMOVED FROM THE SOIL BY CROPS.[6]

CROP.	NITROGEN.	PHOSPHATES	POTASH
Cotton—300 lbs. lint..	1·02 lbs.	1·37 lbs.	1·37 lbs.
650 lbs. seed	20·34 lbs.	7·84 lbs.	7·84 lbs.
	21·36 lbs.	10·97 lbs.	9·21 lbs.
Maize—8¾ bags	32·14 lbs.	12·36 lbs.	7·06 lbs.
4,000 lbs. stover	41·60 lbs.	11·60 lbs.	56·00 lbs.
	73·74 lbs.	23·96 lbs.	63·06 lbs.
Wheat—3½ bags	19·75 lbs.	7·44 lbs.	5·10 lbs.
2,300 lbs. straw	13·57 lbs.	2·76 lbs.	11·73 lbs.
	33·32 lbs.	10·20 lbs.	16·82 lbs.
Tobacco—1,000 lbs. leaf	44·00 lbs.	5·00 lbs.	52·00 lbs.
—353 lbs. stalks	12·00 lbs.	2·00 lbs.	17·00 lbs.
	56·00 lbs.	7·00 lbs.	69·00 lbs.

The manurial requirements are readily met in most of our soils when a green-manuring crop is ploughed under every third or fourth year, and when occasional dressings of phosphates—about 200 lbs. of superphosphate per acre—are provided.

PLANTING.—This should be done from the middle of October to the middle of November. In some areas where frost rarely occurs, the seed is planted as early as September. Generally speaking, the longer the growing season the larger the yield, so that the rule should be to plant as early as conditions permit. In very few areas of the Union is it profitable to plant later than the first week in December. The earliness of planting is modified by the date of the first planting rains and, as previously mentioned, by winter ploughing.

About 20 to 25 lbs. of seed is required per acre. This is best planted with a double-row planter, which is also furnished with a maize attachment. The rows should be 3 feet 6 inches to 4 feet 6 inches apart, depending on the variety and the productivity of the soil. Unlike maize, in the case of cotton the more productive the soil the wider should the spacing be. The seed should be lightly covered, never more than 2 inches, and on soils liable to crust the seed should be covered only to a depth of 1 inch. On the whole the best results are obtained when the planter is so adjusted that the seeds are barely covered.

THINNING.—When the plants are 6 to 8 inches in height they should be thinned, *i.e.*, some pulled out, so that those left stand 9 to 15 inches in the row.

CULTIVATION.—Insect pests are the most formidable pests with which the cotton farmer has to contend. For this reason, particularly, cultivation must be thorough. It should commence as soon as the young plants are sufficiently conspicuous to define the rows. As the season proceeds, cultivation should become shallower and narrower, and should cease when the plants fill the row to such an extent that they are damaged by the cultivators.

PICKING.—As soon as the bolls have opened to such an extent that the field presents a white appearance, picking should commence. The first picking generally takes place three to four weeks after the first bolls have opened. Three to four pickings at intervals of about twelve to eighteen days, depending on the prevailing temperatures, will be necessary to harvest the whole crop. Cotton should be picked only when dry, and for this reason should not be picked immediately after a rain or while moist with dew. Every care should be taken to pick as cleanly as possible, as the value is very much depreciated by the presence of trash or dirt. If compelled to pick when the cotton is slightly moist, it should be spread out to dry before being stored. One native woman should harvest about one muid bag well filled, 50 pounds, in a day, at a cost of one shilling. Should a farmer be growing more than one variety, the pickings, of course, should be kept apart.

When picked, the seed-cotton is put into wool packs; each, if well tramped, will contain 400 to 500 pounds. It is labelled and then sent to the gin, where the seed and lint are separated.

GINNING.—Two types of gins are used—the roller gin and the saw gin. The former is slower, but is generally held to be the better type for long stapled varieties having naked seeds. Saw gins seem to be preferred for the shorter stapled varieties, which usually have fuzzy seed.

A uniformity of output is of the utmost importance; cottons to be ginned must not be mixed indiscriminately. To ensure uniformity, the seed cottons should be graded so that only those of the same style should be ginned together. This grading should take into consideration the length of the lint, its cleanliness and colour. Cotton should not be ginned when moist, as this results in entangled masses; the velocity should not be too high as this produces gin-cut staple; "neps," small matted dots, while frequently found in cotton picked when immature, may also result from poor ginning.

Importance of Uniformity.—Not only are the requirements of the yarns and fabrics produced to-day highly specialised, but the machinery employed is also very specialised. Each count and quality of yarn requires its particular type of cotton, consequently cotton lacking in uniformity is never sold to advantage. Since textile machinery is so delicate that it must be adjusted to the style of cotton employed, and since each mill confines itself to specific count and quality of yarn, it is apparent that large quantities of the particular grade and staple, *i.e.*, "even-running" lots, will be valued highly by the spinner.

Baling.—After ginning, the lint is baled to a density preferably of 30 to 32 pounds per cubic foot, each bale weighing approximately 500 pounds.

Classification According to Staple and Grading.—Grade values represent the cotton fully with reference to its cleanliness and discolouration. "Staple, which is expressed in inches or millimetres, is a separate consideration, and according to length and strength modifies the grade value by adding to or taking off."[7] The staple classification also involves a consideration of the strength of fibre. Long stapled and strong cottons are usually sold at a good premium.

"There are seven grades of cotton, named as follows: fair, middling fair, good middling, middling, low middling, good ordinary, ordinary.

"Cotton is graded according to its superficial appearance, which is influenced by colour, foreign matter and quality of ginning."[7] Good cotton should be white or bright or creamy, and free from any discolouration. In inferior grades dull white and grey, and even a reddish cast as well as a slight bluish cast are found. Particles of leaf, stems, broken seeds, nep, sand, etc., are present in sample, and naturally the smaller the quantity the better the grade. Cotton properly ginned is smooth and of good appearance. The grade is lowered if the bale shows stringy cotton, cut seed, gin-cut, neps, etc.

Cotton-Seed Products.—The more important by-products are obtained from the seed, which is composed of about equal proportions by weight of hulls and kernels (" meats "). After the seed is decorticated, *i.e.*, the kernels separated from the hulls, the kernels are heated and pressed into cotton-seed cake. During this process the cotton-seed oil is expressed. Montgomery[8] says " a ton of cotton-seed will usually yield about 300 pounds of oil, 750 pounds of cake and 800 pounds of hulls, the remaining 150 pounds representing evaporation and waste materials."

Sometimes the seed is not decorticated, but is merely crushed, cooked and pressed, in which case—because the hulls are still present—the cake (undecorticated) is not nearly so valuable as a concentrate. Cotton-seed cake is one of the most valuable of concentrated foods obtainable, particularly for dairy cattle. The following average of analyses of cotton-seed cake will bear this out:—

Water.	Ash.	Protein.	Crude Fibre.	Carbohydrates.	Fat.
8·52	7·02	43·26	5·44	22·31	13·45

The meal is a valuable fertiliser. However, it is too valuable as a concentrate for feeding to allow of its common use as a fertiliser. It contains fertilising constituents in approximately the following amounts:—Nitrogen, 7 per cent., phosphoric acid, 3 per cent., and potash, 2 per cent.

Cotton-seed oil is used in many ways, *i.e.*, illuminating purposes, medicines, soaps, candles; in the manufacture of roofing composition, linoleum, etc. The crude cotton-seed oil produced in America in 1914 was valued at £16,108,000.

At present in South Africa the linters, or fine fluff from the seed, is delinted in the ginneries after the lint has been taken off. In America the linters are removed at the oil mills. They are largely used in the manufacture of explosives, felt, blotting paper, absorbent cotton, etc.

At present the Union's cotton industry is in its infancy, but as it develops and as large quantities become available, no doubt the by-products will be more fully exploited.

Pests and Diseases.—There is probably no commonly grown crop in which insect pests play so important a role. In Egypt the Pink Boll Worm causes enormous losses annually, and in America the Mexican Boll Weevil has been the principal cause of the decrease in American production. These are two of the worst pests known to cotton. Fortunately they are so far absent from the Union, and the authorities are taking every precaution to prevent their introduction. Insect pests, however, although less serious than in Egypt and America, lay a heavy toll on South African production.

Cutworms ((*Agrotis spp.*) are apt to injure the seedlings until these are about a foot in height. The Cotton Aphis, although prevalent, is not looked upon as a serious pest.

Several leaf-eating caterpillars, among these the Prodenia Caterpillar, are found; the damage done varies, but on the whole is seldom really serious.

Three boll worms are found and are considered to be the most serious pests of cotton in South Africa. The grubs eat holes in the bolls and then destroy the developing fibre and seed. If attacked in the young stage, the bolls fail to mature and fall off. Braine[9] gives the following description of these boll worms :—" (a) The American boll worm (*Chloridea obsoleta*): Caterpillar, greyish, brownish or greenish, dull, without red bands or stout spines; a common pest not only of cotton, but of lucerne, maize and fruit trees. It is also known as the earworm of maize. (b) The Spiny boll worm (*Earias insulana*): The adult insect is a small moth, nearly an inch across the expanded wings. The head, thorax and forewings are bright pea green, with a varying dark patch of brown or with three-angled marks of darker green. The caterpillar is smaller than that of the American boll worm, brown, somewhat hump-backed, with many spines. (c) The Sudan boll worm (*Diparopsis castarea*): The caterpillar is smooth, greasy looking, yellowish, white or greenish, with red bands (pinkish when young). Like the American boll worm, it pupates in the soil."

Several species of cotton stainers are found which, like the Cotton Aphis, obtain their food by sucking the juices of the plant. The chief damage caused by these insects is a discolouration of the lint, which arises from the stainers when crushed.

There are numerous minor pests such as the Root gall worm (*Heterodera radicicola*), scale insects, thrips, leaf-rollers, fruit beetles, etc., which seldom cause severe injury to the crop.

In countries where labour is very cheap, hand-picking for some pests is often practised. The South African farmer can combat these best by practising a rotation, winter ploughing and frequent cultivation.

A number of fungous and bacterial diseases are found; fortunately the losses due to these in South Africa are in no way comparable with those caused by the insect pests. The following may be mentioned :—

(a) Root-rot (*Ozonium omnivorum*).—The fungus attacks the roots and causes the whole plant to wilt suddenly, then die.

(b) Anthracnose (*Colletotrichium gossypii*).—This fungus is responsible for the greater part of the rotting of the bolls of cotton. The use of diseased seed constitutes one of the methods by which anthracnose is spread. The disease also affects the leaves and stems; it is worst during damp weather. Small discoloured depressions appear on the boll, which become greyish and eventually become covered with pinkish spores. Either a single lock or the entire contents of the boll may be rotted, or the disease may keep the boll from opening widely. Dry weather checks the disease, which will then appear only as a reddening or spotting of the surface of the boll without serious damage to the crop. Duggar advises wide spacing, avoiding the use of nitrogenous fertilisers, planting the less leafy varieties and those which show a certain amount of resistance to disease.

(c) Cotton Rust or Black Rust (*Macrosporium nigricantium*) causes the premature loss of foliage, and consequently when bad a much depreciated yield. The leaves show at first a mottled, yellowish colour. After wet weather there may be no yellowing, but a sudden blackening, drying and falling off of the foliage.

(d) Angular Leaf Spot (*Pseudomonas malvacearum*): The organism produces through stomatal infections, water-soaked angular areas, which later turn purple and finally become dry and brown.

Besides these, Rhyzoctonia (*Corticium vagum*), Leaf Spot (*Cercospora Gossypina*) and (*Spærella Gossypina*) and Cotton Wilt (*Neocosmospora vasinfecta*) may cause a certain amount of injury.

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CHAPTER XII

TOBACCO

(Contributed chiefly by H. W. Taylor, B.Sc.A.)

As tobacco is a highly specialised crop, and to be dealt with fully would require more space than can be afforded in a book of these dimensions, those wanting more detail than is given herein are advised to procure copies of the references given at the end of this chapter.

HISTORICAL.—In this connection de Candolle says: " At the time of the discovery of America, the custom of smoking, snuff-taking, or of chewing tobacco, was diffused over the greater part of this continent. The accounts of the earliest travellers show that the inhabitants of South America did not smoke, but chewed tobacco or took snuff, except in the district of La Plata, Uruguay, and Paraguay, where no form of tobacco was used. In North America, from the Isthmus of Panama and the West Indies as far as Canada and California, the custom of smoking was universal, and circumstances show that it was also very ancient. Pipes, in great numbers and of wonderful workmanship, have been discovered in the tombs of the Aztecs in Mexico, and in the mounds of the United States."[1]

" In 1539, Hernandez brought seed to Europe. Jean Nicot, French Ambassador, saw the plant cultivated in Portugal, and in 1560 sent seed of it to Catherine de Medicis, from which circumstance the genus obtained its botanical name. In the same year tobacco was conveyed to England by Thos. Haricot; Sir Francis Drake and, subsequently (1570-84), Sir Walter Raleigh and others, made tobacco-smoking popular in England, and about the same time cultivation was started in Virginia. In 1610, tobacco was grown in Ceylon, and in the same year was introduced into Turkey."[2]

The early history of tobacco cultivation in South Africa is not clear. It has been grown in the Kat River area for a great many years, and probably later in the Rustenburg and Piet Retief districts.

The tobacco formerly grown in the Union was grown chiefly for pipe-smoking and for snuff. " The tobacco and tobacco manufacturing industries have experienced considerable change in the class of leaf and manufactured article required by the public during the past 10 to 15 years, *i.e.*, from the heavy type tobacco to the light cigarette tobacco leaf. A fairly large percentage of the crop was put up by farmers into roll tobacco, the rolls being converted into pipe or snuff tobacco by the consumer. There is still a considerable quantity of roll tobacco produced both by the farmers and by factories. During more recent years factories for the manufacture of cut pipe tobacco and cigarettes have been established throughout the Union, and an increasing demand for tobacco of light or medium colour and fine or medium texture has arisen. During this period the manufacture of cigars has made some progress, and several small factories are in operation. This factor has encouraged the production of a type of leaf suitable to the manufacture of cigars. Moreover, cigarettes made from locally grown Turkish tobacco have become very popular, and the production of colonial Turkish leaf has become fairly established. Prior to the European war, a considerable quantity of tobacco was imported, comprising Sumatra for cigar wrapper, and Turkish and Virginian for cigarettes."[3]

Production.—According to the United States Government statisticians, the estimated average annual production of tobacco for the period immediately preceding the war was 4,197,000,000 pounds. The largest tobacco-growing countries were as follow :—

	Pounds.
United States	1,000,000,000
British India	1,000,000,000
China	500,000,000
European Russia	230,000,000
Dutch East Indies	200,000,000
Austria-Hungary	170,000,000
Japan	120,000,000
Philippines	100,000,000
Brazil	100,000,000
	3,420,000,000

The total of these nine countries amounts to 81 per cent. of the world's production.

The total amount of commercial tobacco produced in Africa is probably not above 70,000,000 lbs. at present. In 1917 the production was as follows :—

	Pounds.
Algeria	36,155,000
Union of South Africa	6,999,825
Nyassaland	4,304,124
Rhodesia	620,171

Types of Tobacco Produced in South Africa.—Tobacco is divided into types according to certain qualities, such as colour, flavour, aroma, body, etc., or on certain characteristics produced through the method of curing. Each type is sub-divided into classes according to the purpose for which the tobacco is to be used, and each class is again sub-divided into several grades.

The types of tobacco produced in South Africa can be divided roughly into Turkish, cigar and Virginian. The latter is a very elastic term, and applies to the leaf produced in the Union by air-curing and Rhodesian flue-cured tobacco. Turkish tobacco is only used for cigarettes, and is, therefore, classed as a cigarette tobacco only. Cigar tobacco is divided into three classes—viz., wrapper, binder and filler leaf. Virginian tobacco is used for cigarettes, pipe mixtures, chewing and snuff purposes, and is consequently divided into four classes.

Quality of South African Tobaccos.—Quality as applied to tobacco is a relative term. The quality of tobacco is determined by a combination of properties, such as nicotine content, colour, flavour, aroma, body, texture, combustibility, size, etc. These characteristics are largely dependent on the soil and climatic conditions under which the tobacco is produced, the method of handling during growth, and the manner in which the tobacco is cured.

The quality most desired in tobacco for one purpose may render it practically useless for another. The thin, elastic, light-bodied leaf required for cigar wrappers would be of little value for pipe or chewing purposes. Quality, as applied to tobacco, then, depends to a large extent upon the form in which the manufactured article is to be consumed.

The taste of the individual consumer also largely determines the quality of the tobacco most suitable for his requirements. Some smokers prefer tobacco of mild properties, while others prefer strong tobacco, according to their respective tastes. As the use of tobacco is an acquired habit, it follows that the taste of the individual consumer is largely determined by the quality of the tobacco which he is accustomed to using. In this way the trade of various countries has been built up on certain types and grades of leaf, irrespective of their being of the lowest or highest quality of tobacco.

Since the quality of tobacco largely depends on the environment under which it is grown, and the methods of curing and handling, the tobacco grown in various countries should differ as to characteristics and use. In practice this is found to be true. Cuba is generally acknowledged as producing the finest cigar-filler tobacco, whilst Sumatra leaf is usually regarded as the best for cigar wrapper purposes. For cigarette tobacco of the Turkish type the Levant has long been noted, and Virginia, North and South Carolina, are known the world over for the fine quality of their flue-cured bright tobacco. As each country produces tobacco with different characteristics, it is difficult to compare South African tobacco with tobacco grown in other parts of the world purely on the basis of quality, which is a variable term.

It may be well, however, to give the principal characteristics of the several types of tobacco produced in South Africa.

The Virginian tobacco produced in South Africa varies so much in its natural characteristics that the leaf from each large producing area must be considered separately.

In the Transvaal the three largest tobacco-growing centres are the Magaliesberg area and the Potchefstroom and Piet Retief districts. The Magaliesberg area includes the Rustenburg district and parts of Pretoria, Krugersdorp, and Marico districts. The tobacco produced in this area is used principally for the manufacture of pipe tobacco, though an increasing amount is being used for cigarettes. The leaf used for pipe purposes varies from eighteen to thirty inches in length, and is rather narrow. In colour it varies from deep cherry to dark brown and greenish-brown. It is rather heavy in body, has a medium nicotine content, lacks in elasticity, and has large veins and midribs. The manufactured product burns very freely, has a mild flavour, and a rather pungent acrid aroma. The pipe tobacco manufactured from Magaliesberg leaf might be described as a mild smoke, and is more generally used in South Africa than any other pipe tobacco. The cigarette leaf produced in this area varies in colour from bright yellow to light red, is rather light in body, is inclined to be papery in texture, and is lacking slightly in flavour and aroma. The cigarettes manufactured from this leaf burn fairly well, and are distinct in flavour from the usual Virginia cigarette.

The leaf produced in the Potchefstroom District is similar to the dark tobacco of the Magaliesberg area, but is as a rule darker, coarser, and heavier in body and texture. The tobacco from this District is used principally for pipe and roll tobacco, and a small quantity is used for snuff.

The tobacco of the Piet Retief District has better body, more elasticity, and more pronounced flavour and aroma than most Transvaal tobaccos. It burns well, and has a higher percentage of nicotine than the tobacco from the Magaliesberg area. This leaf is used largely for roll and pipe tobacco as well as for snuff.

All Transvaal tobaccos are air cured, and kraal manure is generally used to stimulate growth.

The leaf from the Vredefort District of the Orange Free State is very similar to that of the Potchefstroom District, and is used for the same purpose.

The Oudtshoorn District and the Kat River District are the two principal areas of the Cape where Virginia tobacco is grown. The leaf from the former district is of good size, heavy in texture, inclined to be coarse, burns moderately well, and has a fairly high nicotine content. This tobacco is usually dark brown in colour, and is used for roll, pipe and snuff purposes. The Kat River District produces both bright and dark leaf. The tobacco in some cases burns poorly, and for cigarette purposes requires blending with leaf of better burning quality. The dark tobacco is somewhat smaller in size than the Oudtshoorn leaf, and somewhat lighter in texture and body. The dark leaf from this area is used principally for manufacturing roll and pipe tobacco.

The Virginia tobacco grown in the Union is well adapted for local consumption, but would scarcely find a large overseas market at present. Once the tobacco-consuming public in other parts of the world becomes accustomed to its peculiar flavour and aroma, the demand would at once be created.

Rhodesian Virginian tobacco is practically all flue-cured, and varies in colour from lemon-yellow to mahogany and dark brown. The leaf is generally inclined to be small and fine, with good body, low nicotine content, mild in flavour; is aromatic and keeps well. It is used for the manufacture of cigarettes and pipe mixtures, which are sold in competition with similar articles made from American tobacco. As there is a very great demand for tobacco of this tyne. the better grades of Rhodesian tobacco find a ready market overseas.

The Turkish tobacco of both the Western Province and Rhodesia has good colour, texture, body and burning qualities, but its flavour and aroma are not so pronounced as that produced in the Levant. The cigarettes manufactured from this tobacco are therefore lacking in the full flavour and pleasing aroma which are characteristic of the imported article of the highest quality. Cigarettes made from South African-grown

Turkish tobacco have the redeeming quality, however, of being a light smoke, and can be consumed in large numbers without decided injurious effects to the nervous system of the average smoker. Properly handled and matured, Turkish tobacco from South Africa would find a ready sale overseas for blending purposes.

Practically the whole of the cigar tobacco grown in South Africa is produced in Natal. The leaf is similar to Connecticut seed leaf, but is narrower and has less body, flavour and aroma. The tobacco is used principally for the manufacture of cheap cigars and cheroots, which have a fairly good local sale, but which would probably not find a large ready market elsewhere in competition with Dutch cigars and Indian cheroots.

The production of tobacco in Natal has been decreasing for some years, which indicates that the demand for this type of leaf is not increasing.

The following table shows the largest tobacco-producing districts in the Union, the methods used for curing, the types of tobacco, and the percentage of cigarette leaf produced :—[4]

Area.	Production in lb.		Type of tobacco produced.	Est. average percent-tage of cigarette leaf.	Method of curing.
	1919-20	1920-21			
Magaliesberg, including Rustenburg, Krugersdorp, Brits, Groot Marico and Scheerpoort	5,395,200	8,500,000	Pipe, roll and cigarette.	15-18 per cent.	Air-cured.
Oudtshoorn	1,836,900	3,000,000	Roll, pipe and cigarette.	10-12 per cent.	do.
Vaal River area, Vredefort and Potchefstroom ..	850,000	1,000,000	do.	8-10 per cent.	do.
Piet Retief and Hlatikulu	600,000	800,000	Roll and pipe.	5 per cent	do.
Stockenstroom ..	440,000	600,000	Pipe and cigarette	15-20 per cent.	do. do.
Western Province: Stellenbosch, Paarl, Ceres, Caledon, Tulbagh	396,900	600,000	Turkish cigarette	100 per cent.	Sun-cured.

The above tabulation is not given for comparative purposes between the air and sun curing methods, as obviously all Turkish tobacco is manufactured into cigarettes, but to give an approximate idea of the percentage of cigarette leaf produced in the Union.

Description and Classification.—Tobacco belongs to the genus *Nicotiana*, which includes about fifty species, mostly of the American tropics. A number of species are grown for ornamental purposes.

Two species, both summer annuals, are grown commercially in the Union. (a) *N. tabacum* (Virginian tobacco) has sessile decurrent leaves; pink, yellow, purple or white flowers. (b) *N. rustica* (Pondo tobacco) has petioled leaves, leathery in texture, somewhat cabbage-like in appearance, and flowers of a pale greenish colour. Turkish tobacco, while very unlike Pondo tobacco, is held by some to be a strain of *rustica*.

That the tobacco plant is, in all probability, naturally close-fertilised, is borne out by the fact that self-fertilisation (inbreeding) under control does not result in a loss of vigour. Cross-fertilisation is probably somewhat frequent.

Seedlings and Seed-Selection.

The methods of culture, curing, and treatment, differ for each type of tobacco grown in South Africa. However, the principles underlying the production of seedlings, and seed-selection, are common to all.

Seed Beds.—These should be well prepared, more thoroughly than for the other common field crops, and the soil should be in a state of high productivity. Unlike Northern countries, where hot-houses or glass frames are generally necessary, in South Africa the open frame is practically the only type employed.

As the beds are sown in the late winter or early spring, they should be placed in a warm situation, protected from cold winds, and where they can receive the maximum amount of sunlight, especially early morning sun. Wind-breaks of maize stalks or reeds should be provided if there is no natural wind-break. The site as well as the beds should be level, otherwise when watering the small seed is liable to be washed to the low parts of the beds.

Soil.—This should be deep, well drained, friable—preferably a light, sandy loam. If no suitable soil is available, and as the beds are comparatively small, wagon loads of sand, etc., should be carted to produce the required soil. The site should be changed from year to year to obviate diseases, and because the heavy waterings and annual sterilising make the soil unsuitable.

Soil Preparation.—Heavy application of well-rotted and pulverised kraal manure should be applied and mixed thoroughly with the soil by digging. This should be done in time to ensure thorough decomposition before the seed is sown. The beds must be scrupulously weeded. Finally, the land must be divided into beds four to five feet in width, having pathways in between. After being laid out the beds must be sterilised. In South Africa the open fire gives satisfactory results.

Sterilising the Beds.—Sufficient brushwood, maize cobs, or other material, should be placed on the soil, so that when burned the sterilisation will be effected to a depth of three inches. Tobacco stalks should not be used, as their excessive potash content affects germination adversely. Besides being friable, the soil when properly sterilised will present a light, dull-red appearance. To prevent baking, the soil should be fairly dry—optimum conditions for tillage are the best for sterilising.

This method kills weed seeds and insects in the soil. The ash acts as a fertiliser (potassium carbonate being the best form in which to apply potash to tobacco), and, according to Rothamstead investigations, a rapid increase in nitrogen is obtained.

After burning, the unburnt wood and large pieces of charcoal are removed, and then the beds are enclosed with boards, brick, or sheets of iron. The following mixed fertiliser is then applied to each ten square yards of bed, viz., one pound of sodium nitrate, one pound of potassium sulphate, and two pounds of superphosphate. After this the bed is dug over to the depth to which it has been sterilised. It is then raked to a fine tilth and accurately levelled each way.

Sowing.—The seed, in order to remove the light seed and chaff, should be passed through a tobacco seed separator. This is done free of charge by the Tobacco and Cotton Division. To combat Wild Fire disease it should be disinfected as well. The seed is extraordinarily small, one ounce containing 300,000 seeds, and is sufficient for 120 square yards of seed bed. If the seed is mixed with wood ash or mealie meal, no difficulty will be experienced in getting it evenly distributed over the seed-bed. After sowing, the surface of the soil should be firmed down with a trowel, and then watered with a fine-rosed watering can. From now on, until the plants are ready to be hardened off for transplanting, the soil should be kept moist.

Time of Sowing.—From the date of sowing the seedlings take sixty days to reach the transplanting stage for early planting, and less for late planting. Seed sown by the 1st August is quite early enough for planting in October. In the Western Province, Turkish seed-beds are sown in June, when open beds are used, and in July when closed beds are employed. Seed beds should be sown at intervals, so that the operations of transplanting, cultivation, and curing, can be carried out in succession, and labour can be used to the best advantage.

Virginia tobacco requires 20 square yards of seed-bed per acre, and Turkish about fifty square yards.

Covering.—The young seedlings should be covered with grass or cheese cloth, to modify the extremes of temperature. Cheese cloth is preferred, since it serves as a protection against insects (Split-worm and Stem-borer), and, moreover, it allows sufficient sunlight for proper growth. At night it checks radiation.

Care of Seed-Beds.—Water should be applied by means of a watering-can only, increasing from a fine to coarse rose until the plants are of a fair size and well rooted, when the rose can be dispensed with. During the early growth, the cheese cloth should be removed only for watering; later it should be removed for a few hours each morning. After this the exposure can be increased, so that by the time the plants are ready for transplanting, the beds, to prevent insect injury, should be covered only at night. This, accompanied by applying only sufficient water to prevent excessive wilting, is to harden the plants for transplanting.

A sickly, poor growth, may be due to insects, poor drainage, lack of plant food, or over-crowding. If the latter, the plants should be thinned. If the plants are of a yellowish colour, owing to a deficiency of nitrogen, then a liquid manure should be applied, *e.g.*, sodium nitrate (one pound to eight gallons of water), or fowl manure steeped and the liquid applied after a few days. This should be applied on a dull day, and watered immediately afterwards to avoid injury to the leaves.

Seed Selection.—The plants from which seed is to be taken should be selected along the following lines. Naturally, only pure types suitable to the locality and fulfilling the desired requirements should be selected.

The Virginia leaf wanted in South Africa is ovate in shape, carrying the width well to the tip, and having a fine midrib. The leaf should not be less than 20 inches long before curing, and should have a smooth surface, as a smooth surface is correlated with a fine silky texture in the cured product. For cigarettes, the leaf should be fine in texture, thin, with fine venation, and light in body. For pipe purposes it should be heavier in texture, longer, and possess greater body. While greatly influenced by soil and climate, these are characteristic in varying degrees in the different strains.

Turkish leaf should be small and fine, with good body and a smooth, silky texture. The leaves should be gummy and of good body, which includes a sufficient quantity of starches and oils, substances which give the fermented leaf its peculiar sweetness and aroma. Large, coarse leaves are very undesirable in this type of tobacco. The leaves should be true to type, and should possess a light greenish colour when approaching maturity. The leaves should be numerous, not pendent in habit, but rather erect or at right angles to the stalk.

Plants showing early and uniform maturity of the leaves should be chosen, as plants of this nature facilitate harvesting and, moreover, the product is more uniform, especially when the whole plant is harvested for air-curing.

The colour of the growing leaf is correlated with the cured colour. Greenish-yellow leaves at maturity give a bright colour when cured, but dark and oily leaves usually assume a dark or uneven colour after curing. If, therefore, tobacco of a bright yellow colour is wanted, plants should be selected for seed that yellow well in the field; if pipe tobacco is wanted, then select dark green plants which show only yellow flecks when ripe and which have a heavy texture.

About twenty Virginia plants furnish one pound of seed, while sixty Turkish plants are required for the same amount of seed.

Cross-pollination is prevented by the use of Manilla bags, which are placed over the inflorescence just before the flowers open. Before doing so, all the top leaves—leaving 12 to 18 per plant—should be removed, as well as all suckers. Only three to four terminal flower branches should be left. In Turkish tobacco, remove only the suckers and those leaves that interfere with bagging. Usually, when seventy or eighty capsules have formed, the remainder of the flowers are pruned away, and the bag may then be removed if not menaced by birds. After the capsules begin to turn brown, the inflorescence is removed, and should be stored in a dry, cool room. When the capsules are thoroughly dried they should be threshed, winnowed, and stored in glass jars, covered with muslin. Tobacco seed can be kept without deteriorating to any marked extent for ten to twelve years.

Finally, before sowing, the seed must be passed through a separator, and only the heavy seed kept. According to Scherffius, tobacco from heavy seed matures about ten days earlier, and in an experiment gave 1,959 pounds to the acre, as compared with 1,644 pounds per acre from light seed.

Number of leaves per plant and size of leaf are transmissible within limits, and self-fertilisation with continued selection along these lines will isolate the desired types. As in other crops, acclimatised seed is superior, and there seems no reason why the practice of importing seed should not be discontinued.

The Culture of Virginia Tobacco.

Climate.—Tobacco should be grown only in hail-free areas. Practically all the tobacco of this type in the Union is grown under irrigation, as the rainfall in the best areas is insufficient and irregular. In Rhodesia, where it is grown on the rainfall, the best quality is produced where the rainfall is moderate, about 25 to 30 inches, but well distributed throughout the growing season, and rather light during the ripening and harvesting periods. The precipitation should be in gentle showers and there should be plenty of sunshine.

For transplanting, the weather conditions most desired are misty, dull days, with frequent showers; where irrigation is available this is not so important. As tobacco is very susceptible to frost, harvesting must be completed before frosts are liable to occur. (Harvesting is completed 120 days after transplanting.)

Soils.—Besides silt and organic matter, the ideal soil for the production of bright tobacco should be composed of about 70 per cent. of sand and 6 to 8 per cent. of clay. The sub-soil should be open but retentive of moisture.

The best soils for dark tobacco contain about 50 per cent. of clay and 25 per cent. of sand, and the sub-soil should be somewhat heavier than that required for bright tobacco.

All soils should be well drained, and the humus content must be well maintained.

The texture of the soil exerts a marked influence on the yield and quality of tobacco produced. Sandy soils of coarse texture usually return poor yields of leaf, light in body and colour, lacking in fineness, inclined to be brittle, lifeless and chaffy. Fine sands should produce yields of silky, elastic leaf, having good body and bright uniform leaf. Clay loams generally produce heavy yields of tobacco, which is inclined to be heavy in body, coarse in texture, and medium to dark in colour. The exception to this is the black turf soil, which produces bright tobacco. In other countries these black turf soils would be avoided. However, in South Africa (where they contain a high percentage of lime), if well drained, although productive they do not produce large, coarse tobacco, but the plants grow quickly, mature early, take on a yellow colour in the field, and the leaf usually cures bright in colour. If brak, they are useless, as the tobacco then has poor burning qualities.

Red clay loams in the Union give tobacco of a red to dark brown colour when cured, suitable for pipe or snuff purposes. Red sandy loams produce light red to yellow leaf. If heavily fertilised, particularly with nitrogenous fertilisers, the tobacco is inclined to be heavy and dark.

Soil Preparation.—The land should be deeply ploughed, usually twice, and the soil then worked down to a fine condition for transplanting.

Fertilisers for Virginia Tobacco.—In growing tobacco a steady growth must be maintained, and the available plant food must be sufficient throughout the growing period. The monetary return per acre, as compared with other crops, is high, therefore larger applications of fertilisers can be employed than with crops like maize. The nitrogen requirements can usually be most cheaply met by the use of a leguminous green manure.

Excessive nitrogen, in the absence of phosphates, gives a coarse, dark tobacco, late in maturing, with a tendency to damage by "red fire," or dead spots, here and there on the leaves. A lack of nitrogen gives small and papery leaves, although these may be bright.

Potash in the form of nitrate or carbonate gives body to the leaf and improves the burning quality.

On light sandy soils, poor in nitrogen, phosphates must be used with discretion, as excessive applications tend to cause premature ripening or "firing," especially during dry weather.

The Union Department of Agriculture recommends the following application per acre every fourth year, viz. :—Sodium nitrate, 160 pounds; dried blood, 200 pounds; potassium sulphate, 200 pounds; and superphosphate (37 per cent.), 320 pounds. This should be broadcasted just before transplanting.

Kraal manure must be thoroughly rotted before use, as fresh manure produces coarse, heavy tobacco, which has a disagreeable flavour and aroma. It should be spread over the land a few months before transplanting and before ploughing.

If a leguminous green manure is used in rotation, tobacco should not be grown the following year, unless dark, heavy leaf is wanted. Non-legumes are most suitable on many soils, as the humus content is maintained without accumulating an excess of nitrogen.

Varieties.—(*a*) For heavy or dark leaf :—Improved Clarksville, Boyd, Genuine Pryor, Tennessee Red and Joiner. These should be grown on heavy soil, heavily fertilised.

(*b*) For medium-bright or light red leaf :—Joiner, Yellow Pryor, Sterling, Hester, Bullion, Blue Pryor, and White Burley. These should be grown on sandy loams, with moderate applications of fertilisers.

(*c*) For bright leaf.—The same varieties as in (*b*), but they should be grown on sandy loams or black turf soils, with very light applications of fertiliser.

Transplanting.—Virginia tobacco should be transplanted during October, November, or December. The early plantings give the best yields and quality of leaf. If the nights are cool at maturity, a satisfactory yellowing does not take place.

The transplants should be 4 to 6 inches in height, and should be put in the sides of furrows just irrigated. To firm the soil round the plants water should be run down the furrows immediately after planting out. The rows should be 3 feet apart, and the plants 2½ to 3 feet in the row.

If the tobacco is to be flue-cured, about 10 to 15 acres should be transplanted at a time, in order that there may be sufficient leaf of uniform ripeness and even texture to fill a curing barn properly at each harvesting.

Cultivation.—The transplanting furrows should be filled up by cultivators, and after this irrigation water should be applied between the rows. Cultivation should cease by the time topping is necessary.

Topping and Suckering.—The operation of removing the terminal bud, to prevent seed development, is called "topping." This should take place when the inflorescence appears, as the stalk is then succulent and brittle, and the operation is easily performed. About twelve leaves should be left, not counting the sand leaves, which are pruned off and discarded. If topped at the proper stage, early and even maturity is obtained.

After topping, suckers appear, which should be removed when small.

HARVESTING AND CURING.—These are two most critical operations. Unless the leaf is properly ripe, good colour cannot be got in curing. If harvested too early, the green colour is retained, and if too late the leaf is uneven in colour, brittle, and lacking in elasticity and fineness.

If the tobacco is to be air- or sun-cured, the leaf should be harvested just before it is thoroughly ripe. For flue- and fire-curing the tobacco should be fully ripe.

RIPENING.—" At about the time the leaves of the plant, as a whole, have reached their maximum power of elaborating the food supply, the flower head begins to develop. This food supply, consisting of starch and other similar substances, is carried from the leaf into the seed-head, to furnish the necessary food for the development of the seed. This accomplished, the leaves have completed their full task, and they now pass into the period of gradual decay. In practice, however, the plant is topped so that the seeds are not allowed to develop. Making a last effort to reproduce itself, the plant now sends out secondary shoots or suckers, which are again removed by the grower. Thus the food built up by the leaves is not carried to other parts of the plant, but accumulates in the leaves themselves. The result is that both the size and the body of the leaf are increased. This accumulation of reserve materials in the leaf induces ripening."

The lower and middle leaves should be ripe in about 90 days from the date of transplanting.

The principal indication of ripeness is a decided change in colour from dark green to a greenish-yellow. If the leaf is heavy in texture, the yellow may show only in flecks or spots. Another indication of ripeness is the change in texture of the leaf from soft and pliable to being rough and brittle, due to the accumulation of starch granules within the cells.

For flue-curing, the leaf should be a greenish-yellow when fully ripe, so that the green colour is reduced to a minimum before the tobacco is placed in the curing barn.

METHODS OF HARVESTING.—There are two methods practised :—(1) Whole plant, and (2) single leaf.

The former is the more economical method for air, sun, or fire-curing, but has the disadvantage in that all the leaves on the plant are not at the same stage. For flue-curing, the single leaf method is essential, as all the leaves should be at the same stage of maturity.

In harvesting the whole plant, the stalk is split to within about four inches of the ground, the stalk bent away and cut off next to the ground. The plant is then placed astride a tobacco stick, which will carry from six to ten plants; these are placed on a tobacco frame or a tobacco trolley, and carried to the curing barn or scaffolds in the sun.

In Rhodesia, Virginia tobacco is flue-cured, and, for this method, the leaves must be harvested singly to ensure uniformity of ripeness. Leaves are first removed from the bottom, then later the upper ones. Three to five pickings are necessary. As the leaves are taken ("primed"), they are placed carefully in suitable receptacles and conveyed to the stringing shed. No bruising should take place, and on hot days the leaves should be covered to prevent sunburn, as this gives a greenish-black colour to affected parts of the leaves. The leaves are now tied in bunches ("hands") of three to four leaves each, attached to tobacco sticks, and placed in the curing barn.

The whole plant method gives a lower yield of leaf than the single-leaf method.

The Curing of Tobacco.

Changes During Ripening and Curing.—"The young growing leaf has an intense green colour, showing that it is quite rich in the nitrogenous constituents which go to make up the lining or vital part of the leaf, and which are active in building up the food supply of the plant. . . . . When the reserve food supply of the mature leaf is no longer required for the nourishment of other parts of the plant, it is deposited in the leaf tissue in the form of starch granules, while the green colouring matters are dissolved and carried to the younger growing parts. This interchange causes the appearance of light-tinted flecks, so characteristic of the ripe leaf. Moreover, the accumulation of the starch granules in the leaf causes it to become brittle, so that it snaps when folded between the fingers, another characteristic sign of ripeness. Now, the replacement of the complex nitrogenous constituents, including the green colouring matter, by starchy matter, has a most important effect on the colour, flavour, elasticity and finish of the leaf. If the leaves are harvested too green, the colour will be dull and dark, because they contain too much chlorophyll, and if harvested too late (ripe), the colour will be uneven, mottled, and lacking in freshness, because they contain too little chlorophyll. For these reasons too-green leaves when cured are tough and leathery, and over-ripe leaves, strawy and lifeless to the touch."[5]

A number of changes were formerly attributed to bacterial action, but this theory has now been disproved, and the view is held that the majority of these changes are due to enzymes, the actions of which have been, in many cases, correlated with definite changes.

"When the plant is slowly starving to death, as it is when it is cut and allowed slowly to dry, there is a rapid formation of these enzymes, which separate themselves from the protoplasm and push out through the plant in search of food for the dying plant cells. Having thus distributed themselves, the enzymes are in position to become soluble again, and take up the work of fermentation whenever the conditions become favourable, as they do in the fermentation pile. If the leaf be killed outright by heat or rapid drying, the enzymes will have no opportunity to escape from the protoplasm, but will become entangled with the insoluble protein, so that later, when the leaf is brought into condition for fermentation, the process will be a total or partial failure, since these enzymes are active only when in solution.

"To repeat, the chemical changes which develop the aroma, as well as eliminate undesirable products, are due to certain enzymes. These changes take place during the second stage of the curing process, which is called the fermentation, or 'sweat.' But these enzymes are largely developed in the first stage of curing, and unless the first stage is properly conducted, the enzymes will not exist in large quantities, or in available forms, and the products developed during fermentation will be disappointing."[6]

Development of the Brown Colour.—"The slow starvation process of the tobacco leaf in the curing barn is connected with the yellowing of the leaves, followed by the characteristic brown. The yellow colour is chiefly due to the etiolating of the chlorophyll granules because of the absence of bright daylight, and sets in while the cells are still alive, while the brown colour sets in after their death. The changes of the green to yellow and of the yellow to brown start and proceed generally in the same order, commencing at the margin and about midway between the lateral veins. The yellow colour is due to a chemical change of the chlorophyll, while the brown colour is due to the oxidation of several different compounds contained in the cell sap. The brown colour shows also in the veins of the leaf, but not the yellow since there is too little chlorophyll in the veins. If the leaves are killed too quickly by desiccation, instead of by slow starvation, when the yellow colour is not formed, then the brown colour develops directly upon the still green leaf. The chlorophyll can be extracted by alcohol, which shows that the green is concealed by the brown. Furthermore, when a fresh leaf is dried at a moderate temperature in an air-bath, it will no longer turn yellow when exposed for a considerable time to a moist atmosphere, showing that the change from green to yellow in the curing barn is still a process of life, although a pathologic one.

"Oxidase acts on the chromogenic substances found in the cell sap when the cells die."[6]

Curing, then, consists in subjecting the tobacco to a process of gradual starvation under proper conditions. The principal external factors involved being heat and moisture. The method of curing is determined by the soil and climatic conditions under which the crop has been grown, and the purpose for which it is intended. The several tobacco-growing countries, therefore, employ methods of curing to meet their market requirements and individual economic conditions. The tabulation given below indicates the several methods of curing and the types of tobacco cured by each method.

Air-cured	Cigar tobacco. Burley. Stemming. Transvaal tobacco.	Cigars, pipe mixtures, chewing, snuff and cigarettes.
Sun-cured	Turkish. Maryland. Virginia. Rhodesia.	Cigarettes, smoking and chewing.
Fire-cured	Virginia dark. Kentucky dark. Tennessee dark.	Chewing, smoking, snuff and cheap cigars.
Flue-cured	Virginia bright. Carolina bright Nyasaland bright. Rhodesia bright.	Cigarettes, pipe mixtures, chewing and snuff.

Air-Curing.—This method of curing is more generally used than any other, and the greater part of the tobacco produced in the world is air-cured. It is also the easiest and simplest method which can be employed, as the usual practice is to place the tobacco in the curing barn, where it remains until thoroughly cured and ready for preparation for market.

Air-curing may be described as a natural process of curing, as the tobacco is merely harvested, placed in the barns, and allowed to cure by natural atmospheric conditions. If the weather conditions are ideal good results are obtained, but if wet weather prevails severe losses may result from "pole sweat." On the other hand, should excessively dry, hot, windy weather occur immediately after harvesting, the leaf may be killed prematurely, which greatly reduces the value of the tobacco. In recent years air-curing has, in certain tobacco producing areas, been modified by the use of artificial heat and moisture, which enables the growers to regulate curing conditions and thus to prevent loss after the crop is harvested.

The conditions most suitable for air-curing are clear, calm days, moderately dry atmosphere, and a temperature of 80° to 90° F. in the shade. Under these conditions the moisture is absorbed by the atmosphere as fast as it is given off from the leaf, and very little oxidation takes place, excepting in wet weather, so that the leaf cures moderately bright in colour.

Normally, all tobacco should take on a yellow colour before it begins to dry. If the tobacco dries out before the yellow colour appears the leaf will remain green and be of very little value. If drying is delayed after the yellow colour appears, oxidation takes place, and the colour will change to red or brown. The purpose for which the tobacco is to be used largely determines the proper colour of the cured leaf. For cigarette purposes the leaf should be lemon-yellow in colour; for cigars, the most desirable colours are shades of brown and olive; for chewing purposes and pipe mixtures a light red colour is most desired. The conditions of curing, then, should be regulated to produce tobacco most suitable for local market requirements. The time required for air-curing varies from six weeks to three months, depending prlmarily on weather conditions, but also on the size of the tobacco being handled.

In the Union of South Africa the buildings used for air-curing are very simple in construction, but in other countries where this method of curing is practised, the tobacco barns are very costly and elaborate. Air-curing barns in South Africa can be divided into three types, according to the material used in their construction. The three types are brick, corrugated iron, and grass. The results obtained at the Rustenburg Experiment Station of the Tobacco and Cotton Division indicate that the best results are obtained from the curing-sheds covered with thatch. Both grass and corrugated iron may be used in the construction of sheds.

Sun-Curing.—Turkish tobacco is sun-cured, and this method is also employed in certain parts of America. Sun-curing is similar to air-curing, in that no artificial heat is employed to facilitate curing. The two methods differ in that curing is hastened by exposing the leaf to the direct rays of the sun in the one, whilst in the other the rate of curing is largely regulated by atmospheric conditions.

For sun-curing, the equipment required consists of a wilting room and packing shed, scaffolds or trellises for exposing the leaf to the sun, and a conditioning cellar for rendering the leaf pliable, so that it can be prepared for market.

In sun-curing, the whole plant is usually harvested, but the single-leaf method can be used when sun- and flue-curing are combined. The usual method of sun-curing embraces the following operations: The tobacco is harvested just before it is fully ripe and placed on sticks in the wilting room until the leaf takes on a greenish-yellow colour. If no wilting room is available the tobacco can be yellowed under grass, but requires careful attention to avoid damage through the leaf becoming too warm and turning black. When the leaf is properly yellowed, it is removed to the scaffolds and exposed to the sun until the whole leaf, including the midrib, is thoroughly dry. During this time some form of covering should be provided to protect the tobacco from rain and from dew at nights. For this purpose sail-cloth, hessian, or grass mats can be used. The coverings are placed in position at night or during showers, and are removed in the early morning, or after showers have passed, to allow the tobacco to receive the full rays of the sun. When the leaf is thoroughly dry the tobacco is removed in the early morning to the conditioning cellar, where it remains until the leaf is pliable, when the tobacco is graded and either bulked or baled for marketing.

The time required for sun-curing varies from four to six weeks, depending on climatic conditions and the size of the leaf being cured.

Growers who practise sun-curing should time their plantings so that the tobacco will be ready for harvesting about the time that the rains normally cease. This will save considerable trouble and expense, besides aiding in the production of better quality tobacco.

Sun-cured tobacco of the Virginia type possesses certain desirable qualities as compared with air-cured leaf. Leaf cured by this method is usually lighter and more uniform in colour, as well as sweeter and more aromatic. Sun-cured tobacco is desirable for chewing and for pipe mixtures.

This method of curing can be recommended for certain areas where only heavy tobacco can be produced, and is especially useful in connection with flue-curing. Unless tobacco yellows in the field it is extremely difficult to obtain a satisfactory cure in the flue-barn. The leaf, which is heavy, oily, and unsuitable for flue-curing, can be sun-cured until the web of the leaf is dry, and the midrib can then be killed in the flue-barn. The combination of the methods reduces the time required for curing and produces a more desirable product.

Fire-Curing.—In this method artificial heat is used to hasten curing as well as to develop the characteristic flavour and aroma of fire-cured tobacco. As the name implies, heat is applied by means of open fires directly beneath the tobacco. The smoke from the burning wood imparts a creosotic flavour and a particular aroma, and at the same time improves the keeping quality of the cured product. Tobacco cured by means of open fires is greatly in favour in Europe, where it is used for various manufacturing purposes. There is also a considerable demand for this type of leaf on the West Coast of Africa, but there is no local demand.

For fire-curing, tobacco should be heavy in body, smooth in texture, with large oily leaf, and rich in nitrogenous constituents. The soil for the production of tobacco suitable for fire-curing should be well drained, naturally fertile, and the growth of the plants further increased by heavy applications of manure or fertilisers. The plants are topped low, so that only large leaf is produced, and the tobacco should be allowed to become fully ripe before harvesting.

The whole plant is harvested and placed on sticks in the field. After the tobacco has slightly wilted it is carried to the curing barn and hung in tiers with the sticks of tobacco about six inches apart. No fires are started until the leaf yellows, which requires from four to six days. Small fires are then made at intervals on the floor of the barn, and the temperature is slowly increased to 90° F. during the first twenty-four hours. The temperature is then gradually raised by regulating the fires to about 125° in three or four days, when the web of the leaf should be partially dry. The fires are then removed and the leaf allowed to become pliable through the moisture spreading from the midrib through the leaf web. Fires are then restarted and the leaf again dried. This operation is repeated until the leaf, including the midrib, is thoroughly cured. The leaf is then brought into condition, stripped from the stalk, graded, and either bulked or packed. In fire-curing, care must be taken not to increase the temperature too rapidly in the early stages, or the leaf will dry prematurely and be of little value. From two to three weeks are required to effect a proper cure by this method. The barns for fire-curing are usually small, so that they can be easily filled with tobacco of uniform ripeness, simple in construction, and inexpensive. This method of curing tobacco is not used at present in any part of South Africa.

Flue-curing.—In this method the rate of curing is regulated by the use of artificial heat, which is distributed by flues passing around and through the inside of the curing barn. The heat is generated by wood fires in furnaces, and radiates from the flues, so that the flavour and aroma of the leaf are not influenced or contaminated by smoke, as in fire-curing. Heat is applied continuously from the time curing is commenced until all of the leaf in the barn is thoroughly dry.

Flue-curing is the most modern method, and also the most scientific, of curing tobacco, and requires careful attention to each detail. Good tobacco can be completely ruined in the curing process, while leaf of apparently poor quality can be considerably increased in value through skilful curing. The colour most desired in flue-cured tobacco is a lemon-yellow, as this grade of tobacco is greatly in demand, and realises the highest prices. In any crop of tobacco, however, the cured leaf will show all colours, from bright yellow to dark brown. Green is the colour least desired, and care should be taken to regulate the curing, so that the leaf of this class will be reduced to a minimum.

In flue-curing, the aim of the tobacco-grower is to hasten the yellowing of the leaf, and when the proper yellow colour is obtained, to cure out the tobacco so that it still retains the desired colour. To secure this end five things are necessary: (1) Suitable soil, (2) proper cultural operations, (3) suitable climatic conditions during the growing season, (4) the leaf to be harvested at the proper stage of ripeness, (5) correct management of the barn during curing.

Many formulas have been given for curing tobacco by this method, and any one of them is correct under certain conditions; but, unfortunately, it is not possible to alter all conditions to suit any particular formula. Tobacco grown on different types of soil, and often tobacco grown on different parts of the same field, requires different periods of time to yellow and to dry out. The same applies to the leaf harvested at different periods from the same plants on any given soil. It can therefore be seen that the formula which is correct in one case would be slightly wrong in another. Although no fixed and definite formula can be laid down, it is possible to give some general directions which, with good judgment, the grower can modify to suit his particular conditions. In flue-curing tobacco, which has been harvested by the single-leaf method, there are three stages to be observed—viz., yellowing the leaf, fixing the colour, and drying the leaf and midrib. If the whole plant is harvested a further stage is required to kill the stalk.

The barn should be filled in one day with leaf of the same texture and in the same stage of ripeness, so that all the leaf in the barn will yellow at practically the same time. When filled, the barn should be tightly closed to prevent the escape of moisture, and a small fire started in each furnace. When the fires are started a thermometer and hygrometer are placed in the centre of the barn on a level with the first or lower tier of tobacco. The hygrometer is used to indicate the amount of moisture in the atmosphere of the barn, and is of great assistance during this stage of curing.

At first, only small fires are required, but these are gradually increased until the thermometer registers about 90° F. It is imperative that low temperatures be maintained at first, as high temperatures would kill the leaf prematurely before it changed from green to yellow; tobacco so cured has practically no value. A temperature of 90° F. is maintained until the leaf begins to yellow around the edges and at the tips, when the heat is raised to 95° F. and held until the colour begins to spread. The temperature is then increased to 100° F. until the yellow colour becomes more pronounced. During this time the atmosphere of the barn should be kept moist to prevent the leaf from drying. This is when the hygrometer is invaluable. Enough moisture must be kept in the atmosphere of the barn during this period, so that the temperature registered by the wet bulb of the hygrometer will not be more than 3° to 4° below that registered by the dry bulb. If a depression of 3° could be maintained the leaf would yellow more rapidly and more uniformly. When the wet bulb registers more than 4° below the dry bulb it indicates that the atmosphere in the barn is becoming too dry, and artificial moisture must be introduced into the barn. This can be done by wetting the walls below the tobacco, by pouring water over the floor, or by placing wet bags on the flues. When the leaf begins to show a distinctly yellow colour the temperature is increased to 110° F., and held until the leaf is practically yellow, when the heat is raised to 115° F. and held until the leaf takes on the proper yellow colour. From 100° F. to 115° F. the amount of moisture in the atmosphere of the barn is reduced until the wet bulb registers from 6° to 7° below the dry bulb.

When the tobacco is properly yellowed the barn must be so managed that no further change of colour takes place in the leaf. This is the critical stage in curing, and requires the closest attention and the most careful manipulation. If the atmosphere of the barn is too humid, or if the ventilation is not sufficient and the temperature is not increased fast enough, moisture will collect on the surface of the leaf and the tobacco will turn a reddish-brown colour, or "sponge," which decreases its value. On the other hand, if too much ventilation is given, and the temperature is increased too rapidly, the leaf will be killed too quickly and a greenish red or black colour will develop, which greatly reduces the value of the leaf. The proper conditions are maintained when the barn is so ventilated that the moisture is carried off as fast as it comes to the surface of the leaf, and the temperature is so regulated that the colour will be fixed in fifteen to eighteen hours.

To secure these conditions the bottom and top ventilators should be slightly opened and the fires increased to maintain the temperature at 115° F. The ventilation and heat are increased and the temperature kept at 115° F. until the tips of the leaves begin to curl, when the temperature is increased to

120° F. and held until the leaf begins to dry. This condition is indicated by the leaves curling in towards the midrib. The temperature is then increased to 125° F., and held until the leaf appears to be dry, when the colour will be fixed.

To dry the leaf thoroughly the temperature is increased to 130° F. in two hours, and held at this point for about four hours, and then raised to 135° F. in one hour and held for four hours, when the web of the leaf should be quite dry. The ventilation is then reduced, and the temperature increased about 5° per hour up to 160° F., and held at that point until the midrib is dry enough to snap when bent between the fingers. If the whole plant is being cured the temperature should be increased to 180° F., and kept for eight to ten hours to dry out the stalk thoroughly.

From four to six days are required to cure a barn, depending principally on the length of time required for the tobacco to yellow. The above temperatures are only given to serve as a guide, and each grower must modify them to suit the conditions which, according to his judgment, are existing at the time he is curing.

It might be well to point out that the rate of curing is influenced considerably by the temperature of the outside atmosphere, which replaces the air in the barn during ventilation. It will be found that higher temperatures are required in wet weather than in dry weather, and that lower temperatures are required in cool weather than in warm weather.

Management after Curing.—Regardless of the method used in curing, tobacco can be either increased or decreased in value by the method of handling employed after the leaf is cured. If properly handled, the colour and quality of the leaf will improve, but if improperly handled considerable loss must occur.

The proper method of handling tobacco is to bring the leaf into condition after curing and place it in bulks or stacks of convenient length and width and about six feet in height. Bulking can either be done with the leaf on the stick or by removing the leaf. In either case the leaf should be roughly graded and the leaf of different colour and texture placed in separate bulks.

The bulks of tobacco should be carefully watched, and should the leaf begin to heat or mildew through being in too high condition the tobacco should be rebulked.

For handling tobacco in this manner a packing shed with conditioning cellar should be provided. The shed would be used for bulking and grading and the cellar for conditioning the leaf. The size of the building would naturally be altered to suit the requirements of the individual grower. If the grower prefers to use steam for conditioning tobacco, the cellar could be dispensed with and a room suitable for his purpose would be provided. The method of handling tobacco under this system is as follows :—As the tobacco is cured it is bulked until curing is completed. Each stack should be examined at regular intervals to ascertain the condition of the leaf, and if in too high condition the bulk must be turned. After curing is finished the tobacco first cured would be graded and either re-bulked or baled. Any leaf from the bulks which was too dry for handling would be lowered into the cellar or placed in the steaming room to be brought into proper condition.

In grading, the leaf would be sorted into the several grades of brights, mediums and darks. Damaged, perished, or green leaf would be placed in separate grades. After grading is finished, or when sufficient leaf of each grade is ready, the tobacco would be packed for market. In preparing the leaf for market, each package should contain only one grade of tobacco.

Leaf which is harvested ripe but cures out with a greenish colour can be greatly increased in value by this method of handling, as bulking removes the green colour and improves the aroma of the tobacco. Bulking also tends to develop a uniform colour in leaf which is lacking in this respect. Care must be taken in bulking tobacco to obtain the best results. If the tobacco is too dry, the leaf does not improve as it should, and if too moist mildew may develop, or the bright leaf may become darker in colour. When in proper condition for bulking or baling, the web of the leaf and lower half of the midrib, from the tip to the butt, should be supple, but the upper half of the midrib should be only slightly pliable.

The Culture of Turkish Tobacco.

Turkish tobacco is grown in the areas of French Hoek, Paarl, Wellington, and Stellenbosch.

Climate.—As Turkish tobacco is sun-cured, it is essential that there should be no rainfall during the curing period; for this reason it is at present limited to districts having a winter rainfall and fairly dry summer. The rains should cease about one month after transplanting. Should heavy rains prevail when the tobacco is approaching maturity, the gum is washed off the leaf and the cured product is thin, papery, and lacking in body, flavour and aroma.

SOIL.—In the Western Province the reddish, friable loams, containing about 30 per cent. of clay, are considered to be the best. Grey and yellow sandy loams are also used with good results, as are sandy soils of granitic origin.

To combat White Rust (*Macrosporium tabacinum*), the fields should possess good water and air drainage.

FERTILISERS.—For the Western Province, sheep manure applied broadcast—some months before transplanting—at the rate of six tons per acre, is advocated. When commercial fertilisers are used, they are applied in drills at the rate of: Superphosphate, 300 pounds; sulphate of potash, 160 pounds; and nitrate of soda, 130 pounds per acre.

TRANSPLANTING.—The plants are spaced in rows 2½ to 3 feet apart, and 8 to 9 inches in the row. September is considered the best month for transplanting in the Western Province.

VARIETIES.—Kavalla, Soulook, Dubec, Samsum, and Yuca are the most popular varieties. Each variety has its own peculiar characteristics of flavour, aroma, and burning qualities, which are useful in blending mixtures for cigarettes. For this reason each locality should grow the several kinds.

CULTIVATION.—Apart from delaying maturity, cultivation throws dust on the leaves; for these reasons cultivation should cease as soon as the flowers appear.

TOPPING AND SUCKERING.—Turkish tobacco is not topped, and the necessity for suckering does not arise. Should suckers appear they must be removed.

PRIMING.—The small leaves at the base of the plant should be removed before the inflorescence appears. These leaves are thin, papery, lacking in body, and of little value.

HARVESTING.—Turkish tobacco is harvested by the single-leaf method. The correct stage of ripeness is indicated when the leaf is limp to the touch, becomes somewhat transparent, and the clear green colour is replaced by a yellowish tinge. If the plants have grown coarsely, ripeness is shown by flecks of yellow and by brittleness of the veins and midrib. The first leaves harvested are those at the bottom, and these are usually ready for picking when the first flowers appear.

It is best to harvest in the early morning, because the colour is then best determined and the leaves snap readily. Harvesting after heavy rains should be avoided, as after heavy rains the leaf, because the gums and oils have been washed out, is thin and papery.

Usually not more than four leaves are picked from each plant at a time. After picking they are placed in boxes or baskets, taken to the stringing shed, strung, and conveyed to the wilting room the same day. If left over, fermentation might result.

STRINGING.—In order to obtain uniformity in curing, before stringing, the leaves must be graded according to size and colour. Diseased leaves must be discarded. Damaged leaves should be threaded, cured, and baled separately.

The leaves should be threaded so that all face the same way, and the butts must be kept even, so that baling later on will be facilitated. The threaded leaves are tied to laths of bamboo or sticks.

WILTING.—As the laths are filled they are placed in the wilting room, which should be cool, fairly dark, and free from draughts and dust. In this room, usually constructed of brick and thatched, the temperature and humidity should be under control. A temperature of 70° F. is considered an optimum one, and, as regards humidity, the reading of the wet bulb should be $2\frac{1}{2}$° to 3° below that of the dry bulb. Moisture should be added, or the ventilation increased accordingly.

Leaf harvested at the proper stage should remain in the wilting room until it takes on a pale, greenish-yellow colour.

CURING.—The tobacco is then taken from the wilting room to the curing racks in the sun. At first, the laths should be placed close together, and if the sun is excessively hot the leaf should be covered with hessian or cheese-cloth to prevent sunburn. So as to prevent premature drying the laths are gradually put further apart, and the leaf thus slowly exposed to the full rays of the sun.

On the curing racks the leaf gradually changes from a pale to a clear yellow, and then, with drying, to the desired yellowish-brown or bronze of good Turkish tobacco.

The leaf remains on the racks for twelve to fifteen days, then the laths are placed on clean canvas on the ground to complete curing. The laths are turned daily, early in the morning, until the whole leaf, including the midrib, is dry. Curing is usually completed in eighteen to twenty-one days.

Light canvas or hessian must be used to protect the tobacco while on the racks, from dew or light showers.

Treatment after Curing.—In the method employed in South Africa the next procedure is to place the leaf in bulks or stacks of convenient size. The thoroughly cured tobacco is removed from the racks early in the morning, when the leaf is pliable, and bulked while still on the laths. The bulks should be examined daily to ascertain the condition of the tobacco. Should the leaf become hot the stacks should be opened, the leaf exposed to the air for a short time, and then re-bulked. Tobacco should be bulked on plank floors, having plenty of ventilation underneath, or on platforms raised about one foot, to allow a free circulation of air under the stacks. Usually the tobacco should be re-bulked once a fortnight, and if properly handled the leaf will improve in colour and develop the aroma and flavour characteristic of Turkish tobacco.

Grading and Baling.—In the Western Province Turkish tobacco is placed into four grades, known as bottoms, middle-seconds, middles and tops.

The strings of graded leaf are pressed into bales of 80 pounds or more, having the butts of the leaves outward and the tips towards the centre; it is then covered with hessian, secured in place with strong cord.

Treatment after Baling.—In the warehouses, Turkish tobacco must undergo a process of natural fermentation before it is ready for manufacturing purposes. In these the bales are placed in rows, two deep, and covered with heavy canvas to maintain the condition of the leaf. At regular intervals the bales are turned and examined.

When fermentation begins the bales are placed on the floor singly, where they can be easily examined each day. During the fermentation process the warehouse is so managed that the temperature and moisture conditions are kept constant, as sudden changes produce poor results. When the temperature of the baled tobacco begins to decrease the bales are placed on end, and when the temperature becomes normal the bales are again stacked. The tobacco should be turned and examined weekly thereafter for a couple of months, when it is ready for sale.

As the fermentation of Turkish tobacco is not forced, the process depends largely on climatic conditions. Should the weather be uniformly warm, fermentation will be completed in about 21 to 28 days, but should cool weather occur at intervals the process may continue for an additional fortnight.

If fermentation is properly carried out the leaf will be much improved as to colour, flavour and aroma. During this process it might easily be ruined, and the operation should only be undertaken by those thoroughly experienced.

COMPOSITION.—The following analyses of air-dried samples, furnished by the Union Department of Agriculture, give some idea of the variation in composition found in ordinary tobacco :—

Sample.	Nicotine.	H_2O.	Ash.	Ca.	Mg.	K_2O.	P_2O_5.	N.
Strong, good Piet Retief leaf	4.34	5.24	18.05	2.09	5.19	6.83	0.43	3.92
Yellow Kat River leaf ...	0.87	0.57	22.59	4.41	1.02	5.30	0.79	1.26

Tobacco evidently feeds heavily on nitrogen and potash, but only to a small extent on phosphorus—since, on the average, one ton removes nitrogen, potash, and phosphorus respectively, as follows—expressed as sodium nitrate, 300 to 400 pounds; expressed as potassium sulphate, 200 pounds; and, expressed as phosphoric oxide, 6 pounds—the necessity for generous applications of fertilisers is apparent.

NICOTINE AND THE RELATION OF NICOTINE TO QUALITY.—Roughly speaking, the nicotine content in South African tobaccos varies from ·75 to 5·5 per cent., but in *N. rustica* the content may be as high as 8 per cent. At present, the profitable production of extract is limited by the small quantity of waste available. However, the high nicotine content of Pondo tobacco might warrant the cultivation of this type solely for the purpose of nicotine extraction.

The percentage of nicotine contained in the leaf increases with the growth of the plant until it reaches maturity. " Productive soils, heavily fertilised with nitrogenous manures, are held to produce tobacco having a high percentage of nicotine. There is also a varietal variation in the percentage of this alkaloid. As curing proceeds the percentage decreases. The finest grades of tobacco contain only moderate, and even relatively small, amounts of this principle. The term ' strength ' is frequently used to designate the degree of physiological reaction of the system to the use of the tobacco in question, and when thus restricted the strength of a sample depends on the amount of nicotine present. But this term is also frequently applied to the more direct effect of the tobacco or its smoke on the mucous membrane of the throat and nose. The true physiological action which constitutes the satisfying effect to the consumer, so strikingly exemplified in the Havana tobacco, is commonly spoken of as 'fullness' of the smoke, while the relative freedom from the pungent, biting quality is designated by the term 'smoothness.'

"There are two forms of nicotine contained in tobacco, one of which is easily volatile and readily soluble in petroleum ether, while the other is volatile only at elevated temperatures, and is almost insoluble in petroleum ether. The undesirable sharpness or pungency contained in the smoke from certain types of tobacco, and which constitutes one of the two factors included in the term 'strength' as applied to the smoke, is due almost entirely to the volatile, easily soluble form of nicotine, which acts as if it were in the free state. On the other hand, the true physiological effects of the smoke, as embodied in the term 'fullness,' are proportional to the total quantity of nicotine.

"The pungent, harsh quality of the smoke is partially, but not entirely, removed by protracted re-sweating and ageing of the tobacco, whereby the easily volatile nicotine is largely expelled."

Burning Qualities of Tobacco.—It is well known that factors such as character of soil, the climate, wet and dry seasons, the fertilisers applied, and curing, modify the burning quality of tobacco.

"As applied to tobacco, the term 'burning qualities' is a comprehensive one, including several different elements, chief of which are fire-holding capacity, the evenness and completeness of the burn, and the character of the ash. The fire-holding capacity refers simply to the length of time the tobacco will continue to burn. Frequently samples of tobacco which possess a satisfactory fire-holding capacity show a tendency to carbonise, or 'coal,' in advance of the burning area, and will not burn evenly. In cigars, this may be due to poor combinations of filler, binder, or wrapper, or in peculiar chemical properties of the leaf.

"As to the quality of the ash, the important characters are colour and the firmness or cohesiveness. If certain of the mineral constituents of the tobacco which interfere with the combustion predominate, the resulting ash will be dark in colour, while if others which favour the complete combustion predominate, the ash will be white, or nearly so.

"Generally, those substances which show the greatest tendency to burn with a flame have the least capacity for glowing, and *vice versâ;* and this rule is applicable to different kinds of tobacco, for in cases of very rank growth, where the leaf is thick and coarse, or in any dry tobacco markedly deficient in mineral constituents, there is a decided tendency to burn with a flame, whereas the capacity for glowing is lacking.

"The organic constituents of the leaf immediately in advance of the burning area are undergoing the process of dry distillation, in which the volatile products for the most part escape and appear in the smoke. It is this process which gives rise to the aroma.

"(1) The fire-holding capacity is dependent primarily on the content of potash combined with organic acids. (Potassium nitrate in excess causes the tobacco to burn explosively.)

"(2) Lime in general does not affect the fire-holding capacity to any great extent, but is an essential factor in the production of a good ash. However, tobacco containing excessive amounts of lime gives an ash which, although it is very light in colour, lacks cohesion or 'flakes.' The potash salts, more especially the organic compositions, yield an ash which is firm and compact but dark in colour. Potash and lime combined in the proper proportion are essential to a firm, light-coloured ash."[8]

Diseases and Pests.—Probably the worst fungous and bacterial diseases occurring in the Union are Wildfire (*Bacillus solanacearum*), Leaf Spot (*Cercospora nicotianæ*), White Rust (*Macrosporium tabacinum*), and Damping-off Disease (*Corticum vagum*). Of these Wildfire is undoubtedly the most serious at present, the industry in the Rustenberg area being severely threatened by its ravages.

To combat these diseases the best measures are to be found in sterilising seed-beds, disinfecting seed, thorough cultivation, rotating crops, and refraining from growing tobacco on land known to be badly infected.

"Mosaic" or "Calico" disease causes the leaf to grow more rapidly near the veins than elsewhere, and thus causes it to become wrinkled and corrugated. No causal organism has been isolated, and at present it is held to be a physiological disorder, due to defective nutrition.

Root Gallworm (*Heterodera radicicola*) is at times a dangerous pest, particularly on land which has grown potatoes. The nematode causes a thickening of the tissues of the root which interferes seriously with the functions of the plant, causing a feeble growth, wilting, and frequently death of the plant. Land badly infested should be discarded for tobacco and planted to maize or another cereal for several seasons.

Of the insect pests, those given below have proved the most troublesome :—

Tobacco Slug (*Lema bilineata*).—This is probably one of the worst pests, particularly in seed-beds. It is readily controlled by spraying with a solution of arsenate of lead, two ounces (powder) to four gallons of water.

Split-Worm Leaf-Miner or Stem-Borer (*Phthorimæa operculella*).—It does most damage in the seed-bed. Seedlings having swellings on the stems should not be used as transplants. Spraying with a solution of arsenate of lead of the strength given for the Tobacco Slug is effective.

Cutworms (*Agrotis spp.*) and Surface Beetles (*Gonocephalum spp.*).—These are destructive to the young transplants. They are best controlled by clean cultivation and winter ploughing.

Tobacco Bud Worm (*Chloridea obsoletea*) damages the seed capsules. After examining the seed-heads for larvæ the manilla bags should be left on. The seed-heads should be examined periodically in order to make certain that no larvæ have been overlooked.

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CHAPTER XIII.

SUGAR CANE

ORIGIN AND HISTORY.—" Sugar cane was first grown in Southern Asia, whence it spread into Africa and later into America. The original habitat of the species is not definitely known, but is believed to have been in India, Cochin-China and the Malay Archipelago. It is at present cultivated in all the warm regions of the world."

Sugar cane was first grown for commercial purposes in Natal about 1850, but there is evidence that it was grown by the natives before this. In 1859 the crop was fast becoming an important one, native labour was found unsatisfactory and the Government of the day legalised the importation of coolies from India.

PRODUCTION.—In 1862, 846 tons were exported from Natal, but until recently comparatively little has been exported. In 1917-18 the total area under cultivation was 184,213 acres. During 1916-17 there were 163,000 acres cultivated and the value of the production of the sugar mills and refineries was £3,134,424. In 1919, 189,000 tons of sugar were produced, and the value of sugar and sugar products exported was £488,000.

In 1917 the following by-products were obtained :—

Natalite	1,004,360 proof gallons.
Syrup	1,600 tons.
Treacle and molasses .	2,366 tons.

Hitherto the annual production has not equalled the local consumption. In 1918, 17,000 tons were imported, but in 1919, 19,000 tons were exported. It is anticipated that sufficient can easily be produced for local requirements. The industry is at present protected by a tax on foreign sugar.

The leading countries in cane sugar production in order of production are :—

India	2,700,000	tons	(approx.)
Cuba	2,600,000	,,	,,
Java	1,600,000	,,	,,
Hawaiian Islands	600,000	,,	,,
Porto Rico	400,000	,,	,,
United States	360,000	,,	,,
Brazil	250,000	,,	,,
Mauritius	230,000	,,	,,

Roughly speaking, half the world's production of sugar is from sugar cane, the remaining half from sugar beets.

DESCRIPTION AND VARIETIES.[5]—" Like other grasses the cane plant shows no tap root, but an adventitious root system springs from the nodes or joints of the stem. This stem may take the form of : (1) Underground mother cane (planted) ; or (2) mother-stalk, being a secondary underground prolongation of the mother-cane ; or (3) of sub-aerial cane, as harvested for the mill. In the second case the internodes between the joints may be restricted in length and the nodes closely crowded, but in all three cases there is uniformity in the essential features. With each node is associated a stem-bud which on development gives rise to either a sub-aerial cane, or to an underground mother-stalk. Two or more circles of transparent dots representing embryonic roots, and in the case of sub-aerial stems a single large and leaner leaf, the base of which at first clasps the internode above the insertion, receding from the stalk during growth and falling off at maturity.

" It is to be noted that the joints of the cane mature and cast their leaves in succession from the ground upwards, and that the shedding of the leaf is an indication of the ripeness of the joint from which it had originally sprung. The upper joints or tops of the canes consequently carry green leaves, and are relatively immature until the final stages of the development of the individual stalk is attained. Should ' arrowing ' or flowering occur, further special growth naturally ceases. Non-flowering varieties are, consequently, in general preferred, as in such cases no check in growth is imposed while weather conditions are favourable."

During protracted wet weather the buds of standing cane may sometimes commence growth, and it is an undesirable characteristic of some varieties, as the milling quality is considerably lessened.

The inflorescence of the cane is a panicle of soft, silky spikelets, borne on the end of an elongated peduncle, called the "arrow," arising from the terminal vegetative point of the cane. It is only exceptionally that the cane forms fertile seed. Some varieties never flower, and others do so only in the tropics. The age at which the cane flowers varies from eight to fifteen months, and is dependent on variety and climate, and also on time of planting. In Natal the growing season is too short to allow the cane to mature sufficiently for flowering to take place.

THE CHOICE OF "SEED."—"The immaturity of the top joints of the cane is associated with a low content of sucrose, or crystallisable sugar, and a large proportion of glucose or molasses sugar. The tops have consequently little or no value for milling, and are removed in practice before the cane is dispatched to the mill. The planting period in Natal coincides with the latter end of the milling season, and, therefore, an ample supply of tops, which would otherwise be a waste product, is available for 'seed.' Experiments in which the different parts of the cane have been planted show the tops to be as productive as the other portions."

BOTANICALLY, sugar cane (*Saccharum officinarum* is a grass belonging to the Andropogoneæ.

The plants are 6 to 20 feet in height, and the culms often as thick as medium-size bamboos—1 to 3 inches in diameter.

The species *Saccharum officinarium* is divided by Hackel into three groups :—

(*a*) *S.O. genuinum*.—Stem, pale green to yellow; darker yellow near the ground. Leaf, grass-green, underside sea-green.

(*b*) *S.O. violaceum*—Stem, leaf, sheath, lower sides of leaves and panicle, violet.

(*c*) *S.O. litteratum*—Stem, dirty green or yellow, marked with dark stripes at equal intervals.

A great many varieties have been tried in South Africa, but at present the greater part of the acreage planted grows the Uba variety, which has displaced the soft canes.

UBA VARIETY.—This was imported from India in 1884-5. It is a somewhat thin cane, yellowish to yellow-green in colour. It is hardy, ratoons excellently, so that where conditions are favourable, four to five ratoon crops may be obtained; it is deep-rooting, and very adaptable to a variety of soils; it is resistant to fungous and insect pests. It produces no fertile seed under ordinary conditions, hence crosses will be difficult to obtain. Uba has a higher fibre content, and requires more power to crush than the softer varieties.

AGUAL.—Resembles Uba in many respects, but is more vigorous and rapid-growing. It is a recent introduction from India.

SOFT CANES.—" These canes are much thicker than the Uba, and the individual canes several times heavier than the individual Uba canes. They are not adapted for growth upon hill soils, but find conditions best suited for their growth in the richer, heavier alluvial and vlei lands. Generally speaking they compare badly with the Uba variety. They are strictly limited to certain areas, shallow rooted, poor in ratooning, more liable to be attacked by fungoid diseases and insect pests, and suffer more from winds. They likewise suffer very much during droughty spells. They yield heavier returns for the first year than the Uba, but after one season's growth they ratoon badly, and subsequent crops cannot compare with the ratoon crops of the Uba, and thus are seldom grown in this country."[2] In other parts of the world the soft canes are largely grown, but in such parts planting is usual every year—largely because of very cheap labour and favourable growing seasons—and powers of ratooning are not of great value where annual planting is the practice.

CLIMATIC REQUIREMENTS AND DISTRIBUTION.—Sugar cane is essentially a tropical plant, and requires high mean temperatures with a heavy rainfall. Consequently, it does best in the warm, moist climates of islands and sea coasts within the tropics and sub-tropics. High humidity seems also necessary. Low temperatures are very detrimental, and frosts are injurious, because they cause the canes to burst and, moreover, difficulty is found in getting the juice of frosted cane to crystallise.

Sugar cane is grown for sugar manufacture in the Union only in Natal and Zululand. In Natal the limit of profitable sugar cultivation is Port Shepstone, on the south coast;

whilst northwards the area extends throughout Zululand. Zululand is better suited for cane culture than Natal, owing to the longer growing season. Parts of Zululand and Portuguese East Africa have a rainfall of 50 inches and more, while the Natal coast has only 35 to 45 inches. In parts of Swaziland and Zululand—*e.g.*, the Lobombo Flats, where cane cannot be grown at present because of the low rainfall—excellent possibilities for growing the crop under irrigation present themselves. Rivers, such as the Pongola, can be readily diverted and used to irrigate the cane, which could then be cultivated on the flat land between the mountain ranges. Such development would be dependent, of course, upon railway extension.

The highest production is found in parts of the world having nearly 100 inches of rain per annum. In Zululand yields up to 50 tons per acre are obtained, and in Natal a yield of 25 tons per acre is considered good. The cane reaches maturity in Zululand in about 18 months, but requires from 20 to 24 months in Natal. In some parts of the world it is an annual crop.

Heavy rains at the time of maturity may be detrimental to sugar formation. Hot and fairly dry weather is required at this time to increase the sugar content.

For stock-feeding purposes, sugar cane can be grown very successfully in the greater part of the Union—*i.e.*, those areas having a fairly high summer rainfall.

It is a bulky crop, and is, consequently, limited to areas having favourable transport facilities.

Soil Requirements.—The crop does best on calcareous loams containing plenty of humus. Compared with crops like wheat it does surprisingly well on relatively sandy soils. In the sugar cane belt two classes of soil predominate—(1) the red or chocolate ferruginous sandy loam found on the hillsides, which is easily worked and when properly manured is a very fertile soil; and (2) black vlei soils. The latter are very productive in favourable seasons, but crops are apt to suffer from water-logging and being low-lying the plants often suffer from low temperatures.

"An excessively saline condition, which is liable to be found on flats along the sea coast, is also detrimental to sugar cane, impregnating the juice with salt to such an extent as to cause much trouble and expense in the manufacture of sugar."

Manuring.—Experiments in Natal show the necessity of liming, 500-800 lbs. per acre at the time of planting is recommended on the ordinary soils. Green-manuring is necessary where the practice is to burn the trash, but if it is ploughed in the nitrogen requirement is met and the humus content maintained. Applications of mineral nitrogenous fertilisers have not proved beneficial. Phosphates are usually urgently required, and superphosphate 200 lbs., and bone meal 300 lbs. should be applied at the time of planting, and for the first and second ratoon crops.

Experiments at Winkel Spruit showed beneficial results from 100 lbs. of potasium chloride when used in conjunction with 120 lbs. of superphosphate. Sawer says: "It is generally agreed that a substantial proportion of the fertilisers intended to be applied for the use of the plant cane should be incorporated with the soil in the furrow at the time of planting; but one-half of the total dressing of phosphates and potash may, with advantage, be reserved for later application. This is to be done by ploughing a furrow 8 to 9 inches in depth on each side of the cane row, at a distance of about a foot from the stools. The fertilisers, carefully mixed immediately before planting, should be spread at the bottom of the furrow, and a small plough, set to a depth of 5 to 6 inches, should be used to cover them with a layer of soil. This dressing should be given at the commencement of the spring following on the planting of the cane."

It is common practice to use the molasses from the centrifugals, and the press cake derived from the liming of the juice is returned to the land as manure; 800 lbs. being used per acre.

Soil Preparation and Planting.—The usual practice in Natal is to plant every 8 to 12 years, consequently the preparation of the soil should be as thorough as is economically possible. If the land is still in the virgin state it should be ploughed sufficiently early to ensure complete decomposition of the natural vegetation. On the larger estates ploughing is done by steam ploughs to a depth of 12 to 20 inches. In many cases, however, ploughs are ox-drawn, and the land is ploughed as deep as possible. Ordinarily, the ground is ploughed, disced, cross-ploughed and harrowed. Furrows are then drawn five feet apart. A practice advocated is to plough 6 inches deep; then re-plough the same furrow to a depth of

4 inches, making 10 inches in all. Naturally, earth falls in again and the cane is planted in this and then covered by shallow ploughing. As cane land is valuable, fields that are impossible to plough are planted by hand. Here holes are made (by hoes) 1 foot by 8 to 10 inches and 18 to 24 inches long, with a space of 6 to 18 inches left between the holes.

The crop is propagated by planting canes. Seed is used only in breeding work, and in South Africa it is rarely formed. Healthy, vigorous cane is used, and is chosen from plant cane or first ratoon cane. The upper portion is cut into lengths having four or five buds each when the canes are twelve months old—that is, before the rind has hardened; these tops are then laid parallel at the bottom of the furrow, overlapping alternately.

Planting is dependent on rains, but takes place usually in August and September, although it may be planted as late as January. To prevent erosion and leaching rows, as far as possible, should follow the contours of the hills, and not up and down slopes. Three to four tons of tops are required to plant an acre.

Cultivation between the rows is necessary to keep down weeds and is continued until the cane covers the ground.

Harvesting.—In Natal plant cane is ready to be cut in about 22 months; ratoon crops take about 20 months to mature.

No suitable machine has been devised for harvesting, consequently it is cut by hand with cane-knives. The lowest portion of the plant is richest in sugar, and it should therefore be cut as low as possible. It is " topped "—one or two joints taken off with the tops and trashed—*i.e.*, the leaves removed. The canes are collected by wagon, trams, trains, overhead cables, etc., and taken to the mills.

Cane usually matures from the middle of June to the end of November. Maturity on the larger estates is determined by chemical analysis. Where the capacity of mills is limited, cutting commences in April, and may continue until December.

All discoloured canes are discarded on the fields, as well as those showing rodent or other injury, as these are liable to cause undesirable fermentation.

In Natal 30 tons per acre is considered a good yield, although up to 60 tons have been obtained; and when the yield yield falls below 20 tons per acre replanting is considered necessary. The first and second ratoon crops are usually the heaviest; after this the yield diminishes rapidly, consequently the fourth to fifth ratoon is the last crop taken. One ton of sugar is obtained from every 8½ to 12½ tons of cane.

The best time of harvesting in Natal is from August to October; *i.e.*, during the drier part of the year, and when the sugar content is highest.

KEEPING QUALITIES OF CANE.—The sugar content decreases rapidly after cutting, consequently no delay should occur in getting the cane to the mills. This is borne out by the result of the following experiment :—[2]

	Days Cut. 0	1	2	3	4
Available sugar (original sample 100)	100	97·3	92·0	78·6	67·9

IRRIGATION.—The crop responds very readily to irrigation and in many parts of the world it is common practice to give 60 inches of water in this way. In Natal however, all cane is grown without irrigation. In parts of Zululand irrigation might be possible and, consequently, an annual crop might be produced of varieties in some ways superior to Uba.

Composition.— Uba (Pearson).

	Average.	Maximum.
Total solids in juice percentage ...	20·32	22·79
Sucrose ,, ,,	18·61	20·79
Glucose ,, ,,	0·18	0·27
Non-sugars ,, ,,	1·53	1·73
Glucose ratio ,, ,,	1·00	1·30
Purity ,, ,,	91·20	97·60
Percentage juice in cane	82·30	84·28
Percentage fibre in cane	15·72	17·70

The above analyses show a large percentage of fibre in the cane, but indicate no inferiority in the juice; in fact, the quality of the juice so far as disclosed by analysis, would not be readily surpassed anywhere.

As a forage plant, sugar cane must be looked upon as being very deficient in nitrogen, but high in carbo-hydrates;

consequently, nitrogenous concentrates should be supplied to rectify the deficiency.

The use of alkaline manures affects the composition of cane appreciably. Within the limits of ordinary applications the composition is not affected very noticeably, unless phosphates are absent in the application.

Milling and Uses.—The cost of a modern full-sized milling plant is very high, in the neighbourhood of £500,000, consequently these are usually erected and run by companies, who grow the major part of the cane which they mill. The smaller growers sell their cane to the mill-owners at 14s. to 16s. per ton.

The cane is conveyed by belts and crushed by means of rollers. About 75 per cent. of the juice is extracted, and the bagasse is often used as fuel to run the mill.

" By the usual process of sugar extraction, the juice from the crushed cane is at once heated to a temperature of 190° to 200°F. to clarify it. Lime is added to the juice at the same time to assist the process of clarification. Sulphur phosphoric acid, and other chemicals have also been used for the same purpose. The purpose of adding lime is to precipitate various impurities out of the juice. After this process of clarification the juice is at once filtered in large filter-presses, for the purpose of removing the mud and the precipitated impurities. The juice is then boiled in a multiple series evaporating apparatus to the consistency of syrup. It contains in that stage about 55 per cent. solids in solution. The syrup is then boiled in vacuum pans until it is condensed to the point where it separates into crystalline sugar and uncrystallisable molasses. The whole mass at this stage is called massecuite. The crystallised sugar is then separated from the molasses by centrifugals, the sugar crystals being caught on a fine wire-gauze strainer, with 400 to 500 meshes to the inch, while the molasses is thrown out by centrifugal force. The crystallised sugar is removed from the centrifugal and at once packed for export as raw sugar.

" The machinery concerned in the manufacture of sugar has reached a stage of great elaboration and of striking perfection. The whole process is a continuous one from the time the cane arrives at the mill until the sugar is sewed up in the bags."[8]

The molasses is used in the manufacture of alcohol and rum, to a certain extent as a stock-food (digestive troubles are found to occur if fed too liberally), and by many as a cane fertiliser.

The "tops" are often fed to animals on sugar estates. As a forage and silage crop, sugar cane has much to recommend it at lower altitudes and parts having a good summer rainfall. It is perennial, high-yielding, and of considerable feeding value, when supplemented with nitrogenous concentrates.

Disease and Pests.—Uba cane is comparatively free from disease. Cane spume (*Pseudomonas rasculanum*) does not affect this variety; it is also immune to the Cane Mealy bug. Cane smut (*U. sacchari*) is sometimes present, but seldom very serious. The cane rat, and, in some places, the Cape monkey, cause considerable damage.

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CHAPTER XIV.

WHEAT

INTRODUCTION.—The annual production of wheat has the greatest money value of the world's crops.

AVERAGE WORLD'S PRODUCTION, 1912-14.

Europe	1,957,103,000	bushels.
North America	1,010,606,666	,,
Asia	559,257,000	,,
South America	181,539,666	,,
Australia	98,073,333	,,
Africa	75,490,000	,,

The average yields per acre in the leading wheat-growing countries for the years 1911 to 1913 are as follows :—

	Bushels.	Bushels per acre.
United States	705,000,000	14·3
Russia (European)	677,800,000	10·0
India	368,200,000	12·0
France	357,700,000	20·5
Austria-Hungary	247,030,000	17·7
Canada	228,700,000	20·8
Italy	190,800,000	17·3
Argentine	170,200,000	10·7
Germany	160,000,000	32·5
Australia	88,930,000	12·2
Algeria	33,260,000	9·5
Egypt	33,320,000	25·2
Union of South Africa—		
1911	6,034,000	7·5
1917-1918	10,140,000	10·2

The production per acre in Europe and North America shows a marked increase in recent years—*e.g.* :—

		Average yield per acre.
Germany ...	1911 to 1913	32·5
	1900 to 1910	28·9
	1890 to 1899	24·5

This increase is, no doubt, due to the better varieties and machinery introduced, as well as to heavy applications of fertilisers, the generally improved methods employed in very intensive farming, and the increased use of concentrates.

The greatest increase in production is found in Argentine.

In 1911, England averaged 33·8 bushels per acre.

South African Production.—This has increased enormously under conditions created by the Great War. The production, however, is likely to fall as soon as the world's transport services become normal, and prices fall accordingly. At present the Union produces about 60 per cent. of her home consumption; Australia furnishes about 85 per cent., and Argentine 15 per cent. of the remaining 40 per cent.

Australia produces wheat much more cheaply than does South Africa, and should the import duties and railway tariffs on imported wheat be abolished, the South African production is likely to fall lower than her pre-war production.

The Provincial and Union production in pounds is given below:—

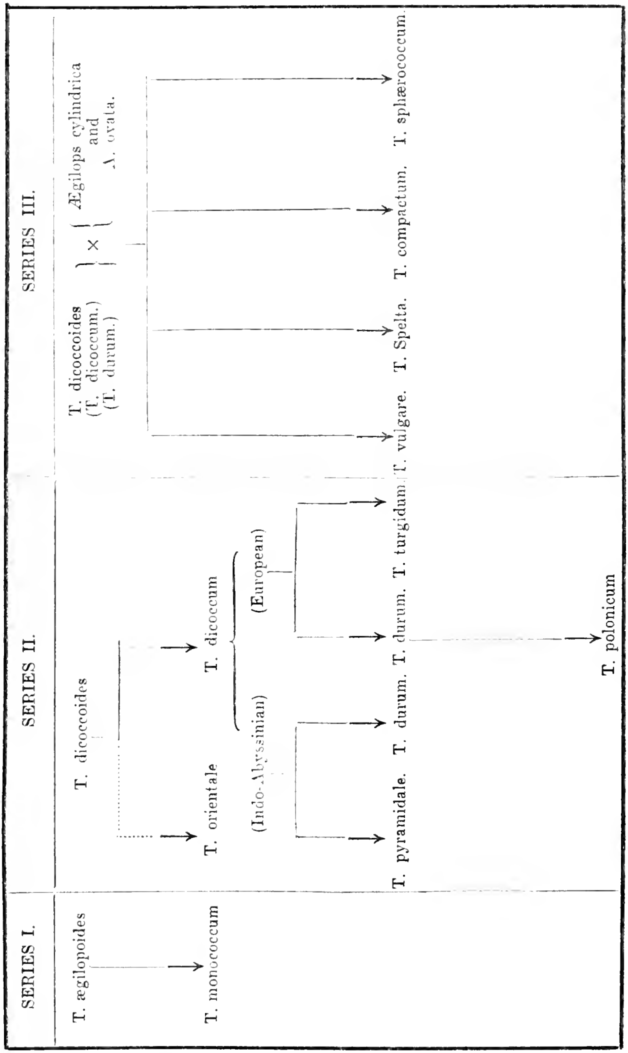
	Cape.	Natal.	Transvaal.	O.F.S.	Union.
1911	261,001,000	1,446,000	53,098,000	46,518,000	362,063,000
1917-18	496,342,000	849,000	48,627,000	63,153,000	608,971,000

The Cape Province produces nearly 85·90 per cent. of the Union's output. The wheat produced in the Orange Free State is nearly all grown in the eastern districts—*i.e.*, the "Conquered Territory," on dry lands; but its cultivation here is being gradually displaced by maize.

Wheat is a crop limited to areas of winter rainfall, and as these areas are the South-West Cape districts and Namaqualand, wheat production is likely to continue there. Except on irrigated land, in the remaining parts of the Union, the crop is so uncertain that summer crops—*e.g.*, maize—will gradually take its place. Valuable irrigated land suitable for lucerne, tobacco, etc., will grow very little wheat as the former are more profitable. Irrigated lands, though, at some distance from the railway, will probably continue to grow wheat.

Origin and Classification.—Specimens have been found in Switzerland in the ruins of the Stone Age. Chinese history emphasises its importance in 2700 B.C.

Percival[9] believes the phylogenetic relationship of the several races of wheat to be as follows:—



The dotted line indicates dubious relationship.

Regarding the number and classification of the races of wheats, Percival[9] has concluded as follows :—

SPECIES	I.—T. aegilopoides, Bal.	..	Wild Small Spelt.
RACE	I.—T. monococcum, L.	..	Small Spelt.
	II.—T. dicoccoides, Körn	..	Wild Emmer.
	II.—T dicoccum, Schübl	..	Emmer.
	III.—T. orientale, mihi ..	..	Khorasan Wheat.
	IV.—T. durum, Desf. ..	..	Macaroni Wheat.
	V.—T. polonicum, L. ..	..	Polish Wheat.
	VI.—T. turgidum, L. ..	..	Rivet or Cone Wheat.
	VII.—T. pyramidale, mihi	..	Egyptian Cone Wheat.
	VIII.—T. vulgare, Host ..	..	Bread Wheat.
	IX.—T. compactum, Host	..	Club Wheat.
	X.—T. sphaerococcum, mihi	..	Indian Wharf Wheat.
	XI.—T. Spelta, L. ..	..	Large Spelt or Dinkel.

Diagnostic Characters of the Species and Races of Wheats.

Species 1.—*Triticum ægilopoides*, Bal. Wild Small Spelt. Coleoptile, 2-nerved.

Young shoots, erect or prostrate, young leaves blue-green or yellow-green more or less hairy, with a line of long hairs on the summit of the longitudinal ridges.

Straw, slender, nodes clothed with white deflexed hairs.

Ear, bearded compressed, very narrow across the face, broad across the 2-rowed profile; Spikelets 1-(or 2) grained; terminal spikelet minute and abortive; rachis very fragile and fringed along the margin with long straight hairs.

Empty glume, long, narrow, keeled to the base with stout, acute apical tooth often turned slightly outwards; on the outer face a prominent nerve ending in a distinct secondary tooth, some distance from the base of the aspical tooth.

Palea, in ripe ears divided longitudinally into two halves.

Grain, small, rice-like, flinty, pointed at both ends, compressed from side to side, gurrow indistinct, tip with few hairs.

Race 1.—*Triticum monococcum*, L. Small Spelt; Einkoorn : Engrain.

Coleoptile 2-nerved.

Young shoots, erect or semi-erect, young leaves yellowish-green, with very short hairs or scabrid projections on the longitudinal ridges.

Straw, slender, nodes clothed with deflexed hairs.

Ear, bearded, compressed, much narrower across the face than the 2-rowed profile; spikelets 1- (or 2) grained; terminal spikelet minute and abortive; rachis fragile, glabrous, or edges fringed with short hairs.

Empty glume, long, narrow, keeled to the base with a stout, acute, apical tooth, straight or turned slightly inwards; the prominent nerve on the outer half ends in a distinct secondary tooth some distince from the apical tooth.

Palet, divided longitudinally to the base when the ear is ripe.

Grain, as in *T. ægilopoides*, but shorter.

Species II.—*Triticum dicoccoides*, Körn. Wild Emmer. Coleoptile, usually 4-nerved.

Young shoots, prostrate, young leaves blue-green, clothed with soft hairs of nearly equal length, culm leaves yellowish-green.

Straw, slender, solid or hollow with thick walls; nodes clothed with deflexed hairs.

Ear, bearded, compressed, much narrower across the face than the 2-rowed profile; spikelets 1- (or 2) grained; terminal spikelet, large and frequently fertile; rachis very fragile, usually fringed along the margin with long straight hairs.

Empty glume, long narrow, keeled to the base; apical tooth blunt or acute; the strong nerve on the outer half converging towards the base of the apical tooth and ending in a short secondary tooth.

Palea, not divided longitudinally.

Grain, very long (9-12 mm.), narrow and flinty, somewhat triangular in section, with a conspicuous tuft of white hairs at the apex.

Race II.—*Triticum dicoccum*, Schübl. Emmer. Coleoptile, in Indo-Abyssinian Emmers usually 4- to 6-nerved; in European Emmers 2-nerved.

Young shoots, usually erect; young leaves with soft hairs of nearly uniform length.

Straw, solid or hollow with thick walls; Indo-Abyssinian forms short, European forms taller.

Ear, bearded, compressed, narrower across the face than the 2-rowed profile; spikelets generally 2-grained; rachis fragile or tough, narrow, fringed with short hairs.

Empty glume, long and narrow, the outer face flat; keel prominent from tip to base; apical tooth in Western European forms acute and curved as in *T. durum;* in the Russian, Indian and Abyssinian forms short and blunt.

Grain, flinty, or semi-flinty, 7-9 mm. long, narrow, pointed at both ends, ventral side flat or slightly concave; cross section more or less triangular.

Race III.—*Triticum orientale*, mihi. Khorasan Wheat Coleoptile, 2-nerved.

Young shoots erect; young leaves narrow, pubescent, hairs of nearly uniform length.

Straw, of medium height, solid or hollow with thick walls.

Ear, bearded, very lax, almost square; rachis tough; awns scabrid to the base, more or less deciduous.

Empty glume, long and narrow; apical tooth blunt.

Grain, white, very long (10.5-12 mm.), narrow, flinty.

Race IV.—*Triticum durum*, Desf. Macaroni Wheat. Coleoptile, 2-nerved.

Young shoots, erect; young leaves quite glabrous or nearly so.

Straw, tall, solid or hollow with thick walls.

Ears, usually bearded, square in section or narrower across the face than the 2-rowed profile; bearded, stiff, usually erect; rachis more or less fragile; the awns of great length, diverging slightly, and almost smooth at the base; spikelets longer and narrower than those of *T. turgidum* or *T. vulgare*.

Empty glume, long and narrow, the outer face flattish; keel curved, prominent from tip to base; apical tooth stout, generally acute and usually curved inwards; glumes somewhat readily detached from the rachis.

Grain, long and narrow, hard, more or less pointed at both ends, with a prominent dorsal ridge, endosperm flinty; somewhat triangular in section.

Transitional forms are met with having slightly hairy leaves and approximating towards *T. turgidum*, *T. vulgare*, and *T. dicoccum*, and one or two hybrids are known differing only from typical *T. durum* in having beardless ears.

Race V.—*Triticum polonicum*, L. Polish Wheat. Coleoptile 2-nerved.

Young shoots, erect, young leaves blue-green, glabrous or nearly so.

Straw, tall, solid or hollow with thick walls.

Ear, bearded; spikelets large, usually 1- (or 2) grained; rachis somewhat fragile.

Empty glume, as long as or longer than the rest of the spikelet, narrow 3-4 cm. long, keeled, with two small apical teeth.

Grain, very long (11-12 m.m.), narrow, flinty, somewhat triangular in section.

Race VI.—*Triticum turgidum*, L. Rivet or Cone Wheat. Coleoptile 2-nerved.

Young shoots, erect or prostrate; young leaves clothed with soft hairs of nearly uniform length.

Straw, tall, solid, or hollow with thick walls.

Ear, usually bearded, square in section or narrower across the face than the 2-rowed profile; bearded, heavy, often pendulous, and less rigid than *T. durum*; rachis tough; awns stout, very scabrid from tip to base, frequently deciduous; spikelets about as long as broad, often ripening 3-4 grains.

Empty glume, short and broad the outer face convex, keel prominent from tip to base; apical tooth stout, usually acute and curved; glumes more firmly attached to rachis than in *T. durum*.

Grain, generally mealy, though sometimes flinty or semi-flinty; large plump and somewhat short, with truncate apex and high dorsal hump behind embryo.

Race VII.—*Triticum pyramidale*, mihi. Egyptian Cone Wheat. Coleoptile, 2-nerved.

Young shoots, erect; young leaves pubescent, hairs somewhat short; culm leaves yellowish-green.

Straw, very short, solid or hollow with thick walls.

Ear, bearded, dense, short, usually tapered towards the apex and oblong in section, wider across the 2-rowed side than across the face; rachis tough; awns scabrid to the base and sometimes deciduous.

Empty glume, keeled to the base.

Grain, usually mealy, short and narrow, somewhat pointed at the apex, dorsal hump prominent.

Race VIII.—*Triticum vulgare*, Host. Bread Wheat. Coleoptile, 2-nerved.

Young shoots, erect, semi-erect or prostrate; young leaves more or less hairy, the hairs of unequal length, with a single row of long ones along the summit of some or all the longitudinal ridges.

Straw, hollow with thin walls, though forms are occasionally found with solid upper internodes.

Ear, bearded or beardless, square in section or more commonly broader across the face than the 2-rowed profile; the awns shorter than those of *T. durum* or *T. turgidum*; some entirely beardless, others classed as beardless have awns of variable length on the upper spikelets; spikelets usually about as long as broad; rachis tough.

Empty glume, broad, the outer face convex, keeled from tip to base or in the upper half only; apical tooth in the bearded forms short, acute, or sometimes prolonged into an awn (1-4 cm. long), in the beardless forms usually short and blunter.

Grain, very varied in forms and size; flinty or mealy; usually plump with bluntish apex, rounded on the dorsal side without prominent hump or ridge.

Race IX.—*Triticum compactum*, Host, Club Wheat. Coleoptile, 2-nerved.

Young shoots, leaves, straw and glumes as in *T. vulgare*.

Straw, hollow, very variable in length.

Ear, bearded or beardless, short and dense from 3·5 to 6 cm. long, density 40-50; spikelets broad and short, often containing 3-4 grains; rachis tough.

Empty glume, as in *T. vulgare*.

Grain, generally soft and mealy, plump, small, variable in shape, some with prominent dorsal hump like those of *T. turgidum*.

Race X.—*Triticum sphærococcum*, mihi. Indian Dwarf Wheat. Coleoptile 2-nerved.

Young shoots, erect; young leaves as in *T. vulgare*.

Straw, very short, stiff, erect, and hollow, usually not more than 65-70 cm. long except where irrigated; culm leaves rigid and somewhat erect.

Ear, bearded or beardless, stiff, erect, 4-6 cm. long, not so dense as *T. compactum*; awns of bearded forms shorter and stouter than those of *T. compactum*; rachis tough; length and breadth of the spikelets about equal.

Empty glume, broad and short, inflated, with strong curved scabrid apical tooth.

Grain, very short (4-5 mm. long), flinty, often angular on account of pressure of the glumes.

Race XI.—*Triticum Spelta*, L. Large Spelt or Dinkel. Coleoptile 2-nerved.

Young shoots, erect or prostrate; young leaves dark green, with few hairs arranged as in *T. vulgare*.

Straw, stout and hollow.

Ear, very lax, bearded, with short awns or beardless; rachis broad and stout, convex on one side, flat or concave on the other, fragile, breaking transversely below each spikelet; spikelets narrow with 2-3 grains.

Empty glume, firm, with broad truncate apex; apical tooth short and blunt; prominent lateral nerve ending in a blunt projection.

Grain, long, usually flinty, somewhat pointed at both ends, apex with tuft of hair, ventral surface flattened or hollowed slightly, furrow shallow.

The following are some general notes on the more commonly occurring races:—

T. monococcum (Einkorn).—One-grained wheat; seed enclosed in chaff with a very compact bearded head. It is grown to a limited extent in Europe for bread-making. On experimental farms in Canada and Australia it has given extremely poor yields. In South Africa it has been grown only on experimental stations.

T. dicoccum (Emmer).—Two-grained wheat, having compact, short, bearded heads and pithy stems. Grown for bread in Europe, elsewhere it is grown as stock feed. The seed is enclosed in chaff after threshing. It is a good yielder. Early and late varieties are found. Emmer has very slender straw and many haulms, and is earlier in maturity than Speltz. The threshed grain contains about 22 per cent. hull. It is very drought-resistant and free from rust. It affords excellent pasture and, in the drier parts of South Africa, may play a more important part in stock-food and for grazing when known.

T. spelta (Speltz).—Grains enclosed in glumes, grows better on poor, dry soils than most wheats, except emmer. Ears, long and usually beardless; strong, upright straw, very subject to rust. Much poorer in yield than emmer. Threshed grain contains about 30 per cent. hull. The crushed grain is used as a concentrate in stock-feeding.

Distinguishing Characteristics of Emmer and Speltz.—Emmer is always bearded, has short compact heads, considerably less hull than Speltz; the rachis attached to the spikelets is sharp and pointed; and, finally, emmer is much more drought and rust-resistant than speltz. Speltz is nearly always beardless, has long and open heads, the rachis attached to the spikelets is broad and flat, and the plant is very susceptible to rust.

These three wheats—Einkorn, Emmer and Speltz—have possibilities from the point of view of the plant-breeder, but commercially they are of little economical importance.

T. polonicum (Polish Wheat).—Heads, very large, eight inches long and one inch thick, chaffy, with outer glumes one inch long, grain translucent, very pointed (resembling rye in shape), and longest of the wheats, sometimes $\frac{3}{8}$ of inch in length. The straw is slender. Ordinarily it is looked upon as a poor yielder.

T. compactum (Club Wheat). —Differs from common wheat principally in its short, stiff straw and short but compact head. The yields are usually unsatisfactory, and it is very susceptible to rust. There are numerous varieties which are usually classed among the soft wheats.

T. turgidum (Poulard, Rivet or Egyptian Wheat).—Is grown mostly in the hot, dry areas bordering the Mediterranean; some of the heads are branched. They are closely related to the durum wheats, some resemble Club Wheat, and others common wheats. They are usually rather tall with broad, often pubescent or glaucous leaves. The culmns are thick, stiff and sometimes pithy within. Spikes are long, often squarely-shaped with long awns, which are white, red or bluish-red in colour, and occasionally black. Spikelets arranged very compactly; glumes strongly and sharply keeled. Those resembling the durums do well in South Africa under conditions similar to those where durums do well. Many wheats classed as durums really belong to this group and *vice versâ*. The grain is semi-hard, and Poulard does better in mild humid climates than in arid parts.

T. durum (Durum or Macaroni Wheats).—Next to common wheat this is the most important group in South Africa and elsewhere. As a class its varieties are among the most drought and rust-resistant of wheats; they are tall and erect, with smooth, bright green leaves, and long, narrow, translucent grain of exceptional hardness, which is invariably rich in gluten, but poor in starch. The heads are usually heavily bearded, and vary in colour from light yellow to a bluish-black. Under dry-land, arid conditions, they are superior to other strains of wheat. Because of the density and high gluten content of the seed, they are well-suited for the manufacture of macaroni. They are used to a certain extent in blending flour to increase the strength. They give, however, a dark coloured flour and bread, which from the consumer's point of view is objectionable. In the United States of America this is overcome by bleaching with nitrogen peroxide.

T. vulgare (Common Wheats).—This is the chief of the bread wheat groups, Poulard and Club wheats being the two other bread wheats. It is the most grown of all and, probably, about 90 per cent. of the world's wheat belongs to this group. The grain is free, ears awned or awnless, stems hollow, grain white or red. As a class they are high yielders and their period of maturity varies considerably, hence winter and spring wheats in northern countries. Drought and rust-resistant qualities vary with the varieties of the group.

The types of wheat fall into two natural groups as to attachment of lemma and palet to grain, as follows:—

(1) *Naked Wheats*, in which the grain comes free from the lemma and palet, and the rachis is tenacious, *e.g.*, *T. durum*, *turgidum*, *compactum*, *vulgare* and *polonicum*.

(2) *Spelt Wheats*, in which the grain remains attached to the lemma and palet, and the rachis is fragile, *e.g.*, *T. monococcum*, *dicoccum* and *Spelta*.

PRINCIPAL SOUTH AFRICAN WHEATS.[7]

Durums	Late	Black Persian.
	Medium to late	Kubanka, Golden Ball, Bontaar, and South African Medeah.
	Early	Black Don.

COMMON WHEATS.

Variety.	Maturity.	Grain.	Awns.	Remarks.
Rieti	Very late	Dark red, soft and hard.	Awn-tipped.	Shatters badly rust resistant.
Red Egyptian ..	Medium to late.	Red and soft.	Short Awns.	Drought and rust resistant.
Spring Early ..	do.	Red, semi-hard and hard.	do.	
Wit Wol Koren ..	do.	Round, White, soft.	Awn-tipped.	Very susceptible to rust.
American No. 8 ..	do.	Small, red, soft.	Awn-less.	Does not shatter easily.
Marquis	do.	Dark, red, hard.	do.	
Wit Klein Koren..	Early.	Small, white half-hard.	Awned	Excellent yielder on good soil. Susceptible to rust.
Federation ..	Medium.	Soft, plump, white.	Awn-less.	
Australian Early ..	Early to Medium.	Soft, large, white.	Awn-tipped.	
Gluyas Early ..	Early.	Soft, large, white, plump.	Awn-less.	Rust-evading.

EARLY AND LATE WHEATS.—From a practical point of view a classification on relative dates of maturity is important, *e.g.*, on irrigated land in the Transvaal the late wheats must be sown during May, while the early wheats should go in later and may be sown up to the end of July. A late wheat sown late will mature early in December, a period when rust is at its worst; if sown very late the crop will probably be destroyed by rust before maturing. In colder countries these are known as spring and winter wheats. On these, Percival[9] makes the following interesting observations: " At Reading, where the average minimum winter temperature rarely falls below -3° or -4° C., I have always sown all kinds of wheats in autumn and have rarely observed any damage by frost, even among the most delicate kinds.

" There is, however, considerable difference among wheats in regard to their resistance to frost, some being killed outright by temperatures which others will withstand without damage.

" Many wheats are little injured at -10° to -15° C., but suffer when the temperature falls much below this.

" In cold climates the difference are readily determined, and farmers term the sorts which can be sown in autumn

'Winter' wheats; applying the term 'Spring' to those which are delicate and must be sown after the winter has passed.

"Varieties of *T. dicoccum*, *T. orientale*, *T. durum*, *T. polonicum*, *T. turgidum*, and *T. pyramidale* are usually delicate; on the other hand, *T. sphærococcum*, *T. spelta*, and *T. monococcum* are hardy races. Some forms of *T. compactum*, and *T. vulgare* are also hardy, while others are tender and die out in several continental winters. Of these, the rapid-growing forms with the erect habit and broad leaves are usually delicate, while the slower-growing late-ripening sorts with narrow leaves which lie close to the ground are hardy.

"Sinz found that winter wheats, showing great resistance to frosts transpire less, have firmer tissues and higher dry-matter content than spring forms.

"I have frequently observed that hares and rabbits pick out and eat typical winter wheats before touching the spring forms when both are grown in the same field." He states further, too, "very distinct differences in the habit of growth are visible in autumn and early spring among young wheat plants of different varieties. Two extreme types are readily recognised—namely, (1) the *erect* type with shoots that spring up almost vertically, and (2) the *prostrate* type whose leafy shoots lie on the surface of the soil. In those of erect habit the young shoots form a somewhat compact tuft, and the culms of the mature plant converge at the base to a narrow point just below ground, resembling the ribs of a nearly closed umbrella. They are very liable to lodge and are easily pulled out of the ground. The tendency to grow in this manner is sometimes seen in plants with only two leaf-blades developed, the first blade then making but a narrow angle with the second. In plants of the prostrate habit the first leaf-blade becomes horizontal soon after the second blade appears. Later, the several shoots of the young plant come away from each other and soon come to lie close to the surface of the soil, the strongly curved parts at this stage being the short leaf sheaths. The extreme forms of this type are sometimes called by farmers *creeping* wheats. Wheats with this habit do not easily lodge and are so firmly rooted in the ground that they are difficult to pull up." The reason why farmers prefer the late wheats (and late oats which behave in the same way) for grazing is apparent.

Hard and Soft Wheats.—At present the markets in South Africa do not make much distinction between hard and soft wheats, although some millers object to the former on account of its hardness. Elsewhere this is one of the major distinctions, hard wheats fetching very much higher prices than soft wheats. Generally speaking, the hard wheats are dark in colour, often translucent, while the soft wheats are light and opaque. The soft wheats show a white starchy interior and the hard wheat usually a dark. The durums are always hard, angular, dark and translucent to an extent not met with in the bread wheats. Some of the common wheats, however, have comparatively hard, translucent grains. In composition the soft wheats are much lower in gluten and make what is called a weak flour. In general, this means they do not make a large porous loaf of bread. For biscuit and pastry manufacture soft wheats are preferred.

Hard wheats have more gluten and make a strong flour, which is especially suitable for making light bread. The strength of flour is mostly due to the quality of the gluten, which not only makes the dough elastic, but enables the bread to absorb more water, and also gives more pounds of bread; a hundred pounds of good, strong flour will make 120 or more one pound loaves.

Structure and Composition.—In wheat the aluerone layer is only one cell thick, while in barley it is usually three cells in depth.

Bran consists of the pericarp, inner integument, nucellus and aluerone layer. In the process of milling these become detached from the endosperm, which forms the flour.

Compared with other portions of the grain the embryo is rich in protein, fat and ash constituents, and though it contains a considerable amount of sugar, it has but little starch.

Nearly one-sixth of the embryo consists of fat and ash and about one-third protein.

The endosperm composes on an average about 80 per cent. of the kernel, consisting mainly of starch with about 8 to 10 per cent. of gluten.

Quality.—In wheat quality involves a number of factors, and numerous theories, some of a highly controversial nature, have been put forward. Probably on no similar agricultural subject has so much research been directed.

Good wheat should, of course, be free from extraneous matter, and should have a low moisture content.

Obviously quality signifies suitability for the purpose intended; thus, wheats of low strength are required for pastry-making, while those exhibiting strength to a considerable degree are necessary for the making of light bread.

The miller, of course, is chiefly interested in the milling yield, which, in the case of Minnesota wheat, was found to vary in flour production from 60·4 to 76·1 per cent.[4] "The percentage of flour which can be produced from any sample of wheat depends largely upon the relative plumpness of the kernels, the texture of the kernels, and the percentage of water they contain. If the texture of the kernel is soft, or represents what is termed the 'Yellow Berry' condition, the percentage of flour will be reduced, since it is mechanically impossible to free the bran from the floury portions so nearly as when the endosperm is hard and vitreous."

The baker, on the other hand, is chiefly concerned with three factors:

(1) The "strength" of the flour, or its ability to produce a large loaf of uniformly porous texture.

(2) Absorption, or the relative quantity of water which can be added to the flour in making dough.

(3) The colour of the flour and of the crumb of bread made therefrom.

Although it might be stated that in general the higher the protein content the stronger the wheat, this statement needs to be considerably qualified, as the nature of the proteins found is of vital importance. The most reliable method of determining this is by actual baking tests. Gluten is found in all wheats and its presence in wheat enables the flour from wheat to be made into bread. As it is absent in cereals, like maize, oats and rye, bread cannot be made from these. Gluten contains the proteins, gliadin and glutenin, and it has been propounded, and since discredited, that the ratio of these two proteins to one another may be responsible for the quality of gluten. The accepted position seems to be that the size of the loaf is dependent on the activity of the enzymes found in the wheat, which convert starch into sugar. This sugar, of course, is fermented by the action of the yeast cells; consequently, the more active the enzymes found in the wheat, the more sugar provided for the yeast cells, and, therefore, the greater production of gas. "As a rule it is not practicable to get the dough moulded into loaves and put into the oven before it has been fermenting for about 6 to 8 hours. If the flour possesses an active ferment it will still be rapidly forming gas at the end of this time, and the loaves will go into the oven distended with gas under pressure from the elasticity of the gluten which forms the walls of the bubbles. The heat of the oven will cause each gas bubble to expand and a large loaf will be the result. If the ferment (enzyme) of the flour is of low vitality it will not be able to keep the yeast supplied with all the sugar it needs, the volume of gas formed in the latter stages of the fermentation of the dough will be small, and the dough will go into the oven without any pressure of gas inside it, little expansion will take place, as the temperature rises and a small loaf will be produced."[5] Wood shows how the activity of the enzymes can be readily determined.

After some excellent research work the same writer says: "After making a great number of analyses, it was found that the amount of soluble phosphate in wheat was a very good index of the shape and texture of the loaf it would make. The toughness and elasticity of the gluten, no doubt, depend on the concentration of the soluble phosphate in the wheat grain, the more the soluble phosphate the tougher and more elastic the gluten, and a tough and elastic gluten holds the loaf in shape as it expands in the oven, and prevents the small bubbles of gas running together into large holes and spoiling the texture." He then outlines a simple method by which the amount of soluble phosphate might be satisfactorily indicated from the smallest sample.

In a recent publication,[9] Dr. Saunders makes the following interesting statements: "Baking strength is not inherited as a Mendelian unit character . . . as a matter of fact, baking strength is extremely complex, varying from season to season, and being sometimes radically transformed by a year's storage of the flour. . . . The highest baking strength was attained when the wheat was stored about three or four years. . . . Bleaching whitens the flour in a manner somewhat similar to natural ageing, but bleaching does not improve the baking qualities of the flour at all, or certainly not to any clearly demonstrable degree. The material improvement of flour by storage continues whether the flour has been bleached or not."

Factors Affecting the Chemical and Physical Composition of Wheat.—The epidermis, epicarp, endocarp, testa, aleurone layer and embryo are the first formed and the endosperm last of all. That is, the framework first develops, then the plastids form starch, and at maturity desiccation takes place. Consequently, any factor limiting starch formation naturally increases the percentage of protein found. Immature, and grain shrivelled through disease, *e.g.*, rust, has a higher percentage protein content.

Probably the composition varies most with changes in climate. It is a well-known fact that what may be classed as a soft wheat in some parts of the world, when grown under other conditions may be called hard wheat. Some varieties in some localities will present an opaque appearance, in others both opaque and translucent kernels will be found in the same crop, while in another situation the kernels from the same strain may be entirely translucent.

Percival[9] states : " The white opaque appearance of the endosperm of mealy (soft) grains is due to the presence of minute fissures, which develop between and within the cells during the desiccation which occurs at the time of the ripening of the grain.

On examination of carefully-prepared transverse sections from grains, showing different degrees of mealiness, it is seen that interstices have formed along the line of union of adjacent cells and around the starch grains within the latter, and the contents of some of the cells have shrunk more or less away from the surrounding cell wall ; these changes appear first near the furrow (crease) and spread radially outwards across the endorsperm towards the aleurone layer on the dorsal side, especially in the basal half of the grain near the embryo.

Minute irregular cavities are also seen in the aleurone cells.

From investigations on mealy grains of barley, Brown and Escombe concluded that the interstices are vacuous or only partially filled with air.

Such minute spaces are absent from flinty, hard, translucent endosperm, in which all the cells of the tissue are completely filled with starch grains imbedded in a protoplasmic matrix, the whole forming a dense coherent mass.

The production of flinty or mealy grains is a hereditary character of some particular races and forms of wheat, *e.g.*, the grains of *T. durum* are almost always flinty, while those of *T. vulgare* are usually very mealy.

Wheats grown on heavy soils have a tendency to produce flint grains, while on light soils the texture of the grains is of a more mealy character. Percival also claims that wheats closely spaced have a higher proportion of mealy kernels than those widely spaced; also, that "forms which ordinarily produce mealy grains only do so under conditions which allow of complete development and normal ripening, for the grains of all wheats harvested in an immature state have flinty endosperm."

That the protein decreases with the decrease in rainfall is shown in the following table:—[2]

District.	Percentage Protein.	Total rainfall. (05—09).
1.	12·82	45 inches.
2.	12·37	50 ,,
3.	12·25	58 ,,
4.	11·56	69 ,,
5.	11·16	73 ,,
6.	10·96	82 ,,
7.	10·75	97 ,,
8.	10·63	103 ,,
9.	9·03	116 ,,

Thus, wheats produced in arid regions have a higher percentage of protein than the same wheats grown in humid parts, and although the composition of wheat varies markedly in the different varieties, as a whole the above statement is also true.

Moreover, climate has an infinitely greater influence on composition than difference in soil may have. In America, soil was taken from a humid part, Pullman, to an arid locality, Ritzville, and *vice versâ*, with the result shown below.[2]

Original seed grown at Pullman, 1905 ... 9·58% protein.
,, ,, ,, Ritzsville, 1905 12·57 ,,

	Percentage protein, 1906.	Percentage protein, 1907.
Pullman seed on Pullman soil at Pullman ..	15·64	13·47
Pullman seed on Ritzsville soil at Pullman ..	15·90	13·50
Ritzsville seed on Pullman soil at Pullman ..	15·67	13·26
Ritzsville seed on Ritzsville soil at Pullman ..	16·10	13·34
Pullman seed on Pullman soil at Ritzsville ..	17·01	12·64
Pullman seed on Ritzsville soil at Ritzsville ..	17·31	12·76
Ritzsville seed on Pullman soil at Ritzsville ..	(lost)	12·55
Ritzsville seed on Ritzsville soil at Ritzsville	16·63	12·60

From this it will be seen that the difference in climate was a dominating factor.

However, the soil does influence the composition, but in general farm practice to only a comparatively small degree. The protein in wheat may be increased by high nitrogenous manuring. Hall, at Rothamstead, has obtained wheat in this manner so high in gluten that it was almost impossible to obtain the ordinary baked loaf, the dough being loose, unstable and gelatinous.

In Ohio a number of experiments was conducted to ascertain the effect of fertilisers on the physical and chemical properties of wheat.[3] The soil on which the experiments were carried out was very unproductive, normally, 50 per cent. of the grain was shrivelled and undeveloped. By increasing the nitrogen content alone of the soil, this condition of the kernels was accentuated.

Potash gave a larger percentage of plump kernels, but the composition was about the same as that found in the nitrogen plots. Phosphates improved the physical appearance of the grain to the greatest extent. The nitrogen plots gave wheat of a higher protein content because of the shrivelled grain produced, while the grain from the plots manured with phosphates gave wheat having a higher carbohydrate content, because of the plumper grain produced.

When the soil deficiencies are remedied by judicious manuring the most satisfactory kernels are produced.

The following correlations have been noted in this respect :—[4]

(1) The average weight of the kernel varies directly with the length of the development period.

(2) The percentage nitrogen varies inversely with the length of this period.

(3) The length of this period is the chief determining factor in the final composition of the grain.

(4) A relatively high rainfall, particularly between flowering and ripening, results in the wheat being lower in protein and higher in starch than when the opposite is the case.

The following shows he average constituents taken to form an ordinary crop of wheat in Australia :—

Plot.	Grain.	Straw.	Total Produced.
Yield	52·2 bushels.	12·96 cwt.	2,364 lbs.
Dry matter ..	766 lbs.	1,222 lbs.	1,988 lbs.
N.	14·1 lbs.	6·2 lbs.	20·30 lbs.
P_2O_5	7·83 lbs.	2·4 lbs.	10·23 lbs.
Potash	5·22 lbs.	11·92 lbs.	17·14 lbs.

Constituents.	Percentage. Federation Wheat.	Percentage. Federation Flour.	Percentage. Federation Bran.
Moisture	10·99	10·48	9·47
Fat	2·37	1·58	4·42
Carbohydrates ..	73·54	78·56	60·72
Fibre	1·87	·30	7·62
Ash	1·34	1·63	4·09
Protein	9·89	8·45	13·68

Mature wheat straw has a lower feeding value than barley or oats, but a little better than rye, as the following table indicates :—

Straw.	Nutritive ratio.
Oats	1 :44·6
Barley	1 :46·2
Wheat	1 :51·7
Rye	1 :57·9

Climate.—The most suitable conditions are those in which a moderately moist and cool growing-season merges gradually into a warm, bright and dry ripening season. These favour free stooling and development, the formation of a hard glutenous kernel and evasion from fungous diseases. These conditions are to be found in many coastal regions, as well as in the interior of continents; while the more humid ripening season which results in a softer, more starchy grain, is just as widely encountered, thus making wheat, unlike maize, adaptable to large areas in various parts of the world.

The wheat areas of South Africa are those having a winter rainfall, chiefly the south-west Cape and Namaqualand. In the parts having a summer rainfall wheat must be grown under irrigation, as the winter precipitation is too small for the growth of wheat on dry-lands. In the eastern Free State, where 20 to 25 per cent. of the rainfall occurs during winter, wheat is only fairly successfully grown on dry-lands. However, the area to wheat there is diminishing, summer crops, chiefly maize, taking its place. In the south and south-eastern coastal area, where nearly 40 per cent. of the rainfall falls in winter, rust is very bad, and the crop is an uncertain one. In fact this area is spoken of as the "Rust Belt."

In the Karroo area, where the rainfall is below 15 inches, wheat free from rust and of very good quality is grown under irrigation schemes, *i.e.*, permanent irrigation dams, saaidam irrigation, and torrential flooding.

Soils.—Wheat will do better than the other cereals on heavy soils; however, generally speaking, loams and clay loams are the best. It requires the plant-food of the soil to be more available than do maize or oats. If green manures or barnyard manures are used they must reach a more thorough state of decomposition to produce a good effect on the wheat crop than in the case of the former two crops. Moreover, since wheat is very sensitive to soil conditions, it requires a more thoroughly pulverised and compact seed-bed than maize, oats or rye. It prefers a neutral soil, being less resistant to alkali than barley, mangels, cotton or sorghums, and does not do so well on acid soils as rye, potatoes, buckwheat, soybeans and cowpeas.

Fertilisers.—In most countries nitrogenous fertilisers are the chief fertilisers applied to wheat. In South Africa the application of nitrogenous fertilisers is not so urgently necessary. In the south-west Cape area sodium nitrate or guano are used with good results. Elsewhere this can be supplied sufficiently by the use of leguminous green manures.

Phosphatic fertilisers are needed on most soils in South Africa, and if judiciously used will give profitable results, especially where the land has received a green manure previously. Present prices are abnormally high and fertilisers should be used with caution.

Each of the applications given below will prove highly beneficial to the crop:—

300 lbs. bone meal, plus 100 lbs. of blood meal, if no green-manuring has taken place, or

300 lbs. guano alone, or

200 lbs. superphosphate, or

200 lbs. to 300 lbs. basic slag, according to the acidity of the soil.

Phosphatic fertilisers stimulate root-growth, hasten maturity, and, therefore, assist in combating rust, cause the grain to fill out well and, consequently, make for increased production.

Potash fertilisers have not proved beneficial, except in small quantities, in the south-west Cape.

The fertiliser is generally applied at the time of seeding by means of the combined seed and fertiliser drills, or else by hand. Where wheat is grown under irrigation, the use of well-rotted kraal manure, about four wagon-loads to the acre, often gives excellent results, when used with light dressings of phosphatic fertilisers.

Seed.—The following score-card for seed wheat may be employed in judging the merits of samples :—

		Possible.
1.	Germination	20
2.	Size and plumpness	20
3.	Freedom from foreign seeds, dirt, and broken seed	20
4.	Weight per bushel	15
5.	Purity of variety	15
6.	Hardness of grain	10
		100

(1) *Germination.*—A high percentage of viable seed, having good vitality, is indicated by brightness of the grain and fullness of the embryo. Old seed usually has a dull appearance, and a dark and streaked embryo. Sprouted grain should be looked for and discriminated against. Repeated germination of the same kernel is possible, but the vitality is much impaired.

(2) *Seed and Plumpness.*—Within the variety the seed should be as large and plump as possible; this ensures a healthy seedling and an uniform stand. A number of experiments have been conducted, often poorly from an experimental point of view, but the results point conclusively to the advisability of using large plump kernels for planting. Bolley has shown fairly definitely that shrunken kernels are very often diseased, and, moreover, transmit the disease to the next generation.

The fact must not be overlooked, however, that the seed of some varieties is not as plump as others, and allowances must be made when judging such varieties. In the durum and Polish wheats the kernels are angular.

(3) *Freedom from Foreign Seeds, Dirt, and Broken Seeds.*—The presence of weed seeds, dirt, and broken seeds naturally detracts from the value of the sample. In the Union the weed seeds most commonly found in wheat are: Drabok or Darnel (*Lolium temulentum*), Chess or Cheat (*Bromus secalinus*), Stinkblaar (*Datura stramonium* and *tatula*), Wild Oats (*Avena Fatua*), and Vetches (*Vicia spp.*).

(4) *Weight per Bushel.*—Good wheat should weigh 60 lbs. Wheat containing a high percentage of moisture gives a low weight per bushel, and is undesirable.

(5) *Purity of Variety.*—Seeds of other varieties are indicated by differences in colour, sometimes by translucency and, of course, by size and shape.

(6) *Hardness of Grain.*—As a class the hard wheats command higher prices than the soft wheats, and moreover the quality of bread made from the former is considered more desirable. Hardness seems to be directly correlated with gluten content, as will be seen from the following results obtained at the Ontario Agricultural College :—

Variety.	Hardness.	Percentage gluten.	Weight per bushel.
Crimean Red	18·2	31·4	62·8
Banatha	17·4	31·5	63·0
Buda Pesth	17·5	32·5	62·6
Genesee Reliable	15·8	29·6	63·0
Dawson's G. Chaff	15·3	26·3	61·1
Prosperity	14·1	27·0	61·4
Abundance	14·8	26·5	61·4

The hardness was obtained by finding the breaking-point of kernels in a specially-contrived apparatus. It can be relatively ascertained, after a little experience, with a fair degree of accuracy, simply by chewing a few grains. The more translucent the kernels, moreover, the harder the grains.

Seed Treatment.—Seed should always be treated for the prevention of "Stinking Smut." A formalin mixture, one pint to 40 gallons is usually employed. The grain should be placed in a heap on a canvas or the floor, sprinkled with the solution then shovelled until thoroughly wet. It should then be covered over with sacks or a tarpaulin for three to four hours, after which it should be spread out to dry. If formalin is unobtainable copper sulphate (blue vitriol) may be used at the rate of one pound to ten gallons of water. The seeds should be sprinkled until wet, and then dried immediately, not being left in a heap, as in the case of the formalin treatment. In both cases about one gallon of the solution is required for each 50 pounds of seed.

In practice, " Loose Smut " can be treated only with difficulty by Jensen's hot water treatment.

Rate of Seeding.—On dry-lands 30 to 45 lbs., on irrigated land 60 to 80 lbs. should be sown. Drought is better withstood by thin seeding, because each plant develops a stronger root-system, and the available moisture and plant-food go further than in the case of thick-seeding. The rate of seeding, however, is governed by :—

(1) Climate.—The lower the average rainfall of the area the less seed is required.

(2) Time of Sowings.—Crops sown early require less seed than the same variety sown late, because wheat sown late does not have the same chance of stooling as that sown early.

(3) Character of the Seed-Bed.—To choke weeds, wheat should be sown more thickly on foul land, and on sandy soil less than on good clay loams.

(4) Character of the Variety.—Some varieties stool more than others; while some varieties are much earlier than others.

(5) Methods of Sowing.—Whether drilled or broadcasted, 25 per cent. more is required when broadcasting than when drilling.

Where possible wheat should be put in a seed-drill. The advantages of drilling over broadcasting are briefly as follows :

(*a*) Economy of seed—which is no mean consideration over large acreages.

(*b*) Uniform planting and covering of seed.

(*c*) Better stand, and more even ripening of crop.

(*d*) Even and easy distribution of fertilisers, when fertiliser-attachment is used.

(*e*) Increased yield, as shown repeatedly by experiments.

The seeding takes place from April to the end of July. The bulk of the crop under irrigation is sown during May and June. On the Highveld wheat is sometimes put in as a spring crop during the months of August and September.

In the Western Province of the Cape, the crop is sown from April to May, while in the Eastern Free State it is put in from April to June.

Both very early and very late plantings are not recommended. The former runs the risk of the plants being killed by frost when in the flowering stage, and in the latter the plants often succumb to rust.

CULTIVATION BEFORE AND AFTER SEEDING.—The preparation of the soil on irrigated lands need not be as thorough as that on dry-lands. On the latter the ground should be ploughed early, about January, and left rough so as to ensure maximum penetration of rain. If weedy, cultivation will be necessary. When ploughed very early a shallow-ploughing shortly before planting will be advisable. If the ground is very loose or cloddy a roller might be used to compact the soil and to reduce the clods. If this is not available, a weighted disc-harrow will do good work. The reasons for a compact seed-bed are :—

(1) A loose soil will not allow proper root development if air spaces are too large.

(2) A loose seed-bed is apt to dry out quickly.

(3) If not compacted the undecayed stubble and weeds turned under prevent good contact with the sub-soil and moisture does not move about freely.

(4) The soil particles come into more intimate touch with the seed and the tender seedling has a better opportunity of developing.

It should be harrowed after this and then the seed drilled in. After the wheat has become well rooted, it should be harrowed with a light harrow, this can be done once or twice until the wheat is about 6 inches high, or until the crop starts piping. The object is to break any shower crusts, which are liable to form on certain soils and to aerate the soil. If broadcasted the seed will have to be disced in, or covered by harrowing.

IRRIGATION.—The ground should be moist enough at the time of planting to ensure good germination and a fair growth before the first irrigation is necessary. The number of waterings will depend largely on the character of the soil, the rainfall during growth, and the variety. It should not be necessary to irrigate more than twice before the piping stage. However, from the time of piping until the grain is well-formed the crop is most in need of water and it should then receive liberal irrigation. Irrigation after the grain has been well filled is of no use, as the roots cease functioning about three weeks before the crop is mature. Experimental work in various parts of the world, and observations in South Africa, show the tendency in practice to over-irrigate. The necessity for irrigation is shown when the plants present a flaccid and yellowish appearance, the tips of the leaves turning brown.

ROTATIONS.—As in most crops in the Union insufficient attention has been paid to this important aspect. As wheat may be classed as a delicate feeding crop, and, therefore, requires readily available plant-food, where practicable, a cultivated crop should intervene between a green-manuring crop and the planting of wheat.

The effect of previous crops on wheat is well shown in the following result obtained from experiments conducted at Potchefstroom Experimental Farm—viz. :—

	1916. Pounds.	1917. Pounds.	1918. Pounds.
Velvet beans cut for fodder, wheat following	1,240	1,080	1,040
Cowpeas cut for fodder, wheat following	1,400	1,380	1,240
Maize summer crop, wheat winter Crop	800	520	540
Sunflower summer crop, wheat winter crop	400	600	600

No fertiliser was used in the above experiment.

The value of the legume, even when used for fodder, is clearly demonstrated. Whenever possible legumes such as cowpeas should be grown on wheat-lands in preference to such crops as maize, sorghums or sunflower.

The following rotations are suggested, but, of course, should be altered to suit the conditions of the locality and the requirements of the individual farmer.

(1) 1st Year—Winter crop—wheat.
Summer crop—cowpeas ploughed under.
2nd Year—Winter crop—wheat fertilised with phosphates.
Summer crop—potatoes or mangels.

(2) On the Highveld of the Eastern Transvaal, when suitable, early varieties are used, the following rotation might be successful :—

1st Year—Wheat, fertilised with phosphates.
2nd Year—Wheat.
3rd Year—Cowpeas ploughed under.
4th Year—Potatoes.

(3) Eastern Orange Free State :—

1st Year—Summer crop—Sudan grass or teff.
Winter crop—wheat fertilised with phosphates.
2nd Year—Summer crop—cowpeas ploughed under.
Winter crop—wheat fertilised with phosphates.

or—

1st Year—Wheat fertilised with phosphates. Teff cut for hay.
2nd Year—Cowpeas ploughed under.
3rd Year—Maize, with a light dressing of phosphates.

(4) South Western Cape :—

1st Year—July-August. Fallow. Field peas ploughed down end of November, followed by summer cultivation.
2nd Year—Wheat, planted in May, fertilised with complete fertiliser.
3rd Year—Oats and vetches for hay, sown together in April and May, with a light dressing of fertiliser.
4th Year—Oats for grain, planted in April and May, with a light dressing of fertiliser;

or—

1st Year—Fallow.
2nd Year—Wheat fertilised 40 lbs. Na NO_3 100 lbs. basic slag, and 20 lbs. muriate of potash.
3rd Year—Field peas ploughed under.
4th Year—Oats for grain.
5th Year—Oats for hay or grazing.

The poor soils of this area are initially poor, and in many cases by a system of continuous cropping have become very unproductive. The remedy would seem to lie in frequent green-manuring, dairy-farming, where the stable manure would be applied to the fields, and the use of artificial fertilisers.

Grazing.—Early sown crops which have reached too advanced a stage, and which are likely to be injured by frost at the time of flowering, may be grazed down. Late varieties are often planted early with the intention to supply grazing during the winter months; the stock is turned out of the field at the end of July and the crop then allowed to mature.

Harvesting.—Wheat should be reaped with a self-binder or mower as soon as the kernels have reached the hard dough stage—*i.e.*, when an impression can still be made with the finger nail. Maturity will be completed in the bundles. If allowed to become too mature heavy losses will occur through shattering, particularly with some varieties. It should be stooked in shocks of 10 to 12 bundles and allowed to mature fully and to dry-out in these shocks. It should subsequently be stacked ready for threshing. If stacked too early the grain may be seriously damaged by over-heating. Where a header or stripper is used the crop is harvested when fully mature.

Threshing.—In growing wheat for seed the first few bags run through should be put aside as these are likely to have seeds of other varieties and impurities carried by the thresher from the last farm.

If the wheat has a large percentage of impurities or shrunken seeds due to rust, poor soil or drought, it should be winnowed. The tailings can be used as stock and chicken food, etc., but if sold with the good wheat the price will be very much decreased. With the introduction of elevators wheat grades will probably be introduced and quality will receive more marked attention than at present.

Uses.—It is chiefly used for bread-making purposes, also in the manufacture of macaroni, vermicelli and breakfast foods such as grape-nuts, puffed-wheat, etc.; it also finds its use in the distilling of alcoholic drinks such as whiskey. The grain as well as the by-products, bran, pollards, etc., is used as stock food. The straw as previously stated is low in nutritive value; but is sometimes used as a roughage, bedding, and for a great number of commercial purposes. The crop is also grown partly for grazing and for hay, the latter particularly in countries like Australia.

Wheat Improvement.—Wheat is self-fertilised. Natural hybrids are rarely found; consequently, improved strains are easily kept pure. The popular belief that wheat degenerates, and, therefore, a change of seed is necessary, is unproven. Zavitz has grown the same varieties for nearly thirty years, and the present yield is somewhat in advance of the original yields. Montgomery says: "While every grower should always be on the look-out for new or improved varieties, he should, in the main, grow the variety that long experience has shown to be the best for the region, and should try the new varieties only experimentally."

The main points to be kept in mind in breeding wheat are :—

(1) *Drought Resistance*.—Some varieties resist drought better than others—*e.g.*, the durums; while others are drought-evading because of their early maturity—*e.g.*, Gluyas Early.

(2) *Rust Resistance*.—Immunity varies with the varieties, some evade rust by early ripening. On the whole, the question of immunity to rust is really little understood. Varieties have been known to be rust-resistant to a marked extent for several years in the Union—*e.g.*, Bob's Rust Proof —and subsequently suddenly to lose what immunity they appear to have had.

(3) *Strength of Straw*.—Varieties vary markedly in this respect, and those having weak straw are apt to be " lodged " or laid badly, the straw lying on the ground or nearly so. When this occurs naturally the crop is very much diminished, through discoloured and sprouted grain; and, of course, a great deal of difficulty is experienced in harvesting lodged wheat. Lodging is best seen after pelting showers or in very windy weather. It may be due to the inherent weakness of the straw of certain strains where the " hypoderm and mechanical tissue round the vascular bundles are reduced and their individual cells comparatively small and thin-walled. Where the straw is weak, the lower internodes are usually bent or broken when lodged." On the other hand, lodging may be caused by the weakness of the roots or by a root system having a poor anchorage on the soil. " Where the root only is at fault, the plant goes down as a whole, the straw being rigid and stiff. The peculiar arrangement of the root-system and the strength of the individual roots which are hereditary characters of different varieties of wheat, have a great influence upon the lodging of the crop.

" In short-strained winter wheats of the Square-head type the bases of the straws, just above the ground, bend outwards in the form of a cup, and from their lower nodes arises a spreading system of adventitious roots; the first inch or two of the roots below the surface is somewhat rigid and thickened considerably, and the cell wall of their tissues strongly lignified. By this spreading arrangement of strong roots the plants are firmly anchored to the soil and prevented from being laid except by the severest storms.

"In most spring forms, however, the straws grow up from the ground in a crowded, more or less compact, bundle, spreading very little, and the adventitious root-system consists of much thinner, less lignified roots closely contracted and descending almost vertically with very little grip on the surface soil; plants with these root characters are very easily bent to the ground as a whole, although the straw may be as strong and rigid as that of the best winter varieties. "Lodging" of this kind, which may even occur among isolated well-grown plants, is due to weak root-hold; the straw being neither bent nor broken."[9]

Other factors also affect lodging. If sown too thickly, insufficient light is accorded the plants and their etiolated condition causes them to lodge badly; high nitrogenous manuring and over-irrigation also have much the same effect, and certain diseases affecting the lower internodes weaken these to such an extent that lodging of individual straws results.

(4) *Shattering.*—At maturity the grain is shattered out more readily in some varieties than in others. The Rieti variety shatters very badly and for this reason its cultivation has diminished.

(5) *Stooling.*—While not very important, the capacity to stool as well as the manner of stooling varies considerably with the varieties. To quote again from Percival's excellent monograph:[9] "During autumn and spring, however, the primary axis continues to grow very slowly, and, at the same time, in the axils of its leaves buds are formed which expand into short secondary stems; the latter also bear axillary buds, which are capable of developing in a similar fashion into branches of the third order, and so on. Thus, from the primary bud of a single wheat grain, a large number of stems may be produced, which remain very short until April [spring in South Africa], at which date they usually begin to expand, the strongest of them ultimately growing out into straws, each with its terminal ear.

"The production of these numerous shoots with unexpanded internodes, which takes place near the surface of the soil, is known as the 'stooling' or 'tillering' of the plant; it is the nominal process of branch-formation in the cereals and grasses generally." The extent of tillering is governed by the variety—*e.g.*, the late wheats tiller more than the early, but may be modified by environment. Crowded plants tiller less than those widely spaced; plants on very productive soils stool more than those on poor soils; a waterlogged condition of the soil inhibits the process, and the date of sowing also affects tillering—*e.g.*, winter wheat sown late does not tiller as much as when sown at the correct date—a strain of wheat which may have only three stems under certain conditions may have under other conditions up to 80 stems. Given optimum conditions for nutrition, then the maximum number of stems will be found.

It is because of what has been said above that, within limits, widely-differing rates of seeding, except on extreme soil types, on the same soil will give almost identical results as regards yield.

(6) *Yield.*—As in all crops each locality offers conditions more suitable to certain varieties than others. Some strains prove themselves more productive than other strains under widely-differing conditions.

(7) *Quality of Grain.*—This, of course, differs very much with the breeds grown. Some highly-productive strains are of poor quality—*e.g.*, Federation and Red Victoria.

Methods of Improvement.

(1) *Mass Selection.*—This consists in the continuous selection of a number of the best ears, grains or plants. It is really the elimination of the least suitable for the locality.

At the Ontario Agricultural College this method has given the following result—viz.:—

	1890-93.	1894-97.	1898-01.	1901-05.
1. Oats (average for 8 years)	74	79	83	100
2. Barley ,, ,,	50	54	63	63
3. Potatoes ,, ,,	120	216	218	249

Mass selection is most effective when the individual plant is made the unit of selection, and not the individual ear or grain, because large ears and large grains may be borne on relatively poor plants grown in favourable environment.

(2) *Individual Selection.*—" In this case the selection commences with a number of superior plants of a given variety, and the seed of each plant or ear is separately planted and kept under observation. This enables a strict comparison to be made of the progeny of each selection so that in a few years the best strain in the original selections may be multiplied for future use."[6] This is a more tedious, but a more

certain method, of obtaining the desirable biotypes, and is generally confined to experimental stations. However, some valuable varieties have been obtained by farmers selecting outstanding plants.

(3) *Cross-Breeding or Hybridisation.*—Besides the important factor of hybrid vigour, the object is to combine the desirable characteristics of the two or more wheats in the one. The following dominants and recessives have been noted :—

Dominants.	Recessives.
Hairy Leaves.	Smooth Leaves.
Solid stem.	Hollow stem.
Firm closing of glumes.	Loose closing of glumes.
Felted glumes.	Smooth glumes.
Susceptibility to rust.	Immunity to rust.
Black chaff.	White chaff.
Flinty grain.	Floury grain.
Winter form (late shooting).	Spring form (early shooting).
Lax ears.	Dense ears.
Red grain.	White grain.
Bald.	Bearded.

Unless reciprocal crosses are wanted, always cross so as to have the mother plant the recessive.

Some of the most valuable wheats to-day have been obtained by hybridisation—*e.g.*, Marquis, Prelude. Federation, the most commonly grown variety in Australia, is a cross between Yandilla King and Purple Straw.

Wheat crosses with barley—*e.g.*, Nepaul Barley x Early Lambrigg Wheat gave Bob's Rustproof.

Common wheat crosses readily with Emmer, Speltz and Einkorn; wheat-rye hybrids have also been obtained, and in a few cases these hybrids have been induced to produce seeds; however, on the whole, they are sterile.

Diseases and Pests.

Rust (Puccina spp.)—The chief menace to wheat-growing in South Africa; in fact, wheat-growing is really restricted to rust-evading areas—*i.e.*, those areas where the early summer is not hot and moist. Under irrigation, early varieties are fairly safe in the Orange Free State and Transvaal, and as a class the durums are very resistant, so is emmer. Occasionally varieties are found more resistant than others; some will remain immune for several seasons, but will suddenly become susceptible. No remedy, but resistant varieties, early varieties and early planting, should be resorted to.

Smut (Tilletia fœtens).—Brand, Burnt or Stinking Smut is of considerable economic importance and can be controlled very easily, as already described. The durums are usually very free from this disease.

Loose Smut of Wheat (Ustilago tritici).—No practical remedy. Jensen's hot water treatment, in which wheat is steeped in water at 129° for ten minutes, may be employed where facilities are available. A change of seed is also recommended.

Take-all, or *Vrotpootje (Ophiobolus graminis).*—This disease has proved serious in the south-west Cape. The best remedial measure is to practise a rotation of crops.

There are two aspects of this disease, "Take-all" and "White heads." The condition called "take-all" occurs at an early stage of the growth of the host, causing the latter to become yellow, and often die before a culm is formed. Infection occurs at the base of a plant, which appears blackened. The condition of "white heads" occurs when the host has attained full growth. The spikes are of normal size, but the grain either remains undeveloped, or is very much shrivelled. The spikes and straw appear to be bleached, or prematurely ripened. The entire plant is found to be dry and dead, and for two or three inches at the base of the culm is blackened as if charred.

Oats is apparently unaffected by this disease, hence it serves as a good change crop.

Wheat Aphis (Toxoptera graminum).—This insect occasionally causes a great deal of damage. Pasturing may be of assistance. The spread of this pest is generally controlled by parasites.

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CHAPTER XV.

OATS

History.—The original wild form of the cultivated oat is not definitely known, although it is believed to have existed in Western Asia and Eastern Europe. Records show that the Egyptians, Greeks and Hebrews were not as familiar with oats as they were with barley and wheat. The crop seems to have been first cultivated in Central Europe. The hulless oat is known to have been grown in China 618 to 900 A.D.

" It is probable that oats were first used for feeding animals and that their use as human food was confined to times when other grain or food was scarce. Its general use as a food for man is evidently of recent origin and is due to the development of milling machinery. Naturally the people of early times used as a food those grains which could be prepared most easily. For this reason wheat and rye, which thresh clean and contain gluten, were used instead of oats, which usually remain in the hull."

Production.

	Average in bushels for 3 years, 1912-14.
Europe	2,655,519,000
North America	1,596,864,000
Asia	126,361,000
South America	70,767,666
Australasia	27,285,666
Africa	25,398,666

In importance, oats ranks fourth of the world's crops, being exceeded by potatoes, maize and wheat. The world's production in this, as in other crops, shows a gradual but marked increase.

The seven countries leading in oat production are given below :—

Country.	Average Yield, 1912-14.	Yield per acre. 1890—99	1904—13
United States ..	1,227,021,666 Bushels.	26·1 Bushels.	29·7 Bushels.
Russia	959,615,000 Bushels.	17·8 Bushels.	21·6 Bushels.
Germany	625,406,000 Bushels.	40·0 Bushels.	52·9 Bushels.
France	416,604,333 Bushels.	29·8 Bushels.	30·3 Bushels.
Canada	369,758,666 Bushels.	—	34·3 (06—10)
Austria-Hungary	249,874,333 Bushels.	25·3 Bushels.	32·0 Bushels.
United Kingdom	180,471,000 Bushels.	43·6 Bushels.	43·7 Bushels.

The comparatively extensive farming practised in the United States and Russia accounts for the low acre yield, as opposed to the high yield per acre of Germany and the United Kingdom, where farming of necessity is intensive.

African Production.

	1911. Bushels.	1918. Bushels.
Algeria	11,520,000	
Union of South Africa	9,661,000	10,790,000
Tunis	4,650,000	

Since fully half the oats grown in South Africa are fed to stock as forage, the total production as grain would be approximately double the amount given above.

The order of production by Provinces is the same as in the case of wheat, *i.e.*, Cape Province, Orange Free State, Transvaal and Natal, which is to be expected, since the climatic requirements of the two crops are very similar.

General Description and Classification.[2]—The roots are coarser and more numerous, and it is generally accepted that the oat plant is coarser feeding than the wheat plant.

The culms are larger and more succulent than those of wheat ; the oat plant, too, is more leafy, and on the average the leaves are wider than wheat leaves, sometimes equalling one and a half inches in width.

The inflorescence is a panicle usually 9 to 12 inches in length.

Except in the hulless group the kernel is enclosed by the palea and lemma. The kernel proper is usually almost cylindrical, very hairy, yellow to brown in colour, with thin and tender bran.

Etheridge has classified the principal cultivated oats into eight groups, given in the following outline :—

A. Kernel loose within the surrounding hull; lemma and glumes alike in texture—*Avena nuda*.

AA. Kernel firmly clasped by the hull; lemma and glumes different in texture.

B. Upper grains persistent to their rhachillas—*Avena sterilis*.

BB. Upper grains easily separating from their rhachillas

C. Lemma extended as teeth or awn points.

D. Lemma with four teeth or awn points—*Avena abyssinica*.

DD. Lemma with two teeth or awn points.

E. Lemma elongate, lanceolate, with distinct awn points—*Avena strigosa*.

EE. Lemma short, abrupt, blunt, rather toothed than awn pointed—*Avena brevis*.

CC. Lemma without teeth or awn points.

D. Basilar connections of the grains articulate —*Avena fatua*.

DD. Basilar connections of the grains solidified.

E. Panicles roughly equilateral, spreading *Avena sativa*.

EE. Panicles unilateral, appressed—*Avena sativa orientalis*.

Avena nuda (Hulless Oats) is grown very little in South Africa and elsewhere. The caryopsis is freed in threshing and is usually larger than in common or side oats. The panicle may be of the spreading or mane types. The yields are small and the keeping qualities of the grain are poor. It is grown more as a novelty than as a commercial commodity.

Avena sterilis (Red or Algerian Oats).—The upper grains carry with them a part of their rhachillas. The colour of the hull varies from pale red-brown to black, and the caryopsis is more elongated than most of the other cultivated forms.

Examples : Algerian Oats, Ruakura, Red Rust-proof and Burt.

Avena abyssinica (Abyssinian Oats).—The lemma extends into four teeth. Etheridge states that this group is grown chiefly for forage in the desert regions of Abyssinia and Southern Arabia.

Avena strigosa (Rough or Sand Oats) and *Avena brevis* (Short Oats) are species often occurring wild in Europe, and occasionally found cultivated there. They are of relatively small importance.

Avena fatua (Wild Oats) is of interest in that it is supposed to be the progenitor of *A. sativa* and *A. sativa orientalis.* The seed is usually brown to black, the base and the rhachilla of which are very hairy, and the lemmas are strongly awned. The awn of the lower grain is very twisted and right angular. The panicle is very loose and of uneven maturity. The seed when planted has a delayed and uneven germination. It is one of the worst weeds found in winter cereals.

Avena sativa (Common or Spreading Oats).—The majority of cultivated varieties belong to this species. The panicle is open and spreading, thus differing from Side Oats, and because the lemma and palea remain attached to the caryopsis after threshing, it can be distinguished from the hulless forms.

Examples: Winter Dun, Boer Oats, Potato Oats, etc.

Avena sativa orientalis (Side or Mane Oats).—The panicle is compacted and unilateral. The varieties of this species are more restricted to localities and soils than Common Oats, usually coarser strawed, smaller yielders, with a high percentage of hull. The panicle is very apt to be broken off by wind.

Examples: White Tartarian and Black Tartarian.

General.—The colour of the glumes varies—white, black, red, yellow or grey (dun) colours being commonly found. Spring and winter oats are distinguished very sharply from each other in the Northern Hemisphere.

Early and late oats are found. Varieties vary in time of maturity from 95 to 150 days, depending to a great extent on the time of sowing.

South African Varieties.

Winter Dun or English Grey Winter.—A late variety frequently sown for grazing; if used for this purpose it should be sown in March and not later than April. It is very well suited to pasturing and has a spreading panicle and dun-coloured grain.

Algerian.—This variety is grown more than any other variety. It is popular on account of its hardiness, resistance to rust and yielding qualities. Being a robust grower, it grows on soils too poor for Boer Oats. It has a spreading panicle and a yellowish brown grain.

Burt and *Boer Oats* are both early and good forage varieties, and may be sown up to the end of July, in which case, of course, they will not stool as much as when sown earlier.

Hyjera and *Sidonian.*—These varieties are identical in the Transvaal, and as they are very rust-resistant, they are often grown as summer crops. They have fair fodder qualities, being fine in straw, but the grain is small and light. This Sidonian appears to be wholly different to the variety grown under that name in the Cape. The grain is white in both cases.

O.A.C. 72 is an excellent grain or forage variety of fairly early maturity, and will probably become more popular. It has a spreading panicle, with yellow grain.

Texas.—This variety does not grow as tall as Algerian and is slightly later. It has a fine straw and a plump red kernel. Grown extensively in the coastal areas of the South-West Cape.

Smyrna.—This is a robust growing variety, with very large grain and very coarse straw. It is about a fortnight earlier than Algerian and does very well under irrigation.

Other varieties which have been tried and have given fairly satisfactory results are: Ruakura, Appler, Bancroft and River Plate.

In a comparative trial with a number of different varieties at the Elsenburg Experimental Farm, the following results were obtained :—

Variety.	Grain Yield in Pounds per Acre.				Average return for four years.
	1916	1917	1918	1919	
Algerian	1,020	1,110	1,030	1,805	1,241 pounds.
Sidonian	1,060	1,335	1,080	1,375	1,213 pounds.
Smyrna	1,120	970	1,098	1,500	1,172 pounds.
River Plate	955	1,025	1,124	1,445	1,137 pounds.
Texas	805	1,200	1,014	1,525	1,136 pounds.
Appler	785	855	900	1,655	1,049 pounds.
Bancroft	735	885	798	1,525	986 pounds.
Burt	870	835	1,025	990	930 pounds.

Composition.—The United States Department of Agriculture[4] gives the following analysis of the parts of the oat :—

	Ash.	Protein.	Fibre.	Carbos.	Fat.
Oat grain ...	3·3	13·3	10·7	67·1	5·6
Oat kernal ...	2·2	16·0	1·0	73·1	7·7
Oat hull ...	7·2	3·6	32·0	56·1	1·1

The hull is seen to be very high in fibre, and the kernel contains a large percentage of fat and protein. The straw of oat hay has a higher feeding value than the straw of any of the cereals.

"The proportion of straw to grain, while of course showing no constant relation, is comparatively high in oats, generally estimated as two to one, while one and one-half to one in wheat and one to one in maize."—Montgomery.

Improvement.—The methods employed are essentially the same as those outlined for wheat.

In the Union improvement in oats should be regarded from the following considerations :—

(1) The isolation of biotypes having a small percentage of hull.
(2) Strength of straw.
(3) Disease-resistant strains.
(4) Early maturity.
(5) High seed-producing strains.
(6) Grazing types, *i.e.*, slow, early development, strong root system, and of desirable stooling propensities.
(7) Forage types, *i.e.*, fine strawed and leafy.

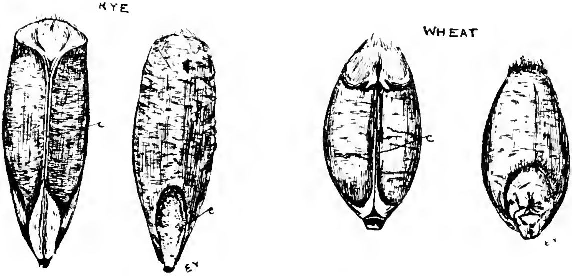
Climate.—Oats are more restricted as regards climatic conditions than wheat, requiring a colder climate with a higher rainfall. Its transpiration ratio is much higher than that of wheat or barley. The following ratios have been obtained :—

Oats.	Barley.	Wheat.	Maize.	Sorghum.	Millet.
614	540	507	368	322	275[5]

The climatic conditions required for oats are very similar to those required for potatoes. Some of the quick maturing varieties, *e.g.*, Boer and Burt, can be used as a catch crop where wheat has been destroyed by Take-all.

Soils. The oat crop is a "coarse" feeder as compared with wheat or barley, which may be classed as "delicate" feeders; consequently it will thrive well on a greater variety of soils than the last-named crops. Extra preparation of land for oats is not so essential as for wheat. Very rich soil, especially

A FIELD OF ALGERIAN OATS.

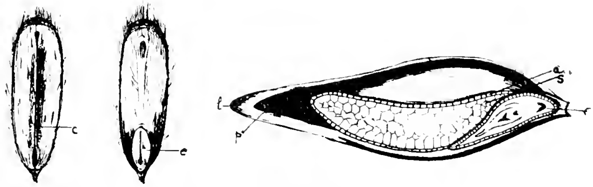


LEFT : RYE KERNELS.
RIGHT : SOFT WHEAT KERNELS.

PLATE XVIII

UBA SUGAR-CANE—WINKELSPRUIT EXPERIMENTAL STATION.
(COURTESY UNION DEPARTMENT OF AGRICULTURE).

PLATE XIX



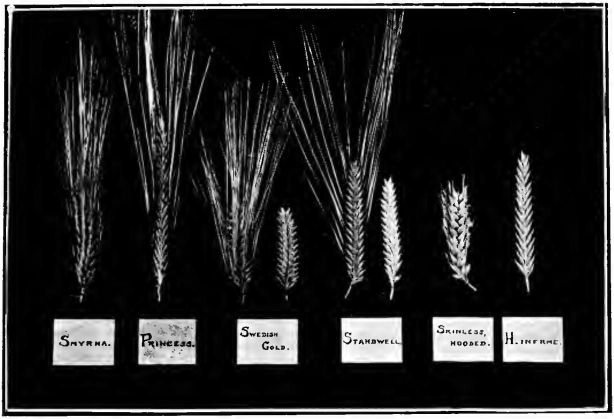
LEFT : OAT KERNELS SHOWING CREASE AND EMBRYO.

RIGHT : CROSS-SECTION OF OAT SEED, SHOWING EMBRYO, ENDOSPERM, ALEURONE LAYER, PALEA AND LEMMA.

LEFT : WILD OATS.

RIGHT : COMMON OATS.

PLATE XX



HEADS OF VARIOUS VARIETIES OF BARLEY.
(COURTESY MR. J. SELLSCHOP).

in nitrogen, is often not suited to oats, as the crop lodges very readily when the growth is rank. Oats will often do fairly well on badly drained land where other crops fail. It is more alkali or " brak " resistant than wheat, but like the latter crop and maize, prefers a neutral soil.

The field intended for oats should be prepared more or less in a similar way to that described for wheat. If the land has had a summer crop on it, as is often the case, it should be ploughed immediately after the crop has been removed, and if possible worked up into a good tilth before the seeding takes place.

FERTILISERS.—In older countries fertilisers are usually supplied to some other crop in the rotation rather than to the oat crop. In South Africa phosphates are more often lacking than nitrogen or potash, consequently in the rotation phosphatic fertilisers should be the chief consideration. The application of superphosphate at the rate of 200 pounds, or, Government guano, at the rate of 300 pounds per acre, generally give good results. In the South-West Cape light dressings of nitrate of soda have proved beneficial.

SEED.—Oat seed may be judged by the use of the following score card :—

(1) Vitality	20
(2) Size and plumpness	20
(3) Freedom from foreign seed and damaged grain, dirt, etc.	20
(4) Thinness of hull	25
(5) Purity of variety	15
Total	100

(1) *Vitality.*—Seed which will germinate well is of a bright polished appearance. When used for seed, oats must have good vitality, but for feeding purposes too much attention should not be given to this point.

Often hulless seeds are found in hulled varieties, and provided the sample is not an old one, it should not be discounted on this account, as these hulless kernels usually escape most easily from thin-hulled varieties. However, hulless oats lose their vitality sooner than do oats enclosed in the palea and lemma.

(2) *Size and Plumpness.*—Within the variety, the larger the seed the better. In all varieties the seed should be plump,

well filled out; this indicates a high weight per bushel and satisfactory maturity. For seeding purposes, large, plump seed is very important. At the Ontario Agricultural College the following result was obtained as an average of a seven years' trial:—

Large plump seed	62·0 bushels per acre.	
Mixed sample	54·1	,,
Small seed	46·6	,,

A great many experiments of this nature have been conducted at various institutions, and while often faultily planned, the general conclusion to be drawn from them is that the use of large, plump seed for planting is very much the superior. Bolley attributes the governing factor to be one largely of disease, and he is, no doubt, very near the mark. These experiments, too, emphasise the necessity for a greater use of winnowing machines in the Union.

(3) *Freedom from Foreign Seed, etc.*—Wild oats (*Avena fatua*) is one of the worst weeds found in the oat crop, and it is almost impossible to separate the seed from that of the ordinary cultivated varieties. The seed of Darnel or Drabok (*Lolium temulentum*) is also frequently found in oat seed.

(4) *Thinness of Hull.*—The percentage of hull varies extraordinarily with the varieties, and while, of course, never constant for the same variety, some breeds show an undesirable and consistently high percentage. Since the hull, bran and embryo are formed before the starch is fully developed in the endosperm, naturally anything affecting full development, *e.g.*, unsuitable climatic and soil conditions, disease and insect injury must, of course, affect the percentage of hull. At the Ontario Agricultural College, in apparently well-developed oats this was found to vary from 18·5 to 49·0 per cent. in different varieties.

The importance of this point is well shown in the following figures obtained at the above institution:—

Variety.	Bushel. weight.	Percentage hull.	Yield. per acre. Bushels.	Pounds Kernels per bush.	Pounds Kernels per acre.
Joanette	33.16	23.8	72.1	25.27	1822
Danbency	35.29	25.1	65.98	26.43	1744
Early Devon	37.67	34.5	65.18	24.67	1603
Pioneer	32.50	38.0	78.42	20.15	1568

The weight per bushel, while important, is likely to be misleading, *e.g.*, the Early Devon in the above table weighed 37·67 pounds per bushel, but the seed contained 34·5 per cent. hull. The feeding value of the hull is approximately equal to oat straw, and the real value of the oat from a feeding point of view must be considered from the standpoint of kernels produced per acre. In the preceding table the Joanette variety has a lower yield per acre of seed than Pioneer, yet the former produced 254 pounds of kernels per acre more than the latter.

The legal weight per bushel varies in different countries. Thus in the United States 32 pounds is the accepted standard; in Canada 34 pounds, and in England 40·2 pounds.

At Lulea, in Sweden, in 1904, the average percentage of hull for all varieties was nearly 10 per cent. less than at Svalof, further south.[3]

To ascertain correctly the percentage hull of a sample, 100 pounds of seed should be weighed, the kernels removed and weighed, and from this the percentage of hull is ascertained. By inspection, thick hull is detected by removing the kernel and then feeling the flexibility of the hull between the fingers. It is also indicated when nearly the whole of the palet is enclosed by the lemma, in which case the kernel is nearly always small. If the seed is plump and the palet well shown, the seed is usually proportionately large and the percentage of hull small.

The percentage of so-called "double seed" in oats is also of importance in considering this point. A "double seed" consists of the secondary kernel or spikelet enfolded in the lemma of the primary spikelet, the kernel of the latter being undeveloped. Certain varieties give a larger proportion of these "double seeds" than others, but rarely above 5 per cent. However, in these the percentage of hull is very high and, moreover, the germination from them is poor.

(5) *Purity of Variety.*—Foreign varieties are detected by colour, length and shape.

Seed Treatment.—The seed should be treated with formalin, the same as for wheat.

Time of Seeding.—The time of sowing will vary with the locality, variety, purpose for which intended and whether grown under irrigation, dry land or humid conditions. Under irrigation the seed should be sown during the months of April and May, so as to provide the crop with a long growing season to stool and reach full development. Early maturing varieties like Boer and Burt may be safely sown as late as July, but the crop is not so productive. For grazing purposes, late varieties, *e.g.*, Winter Dun, are best sown on dry lands in February and March, so as to produce a fair growth before the dormant winter period.

Unless the soil is deep and fertile and has a good water-holding capacity, dry land winter sown oats are not likely to succeed except for grazing purposes. Sometimes on productive soil, with sufficient early spring rains, the crop, after being grazed off in winter, will shoot up again and be ready for harvesting in November and December. On the highveld of the Transvaal, where rust is not very prevalent, oats are sown on dry lands in August and September with a fair amount of success.

Rate of Seeding.—This is governed by the stooling characteristics of the variety, time of the year when sown, whether drilled or broadcasted, soil conditions and the purpose for which the crop is grown. For grain production under irrigation, 50 to 70 pounds is sufficient; without irrigation, 40 to 50 pounds is required. Thicker seeding may be employed on very productive soils, when sown late, when the crop is to be used for pasturage or for hay, and when broadcasted.

The depth of planting and the subsequent treatment of the crop as regards after cultivation and irrigation is identical with that of wheat.

Oats and barley are often sown in mixtures in Canada, where the mixed grain harvested is ground and fed to stock. An early variety of oats and a late variety of barley is required in order to get the maturity of the two crops to synchronise. In this way, since the oat has a more extensive and deeper rooting system than the barley, a larger total yield is obtained than if the same acreage were divided and sown separately to barley and oats.

In the South-West Cape oats, vetches or field peas are often sown together, the vetches, or field peas, being supported by the oats. This is often grazed off or cut for hay, giving a nutritious hay; moreover, the soil productiveness is not so quickly exhausted as would be the case were the oats sown alone. A few pounds of rape is sometimes sown with the oats. The rape makes very little growth while the oats are growing, but when the oat crop is harvested the rape furnishes a good growth for sheep pasture.

Harvesting.—For forage, the crop should be cut when the upper tips of the panicles have turned white and when the plants are changing from a dark green to a yellowish appearance. At this, the soft dough stage, the hay is more palatable and most nutritious.

A general mistake in the Union is to cut oats for forage purposes when much too mature.

For grain the crop should be harvested when the panicles are quite white and the grain is in the hard dough stage.

The crop is usually cut with a self-binder and reaper, or by hand, and the bundles, 10 to 12 in number, are stooked in shocks, where they are allowed to stand until well dried before being stacked.

Oat-hay or forage is put on the market in bundles of 5 to 6 pounds, or in bales of 200 to 300 pounds each.

The yield of forage is considered good when two to three tons per acre are obtained, and when grown for grain eight to ten bags are procured. These yields are given for irrigable land; without irrigation—particularly in the South-West Cape—the yields are naturally much smaller.

Uses.—In the Union the oat-hay crop is used most extensively as a foodstuff for equines and as pasturage for sheep. It is also used as human food in the form of oatmeal. The straw, best chaffed, is fed as a roughage to horses, cattle and sheep. The oat grain treated in various ways is used too as a concentrate for poultry.

Diseases.—Smut (*Ustilago avenæ* and *U. levis*).—Loose Smut and Covered Smut are prevalent and often serious. They are readily controlled by the formalin treatment described for wheat.

Rust (*Puccinia graminis*, *coronata* and *rubigo-vera*).—These are very common and destructive. The use of early maturing varieties and early sowing of the less susceptible varieties are the best means of combating these diseases.

Spikelet Blight and Blade Blight are disorders which are sometimes troublesome. The casual organisms have not been identified and no remedy is known.

Oats are not supposed to be a host of *Opiobolus graminis*, consequently it should take the place of wheat, or should form a crop in rotations where meat is affected with Take-all or Vrotpotje.

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CHAPTER XVI.

BARLEY AND RYE

History.—*Hordeum spontaneum*, a wild form, occurs in Asia and is supposed to be the progenitor of our two-rowed forms. A six-rowed wild form is supposed to have existed, since the oldest records of barley describe it as six-rowed. Specimens of grain taken from Egyptian tombs, estimated to be 3,000 years old, are in the British Museum; representations of barley ears are also found in these tombs. As human food, it was gradually replaced by wheat and rye.

Production. The world's continental production for the period 1912-14 is given below :—

	1912 to 1914.	
Europe	1,067,210,000	bushels.
North America	250,121,333	,,
Asia	115,816,000	,,
Africa	45,443,666	,,
Australia	4,715,333	,,

The following table gives the leading countries for 1912-14 and their average annual production per acre for the period 1904-1913 :—

		Average Yield per acre.
United States of America	198,988,666 Bushels.	25·1 Bushels.
Russia	471,177,666 Bushels.	15·3 Bushels.
Germany	162,877,666 Bushels.	36·8 Bushels.
Austria-Hungary	152,936,000 Bushels.	25· Bushels.
Japan	98,264,333 Bushels.	30· Bushels.

South African provincial production according to the 1917-18 agricultural census is :—

		Total Union Production.
Cape Province	93,206,000 lbs.	1,790,400 Bushels.
Transvaal	1,876,000 lbs.	1,790,400 Bushels. (1917—1918)
Orange Free State	1,845,000 lbs.	
Native Reserves	1,395,000 lbs.	1,111,700 Bushels.
Natal	250,000 lbs.	(1911—1912)

The average yield is about 18 bushels, of 48 pounds each, per acre. The total production of South Africa is likely to increase considerably, as at present there is a tendency among the farmers in the lowveld, *e.g.*, Lydenburg, to go in more for the cultivation of this cereal, which is a more certain crop in those parts than wheat.

USES.—Barley is grown chiefly for malting purposes in South Africa, and the two-rowed barleys, having large plump seed, were considered best for this purpose, until it was discovered that good malt can also be produced from Smyrna, a six-rowed type grown extensively in the Western Province of the Cape. To a limited extent barley is also used as a concentrate in South Africa. It is especially useful in fattening animals. Fairly large acreages are sown for soiling and pasturing purposes. Prohibition in the United States may of course affect the Union's production adversely.

CLASSIFICATION AND DESCRIPTION.

Genus.	Section.	Sub-section.	Species.
Hordeum.	*vulgare.*	*Eu. vulgare.*	*vulgare.*
		intermedium.	*intermedium.*
		distichon.	*distichon.*
			deficiens.

Key to cultivated species :—

All spikelets fertile (six-rowed barley).

Lemmas of all florets awned or hooded—*Hordeum vulgare.*

Lemmas of lateral florets without awns or hoods—*H. intermedium.*

Only the central spikelets fertile (two-rowed barley).

Lateral spikelets consisting of outer glumes, lemma, palea, rachilla and usually rudiments of sexual organs.—*H. distichon.*

Lateral spikelets reduced usually to only the outer glumes and rachilla, rarely more than one flowering glume present and never rudiments of sexual organs—*H. deficiens.*

There are thirty-two agricultural varieties and a great many agricultural sub-varieties, the botanical nomenclature becoming somewhat lengthy, *e.g.*, *Hordeum deficiens gymnospermum typica.*

HULLESS BARLEY.—In these, unlike ordinary barleys, the kernel escapes from the lemma quite freely as in wheat. Varieties of these occur in each of the above four species. They are very commonly known as " barley wheat," since the grain resembles wheat somewhat.

Both the six-rowed and two-rowed barleys may have compact (zeocriton) erect (erectum) or nodding (nutans) types of ears.

In sample the six-rowed types may be identified by having two-thirds of the grain twisted at the base.

AWN TYPES. -While most cultivated barleys have long, stout awns, there are four types of awns :—

1. Ordinary long, stout awns.
2. Deciduous awns, *i.e.*, drop off as the grains ripen.
3. Awnless or awn-pointed.
4. Hooded or trifurcate types.

These various awn types may be found in varieties of all four species.

Barley is self-fertilised, and natural hybrids are extremely rare.

COLOUR OF GRAIN.—Ordinary cultivated barleys have a whitish grain, but in some the husk may be black or bluish. In others the grain is either white, green, purple or black. White barleys are preferred commercially, but quality does not seem to be correlated with any particular colour. There are two colouring materials—anthocyanin and a melanin-like compound. These colouring materials may be present in the husks, the aleurone layer or in the endosperm.

WINTER AND SPRING BARLEYS.—Barleys do not stand the same extremes of temperature that wheat or rye do. In mild climates, however, winter varieties are grown successfully. In South Africa the practical importance of this is that the late maturing (*i.e.*, winter types) should be sown very much earlier than the early maturing or spring types.

VARIETIES GROWN IN SOUTH AFRICA.

Six-rowed.

- Cape six-rowed or Smyrna (awned, white kernels).
- O.A.C. 21 (awned, bluish kernels).
- Swedish Gold (white grains, awn semi-deciduous).
- Six-row Hulless (awnless, hulless, white kernels).

Two-rowed.

- Chevalier (awned, white kernels).
- Invincible (awned, white kernels).
- Standwell (awned, white kernels).
- Duckbill (awned, white kernels).

The following score-card may be used in judging barley seed, viz. :—

1. Size and uniformity ...	20
2. Plumpness and texture ...	15
3. Soundness ...	10
4. Freedom from foreign matter and seeds ...	15
5. Brightness of colour ...	15
6. Weight per bushel ...	15
7. Purity of variety ...	10
Total ...	100

(1) *Size and Uniformity.*—The grain should be as large and uniform as possible. Two-rowed barley is usually plumper, longer and more uniform than six-rowed.

(2) *Plumpness and Texture.*—Good malting barley must be plump, and when cut the surface of the grain should be mealy and snowy white in appearance, and not vitreous. A flinty appearance indicates a high percentage of protein, which is desirable when the grain is used as a concentrate, but is objectionable from the brewer's point of view. The percentage

of protein varies somewhat with climate and soils, being higher under semi-arid than under humid conditions, and when the nitrogen content of the soil is high. In a good malting barley the protein content should be low and the carbohydrates high. Good samples for this purpose contain 62 to 64 per cent. starch, and protein 9 to 13 per cent. The protein content of barley seed varies from 6½ to 17 per cent.

The per cent. hull is usually considered under this point. If the grain is plump the hull is usually thin, particularly when wrinkled across the back, and when two strong veins are absent. For malting, hulled types are preferred to hulless types.

(3) *Soundness.*—There should be no sign of disease, dampness or broken kernels.

(4) *Freedom from Foreign Matter and Seeds.*—Dirt and weed seeds must be looked for and the sample discounted accordingly.

(5) *Brightness of Colour.*—A bright appearance is the chief superficial indication of good viability. For brewing purposes at least 99 per cent. of the seeds should be viable, but, moreover, the germination must be even and sufficiently vigorous to show a germination of at least 95 per cent. in 72 hours. If at all weathered or imperfectly matured, the germination will be erratic and the value from a malting standpoint much reduced.

(6) *Weight per Bushel.*—Well matured, plump barley should weigh 48 pounds to the bushel.

(7) *Purity of Variety.*—Seeds of other varieties are indicated by difference in colour of the hull and caryopsis, shape and size. For seeding purposes, greater stress must be laid on this point than for malting; however, a mixture of types is unlikely to be uniform in germination.

Malting barley should not be closely threshed, *i.e.*, to give seeds with exposed caryopses. If well threshed a fair number of the grains will be found to have a short portion of the awn adhering.

" An ideal malting grain of barley is one possessing a relatively short longitudinal and a correspondingly long transverse diameter, with both the distal and proximal ends broadly oval. It contains an embryo, with a large scutellum reaching over the edges of the endosperm, and an epithelial layer composed of long narrow cells.

"An inferior grain of barley is elongated and is pointed at both ends. It contains an embryo with a narrow scutellum and an epithelial layer which is made up of short, broad cells."

COMPOSITION AS COMPARED WITH WHEAT AND OAT GRAIN.

	Water.	Ash.	Crude Protein.	Fibre.	N-Free Ext.	Fat.	Nut Rat.
Wheat ..	10·2	1·9	12·4	2·2	71·2	2·1	1 : 77
Oats ...	9·2	3·5	12·4	10·9	59·6	4·4	1 : 6 : 3
Barley ..	9·3	2·7	11·5	4·6	69·8	2·1	1 : 7 : 8

The fibre content is lower, but the nutritive value is less than that of oats.

SOIL AND CLIMATIC REQUIREMENTS.—Barley requires a comparatively rich, porous soil, and because of its somewhat weak, shallow root system will often fail on a heavy soil which might yield quite good wheat crops. Unlike rye, it will not grow well on acid soils. It is fairly resistant to alkali, but possesses poorer qualities of withstanding drought than wheat, consequently in the Union it is seldom grown without irrigation, excepting in the South-West Cape, where a winter rainfall obtains.

Barley requires a cool growing season, with plenty of sunshine.

CULTURAL METHODS.—These differ very little from those employed for wheat cultivation. Drilling is preferable to broadcasting. The seed should be sown at the rate of 50 to 60 pounds per acre on dry lands, and 60 to 90 pounds on irrigated land. For grain, early varieties should be sown in April and May, and late varieties from the end of March to the end of April. For soiling, late varieties should be used, and may be planted in February and March so that advantage may be taken of the late summer rains, and, moreover, so that green feeding is provided during the dry winter months.

ROTATIONS.—(1) *Under Irrigation in Orange Free State and Transvaal*—

1st Year.—Summer crop—Potatoes, fertilised with kraal manure and bonedust.

Winter crop—Barley.

2nd Year.—Summer crop—Cowpeas ploughed down.
Winter crop—Barley, fertilised with phosphates.

(2) *South-West Cape*—

1st Year.—Barley (300 pounds guano or 300 pounds bonedust).
2nd Year.—Barley and vetches mixed for hay.
3rd Year.—Wheat, with light dressing of basic slag or bonedust.
4th Year.—Field peas ploughed down and then fallowed.

HARVESTING.—Barley should be harvested for grain for malting purposes when fully matured, and every precaution should be taken to prevent weathering of the seed, as any discolouration markedly decreases the price. For feeding purposes it might be cut earlier in the hard dough stage. At this stage the straw will be more palatable and nutritious.

Some of the hooded barleys when grown for seed need careful handling in harvesting, since being very brittle when mature, the ears are apt to break off. These types should not be allowed to become too dry, and should be harvested in the early morning when still fairly damp with dew.

When sufficiently dry in the stooks, the crop should be stacked, or in some cases may be threshed without being stacked.

The following yields have been obtained in variety trials at Grootfontein Experimental Farm, under irrigation, 1917 :—

Cape six-rowed	2,458 lbs.
Chevalier	1,386 ,,
Beardless Success	1,288 ,,

At Elsenburg, 1913, without irrigation :—

Duckbill	440 lbs.
Grubproof	540 ,,
Cape six-rowed	790 ,,

DISEASES AND PESTS.—Loose Smut of Barley (*Ustilago nuda*).—This is a parasitic fungus infecting the plant at the time of flowering. The plants grown from seeds matured from infected flowers produce smutted heads; the following year within a short time after maturity of the spores they are scattered by the wind and only the bare stem remains. No practical seed treatment is known, but rotative cropping will keep the disease in check.

Covered Smut of Barley (*Ustilago hordeii*).—The spores mature and are scattered later. They adhere to the grain and can be easily killed by the use of formalin. Immersing the seed for 30 minutes in a solution of one pound of formalin to 40 gallons of water will assist in controlling this disease.

Leaf Rust (*Puccinia simplex*) and Stem Rust (*P. graminis hordeii*) are both common and can be checked only by growing resistant strains in favourable localities. The rusts of barleys are not, however, such a menace to barley growing as are the wheat rusts to wheat growing.

Ergot (*Claviceps purpurea*) is occasionally found. Care should be taken in feeding affected barley, and it should not be used either for malting or for planting.

Yellow Leaf (*Helminthosporium graminum*) is uncommon, and is recognised by a yellowing and splitting of the leaves of young plants. No remedy is known.

The Angoumois Moth (*Gelechia cerealella*) and Weevils (*Calandra oryzæ*) are often serious storage pests. They can be controlled by fumigation with carbon bisulphide. An Aphis (*Toxoptera graminium*) may be bad at times and is difficult to control. Grazing down the crop may be of assistance.

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RYE.

Rye is the fifth cereal of importance in the world, maize, wheat, oats and rice being of greater account. It is cultivated in much the same way as wheat and in the Northern Hemisphere for very much the same purpose. In South Africa it is grown chiefly for grazing, or as a soiling crop, and occasionally, of course, for grain.

Production.—Nearly 90 per cent. of the world's crop is produced in Europe, as the following table indicates :—

Average for Three Years (1912-14).

Europe	1,751,787,333	bushels.
North America	42,259,666	,,
Asia	33,928,000	,,
South America	1,892,000	,,
Australasia	174,666	,,

In Europe rye is of about the same importance as is wheat, but in Russia and Germany more of the former is grown than the latter. Production in the Union is confined chiefly to the Cape Province, where approximately 80 per cent. of the Union's yield is obtained. A fair amount is grown in the eastern districts of the Orange Free State, but little is cultivated in the Transvaal and Natal.

In 1911 the Union produced 675,700 bushels and in 1918 830,700 bushels. However, more rye is grown in South Africa than is indicated by the above figures, since a considerable acreage is not allowed to mature, being pastured and then ploughed down.

Origin and Description.—De Condolle states that while rye was known to Pliny, its cultivation when compared with wheat is of comparatively recent times.

Rye (*Secale cereale*) is one of the hardiest and yet one of the least grown of the cereals in the Union. The fact that if closely pastured it may be induced to live over a second winter, shows it to have a tendency towards a perennial form. It is supposed to have originated from *Secale montanum anatolicum*, a perennial sub-species and native of Western Asia. Unlike wheat, it normally cross-fertilises and all the flowers are fertile. It usually grows much taller than wheat, the stems are thinner, and the first leaf sheath which comes above the ground is of a purplish red colour which distinguishes it from other cereals at this stage.

The grain of rye is usually white to grey-greenish in colour, more slender than wheat, not so smooth, with a shallower crease, sharply pointed towards the embryo end, and characteristically blunt at the apex.

The percentage of protein is less than found in wheat. It contains gluten, and for that reason can be made into porous bread. The straw is much tougher and more flexible, less palatable and nutritious than that of other cereal straws.

It has been crossed with wheat, but only when wheat is employed as the mother plant; the hybrids are usually sterile.

Varieties.—Since it is normally cross-fertilised, there are very few varieties. In northern countries winter and spring varieties are grown; in South Africa these are distinguished as late and early varieties, the former being sown from March until the beginning of May, and the latter as late as the middle of July.

Requirements.—It is best suited to cooler and drier climates than wheat, and will thrive on poorer and more sandy soils than the other winter cereals.

The cultural methods are similar to those employed in the cultivation of wheat, but because of its hardiness it will succeed with less favourable soil preparation than the latter crop. It is sown at the rate of 50 to 70 pounds per acre, and must be harvested for grain only when fully ripe.

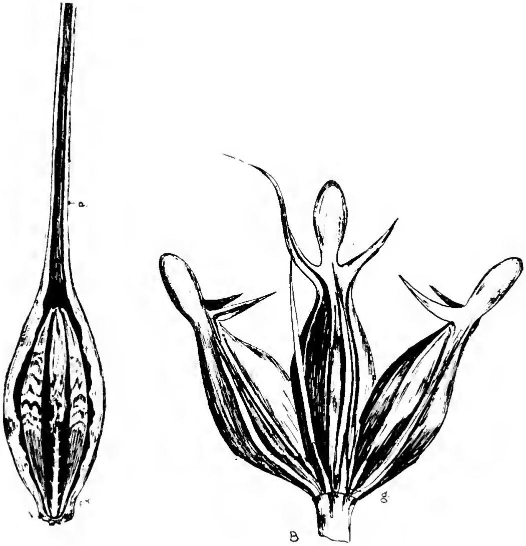
General.—The object in growing rye in the Union is chiefly for grazing and soiling, for which purposes it is admirably suited. It will also give fair returns on soils too poor for the profitable cultivation of other cereals. It is surprising that rye is not grown to a greater extent in this country for bread-making, as, in many parts where wheat is at present grown, rye would be undoubtedly more successful than the latter crop. Bread made from rye flour is dark coloured, but very wholesome and palatable.

When used for soiling, the crop should be sown at intervals from February to May, and should be cut before the flowers appear, as at later stages the plant becomes too fibrous. Because of its relatively good growth on poor soils, it is often used as a green manure to renovate impoverished soils. The usual practice is to sow early in March, pasture with sheep during winter, and to allow the crop to make a certain amount of growth in spring before it is ploughed under.

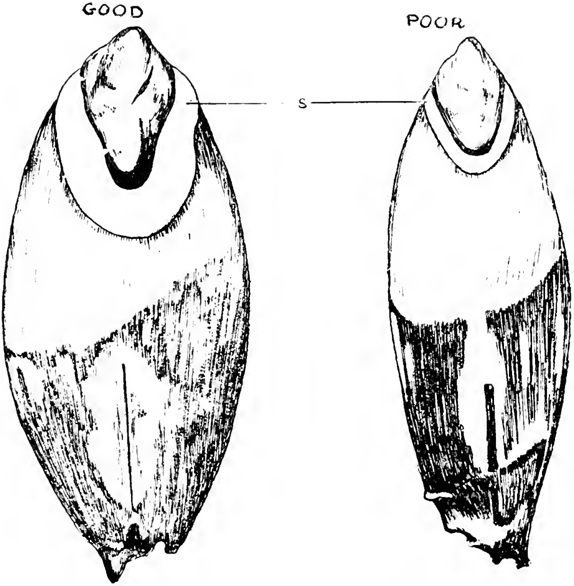
In America the crop is grown extensively for the straw, which is used for making mats, stuffing horse-collars, and so forth. When grown for this purpose it is cut when the straw is still quite green, made into small bundles and carefully cured. Alcoholic beverages are also manufactured from the grain of this cereal.

Rye yields about one to two tons of straw, and under irrigation 20 to 26·6 bushels of grain (6 to 8 bags) per acre ; without irrigation about half the above is obtained.

Diseases.—It is subject to rust, but not to smut, and is usually much more rust-resistant than wheat. It is often badly attacked by ergot, which causes the grains to grow three to five times their normal size, turn black, and be filled with black spores. While of a pharmaceutical value, rye badly infected with this disease, which causes abortion and certain forms of paralysis in live stock, should not be fed.



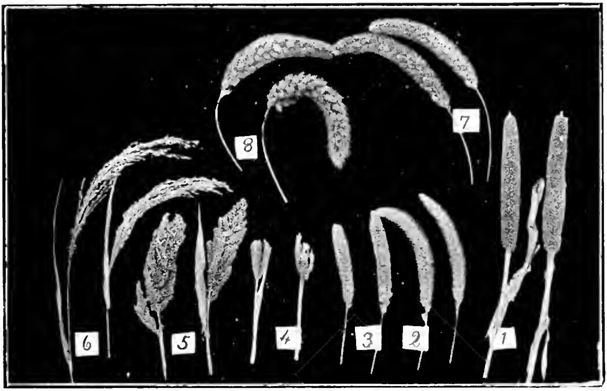
LEFT: KERNEL OF AWNED, TWO-ROWED BARLEY.
RIGHT: KERNELS OF HOODED SIX-ROWED BARLEY.



BARLEY KERNELS WITH HULL REMOVED

LEFT: GOOD MALTING BARLEY, SHOWING PRONOUNCED SCUTELLUM.

RIGHT: POOR MALTING BARLEY, OF POOR SHAPE AND SHOWING REDUCED SCUTELLUM.



MILLETS: 1, PEARL MILLET (PENNISETUM GLAUCUM); 2, 3, 7 AND 8, TYPES OF SETARIA ITALICA; 5, ECHINOCHLOA FRUMENTACEA; AND 6, PANICUM MILIACEUM.

PLATE XXIV

TOP ROW: MANGELS (A) LONG TYPE, (B) INTERMEDIATE, (C) TANKARD, (D) GLOBE. BOTTOM ROW: SUGAR BEETS (AFTER PERCIVAL).

CHAPTER XVII.

GRASSES AND MILLETS

GRASSES.

The culture of grasses for animals is mainly an outcome of European civilisation, and then only in regions where Europeans have become established. In Oriental countries the by-products of crops grown for human beings have been utilised for stock, and only in recent years, and to a limited extent, have grasses been grown for stock.

The grasses cultivated for hay, pasture, fodder and soiling play a relatively small part in South African agriculture when compared with that of European, American and even Australian farming. The hay crops of America, composed chiefly of grasses, are valued second only to maize.

The reason for this lies, firstly, largely in the fact that, farming in South Africa being still in an extensive phase, stall feeding has not supplemented ranching to the extent it has in many older countries. The chief necessity on the large farms of South Africa is to produce hay and fodder for the winter months, when the natural pasturage does not meet the needs of the stock. As farming becomes more intensive, the cultivation of grasses for pasture, hay, fodder and soiling will doubtless become more necessary. Secondly, the climate of South Africa is totally unsuited to the growth of many of the grasses cultivated in America, Canada and Europe, *e.g.*, Timothy and Kentucky Blue Grass. Hitherto, experimental work with grasses has rather centred on European and American grasses, and their success on South African farms has been very local and never general. The cultivated grasses in the older countries owe their success to the relatively high rainfall, more evenly distributed than in South Africa, and to the more moderate summer temperatures of those countries.

The cultivated grasses of agricultural importance in South Africa to-day are all indigenous to Africa, chiefly tropical Africa, and all are exotic to the Union. It would seem, therefore, that new grasses should be sought for, not only in the tropical parts of Africa, but also in tropical parts of other countries.

Cultural methods have a tremendously modifying effect upon the environment, and it is possible that certain minor grasses in the grass associations of the Union may be found to be excellent under cultivation, *i.e.*, when not in natural competition with the dominant grasses. Most of the commonly occurring grasses of the Union have frequently been tried, and so far none has proved outstanding under culture.

CLASSIFCATION ACCORDING TO USE.

Hay Grasses.—Hay consists of the entire dried herbage of comparatively fine stemmed grasses or other forage plants. If properly treated, hay is not only grass that is dried, but in which certain fermentative changes have taken place, *i.e.*, curing. Hay grasses are fine stemmed grasses making an erect growth sufficient to enable cutting by mowers, *e.g.*, Teff, Sudan grass, Boer Manna, etc.

Fodder Grasses are coarse stemmed grasses cut and dried for stock feed, e.*g.*, Napier grass, Maize, Saccharine Sorghums, etc.

Pasture Grasses are grasses grown principally for grazing. These are usually decumbent perennials, having adventitious roots or rhizomes, *e.g.*, Kikuyu grass and *Paspalum dilatatum*. Grasses are particularly adapted for grazing in that the growing portion is not terminal as in shrubs, but near the base of the grass leaf; consequently the grass is not injured by having the upper portions of the leaves eaten or cut off.

Soiling Grasses are grasses which are cut and fed green to animals off the field on which they have grown, *e.g.*, *Phalaris bulbosa* and New Zealand tall fescue.

Lawn Grasses.—A good lawn grass should propagate by adventitious roots or rhizomes, should be fine and soft in texture, dark green colour, aggressive with vigorous decumbent growth, and perennial, *e.g.*, Bermuda grass and Kikuyu.

Soil-Binding Grasses.—These are perennials, more commonly those having adventitious roots or rhizomes, *e.g.*, Beach grass (*Ammophila grenaria*).

Apart from the cereals, the most important cultivated grasses in the Union are :—

(1) Teff (*Eragrostis abyssinica*).

(2) Sudan grass (*Andropogan sudanense*).

(3) Kikuyu grass (*Pennisetum clandestinum*).

(4) *Phalaris bulbosa* (Toowoomba grass).

(5) Napier or Elephant grass (*Pennisetum purpurem*).

(6) The various millets.

Essential Factors.—C. V. Piper : " Among the characteristics a grass must have to be valuable under cultivation are a satisfactory yielding capacity for the purpose employed, whether pasture, soiling, silage or hay; good feeding quality, *i.e.*, palatable, not too woody, and without any injurious effects; good productive characters, such as abundant easily-gathered seed, or ready multiplication by vegetative methods; and aggressiveness, or ability to maintain itself under the conditions of culture, and yet not be too troublesome as a weed."

Under South African conditions, because of our uneven distribution of rainfall, grasses not grown under irrigation must be drought resistant. Cultivated grasses should be high in protein, and low in crude fibre, constituents in which grasses vary very appreciably.

TEFF.

Teff (*Eragrostis abyssinica*).—More extensively grown than any grass in South Africa. At present teff hay is second in importance and in price to lucerne hay.

History.—Teff has been grown by the native Abyssinians as a cereal foodstuff probably for centuries. It was introduced into Natal about 30 years ago, and, although favourably reported on, it attracted little attention until again introduced from California by J. Burtt-Davy in 1903. Seed was distributed among farmers in the Union in 1904 and subsequent years; favourable reports were received, and the grass was soon established as one of the Union's important crops. It is supposed to be indigenous to Abyssinia.

Description.—It is a summer annual of very rapid growth, as it can be cut for hay six to eight weeks after sowing, and matures seed from eight to twelve weeks. The plant is leafy, with very fine stems, two to four feet in height. If sown and cut early the aftermath will frequently give a very good second cutting. The seed of the variety grown in the Union is very small, dark reddish in colour. Because of its quick growth it is drought evading, but teff cannot be looked upon as a drought-resistant crop. It is essentially a hay crop, to a limited extent a green-manuring crop (the aftermath if not of sufficient growth to warrant its being mowed is often ploughed down as green manure), and, being a short-lived and shallow-rooted annual, is not a very suitable grass for pasturage.

As a hay crop it is extraordinarily easy to handle and cure. The hay is very palatable and of a very fair nutritive value. It has a protein-content of about 5·5 per cent., being a little higher than that contained in Boer manna, very similar to oat hay, but inferior to lucerne. The grain contains less protein (8·2 per cent.) than the soft wheats (10 per cent.), but in other constituents it is very similar to wheat grain. The weight of seed is 60 to 72 pounds per bushel.

Climate.—Being a summer annual, it is best suited to parts having a summer rainfall. Because of its quick maturity, which enables it to mature often on the soil moisture stored by one or two good soaking rains, it can be grown successfully in comparatively dry regions. In parts having a very heavy rainfall—40 to 50 inches—it frequently lodges badly and is somewhat difficult to harvest and cure. Its yields are not sufficiently high to warrant its cultivation under ordinary irrigation.

It is particularly suited to the Highveld of the Transvaal and Free State, as well as the higher altitudes of Natal, *e.g.*, Mooi River. It is not suited to the Western Province or Namaqualand, but does fairly well in parts of the Eastern Province, Western Transvaal, and in some localities of the Transvaal Bushveld.

Soils.—Teff does well on moist soils and, unlike many of the other cultivated grasses, will give good yields on sandy soils. On very rich soils it has a tendency to lodge badly. The seedling is of very delicate growth, and the crust formed by beating rains on some clay soils on drying out often prevents the shoots from reaching the surface.

It is a shallow-rooted crop; consequently, if grown continuously on the same land, it soon exhausts the plant food in the upper surface. For this reason, it has been erroneously described as an exhaustive crop on soils.

Rotations.—In rotations it forms an excellent catch crop when the main crop fails. The following five-year rotation is recommended for Highveld farmers :—

1st Year—Maize, and superphosphate.
2nd Year—Maize.
3rd Year—Teff.
4th Year—Cowpeas to be ploughed under.
5th Year—Potatoes, and bone meal.

Soil Preparation.—As the seed is extremely small and the seedling of delicate growth, the ground should be in very fine tilth and the seed must be buried only to the slightest degree. After sowing, if the ground is rolled with a Cambridge Roller this will be sufficient. (On moist, heavy soils this instrument cannot be used.)

Some of the best stands are obtained by sowing just before rains or by sowing during rains. No further covering of the seed is necessary.

Brush dragged lightly over the ground is used by some farmers. Weeders are very useful in this respect, but most harrows cover the seed too deeply.

Insufficient moisture for the germination and early growth is one of the chief causes of crop failure.

Sowing.—Five to six pounds of seed is used per acre, either broadcasted by hand, with a " fiddle Cahoon Broadcast sower," or a wheelbarrow seeder. To obtain even distribution, the seed should be thoroughly mixed with dry sand or silt—about one to 40. It is often recommended as a smother crop, in which case 8 to 10 lbs. should be sown to the acre. On sandy soils light rollers are employed to compact the seed bed after the seed has been sown. It should be sown from October to the end of January in most parts of the Union, and, if possible, to avoid hay-making in January and February, the wettest season in the Transvaal.

Harvesting.—(1) For Hay.—For this purpose it should be mown as soon as the flowers are well out and before the seed has set to any extent. If cut in the afternoon it can be raked the following morning when the dew has disappeared, and cocked in the afternoon. In good weather it can be stacked a day or two after being cocked.

For market it should be pressed in bales 16 x 18 x 36 inches. These usually weigh 75 to 100 lbs.

Teff yields one to two and a half tons of hay per acre.

(2) For Seed.—Teff should be cut as soon as the seed is mature; if allowed to get over-ripe a good deal of it will be lost through shattering.

By sowing early the first crop can be used for hay, and the aftermath for seed.

Diseases and Pests.—*Striga lutea* and a leaf rust, *Uromyces teffi* (P. Evans) are found. The latter has not proved serious.

Striga lutea can be controlled in some parts by sowing in October and November, cutting the first crop of hay, which will be before the parasite has seeded, allowing a fair growth of aftermath, and ploughing down the whole.

GRASS SORGHUMS (JOHNSON'S, SUDAN AND TUNIS GRASSES).

Sudan Grass (*Andropogan sudanense*).—This is a summer annual hay grass rapidly becoming popular and of increasing importance in South Africa. It was introduced into South Africa in 1914 by the Department of Agriculture (obtained from Khartuum, Sudan, by the United States of America in 1909).

Description.—It is indigenous to Northern Africa, and is believed by Piper to be the wild original form of the cultivated sorghums, since it crosses spontaneously with the cultivated sorghums.

It is a tall, leafy grass, reaching a height of six to ten feet, stools very freely, of quick growth, with comparatively fine, erect stems and heavy yielding. It differs from Johnson's grass in that it has no underground stems and is an annual.

"The seed of Sudan grass is plumper and larger than that of Johnson grass, and it breaks off from the branch with a small portion of the rachis attached, whereas the seed of the former grass is flatter and breaks off smoothly, with a well-defined scar."

Tunis Grass (*A. sorghum var. virgatum*) has seed with more conspicuous awns, narrower seed, and shatters at maturity while leaves are still green, whereas the seed of Sudan grass is persistent after maturity.

The hulls or glumes of Sudan grass are awned (may be broken off in threshing), and when in flower are often purplish in colour, some fading to a yellow colour when the seed ripens.

Up to 200 stems have been counted on one plant, and, as this strong tendency to stool is more apparent after the first cutting, the hay of the aftermath is less coarse than that of the first cutting.

Several indigenous grass sorghums (*wilde soetriet*) are found in the Union.

Adaptations.—It is adapted to the same general conditions as sorghums, and is one of the most drought-resistant hay crops. Like other sorghums, it will stand semi-dormant during severe dry spells, but renews its growth vigorously when conditions improve, a distinct advantage over the millets.

It will do well on a variety of soils, preferably a rich loam.

Soil Treatment.—This should be the same as described for sorghums.

Planting.—It can be planted from October to January 31st in most parts of South Africa. November to December, however, are probably the best months. The seed should be buried one to two inches in ordinary soils.

For hay, the ordinary drill for small seeds may be used, taking 10 to 15 pounds, or it may be broadcasted at the rate of 15 to 20 pounds per acre.

For seed and for hay in the drier parts it is better to plant in 3-feet rows, using 3 to 5 pounds of seed per acre. This allows the crop to adjust itself to the moisture conditions.

If planted early, the first crop may be cut for hay, and the aftermath allowed to mature seed.

Harvesting.—(1) For Hay.—Little difficulty is experienced in drying out or curing. An ordinary mower can be used. In good weather it can be mowed one day, raked the next, cocked the following, and stacked a day or two after the last operation. It should be cut when in full bloom. If the aftermath is to be left to mature seed, the crop for hay should be cut soon after flowering has commenced. Planted at the beginning of November at Potchefstroom, the crop had grown sufficiently to give a heavy yield of hay early in January.

If the crop is to be used for hay only, it can be allowed to grow for a considerable time after flowering, as, unlike most grasses, it continues to produce fresh shoots, so that, while some of the stems may become somewhat fibrous, this is counteracted by the addition of the fine young stems.

According to the date of planting, two to three cuttings may be obtained, yielding two to five tons of cured hay per acre. Under irrigation in America nine to ten tons are obtained.

At Potchefstroom Experimental Station the following yields were obtained :[5] "The crop was planted on the 10th November, the flowers appeared on the 12th January, and the crop was cut shortly afterwards, when it was nearly six feet high. The yield was 26,200 pounds of green fodder per acre; the second cutting was taken off on the 11th March, when the crop was again $3\frac{1}{2}$ feet high, and yielded 12,900 pounds of green fodder. The total weight of green fodder from the acre was 39,100 pounds, or approximately 19·2 tons. This yield was obtained under very favourable conditions. Sown for seed purposes on 10th November and harvested on 11th March, it was eight feet high and yielded 900 lbs. of seed, as well as 20,900 pounds of straw per acre."

(2) For Seed.—Seed will mature from 75 to 90 days, giving an average yield of 400 to 600 pounds per acre. In Arizona under irrigation Sudan grass yielded 2,250 pounds of seed. The straw from the mature crop is of good feeding value, and is fairly well liked by stock.

If well matured and dry, the ordinary wheat thresher will thresh the seed, which weighs from 32 to 44 pounds per bushel, successfully.

Composition of Sudan Grass and other Havs : (2).

Hay	Water.	Ash.	Protein	Fibre.	N-Free Extract.	Fat.
Sudan Grass ..	7·20	5·60	7·94	31·56	45·45	2·25
Lucerne	8·40	7·40	14·30	25·00	42·70	2·20
Millet	7·70	6·20	7·50	27·70	49·00	2·10
Teff	9·02	6·13	5·50	37·35	40·90	1·14

The composition compares favourably with most hay grasses and millets. Sudan grass hay is reported to be more palatable than the millets. Judging from the analyses, it would seem to have a feeding value considerably higher than teff hay. There is very little waste in feeding; the use of the crop for silage, therefore, does not seem to be warranted, particularly as it is easily made into hay.

The analyses given below show the undesirability of allowing the crop to mature fully before being cut for hay.

	Cut 7th August.				Cut 1st Sept.	Cut 1st Oct.
	Before Heading.	Heads just appearing	Beginning to bloom.	Full bloom.	Before Heading.	Fully Matured.
	%	%	%	%	%	%
Moisture	6·13	3·54	3·46	3·51	4·82	4·38
Ash ..	6·61	5·55	5·02	6·64	7·12	5·59
Ether Extract	1·72	1·39	1·23	1·27	1·49	1·48
Protein ..	7·75	6·06	5·16	4·66	5·63	4·19
Crude Fibre	30·68	31·94	33·23	35·62	34·30	34·44
Pentosans	21·82	24·01	24·70	24·51	23·38	26·70
Undetermined	27·29	27·51	27·20	24·19	23·26	26·70

It is a good crop for soiling, but its use for this purpose is not likely to be extensive, since it is a summer crop. Being a sorghum, it may be dangerous as a pasture crop. As it is high yielding and of very quick growth, it will doubtless play an important part in South African crop rotations. As a catch-crop, where the main summer crop has failed, it is admirably suited.

Pests.—It has not been grown for any length of time in South Africa. At present no serious insect pests have been reported, but, since it is sorghum, it is liable to the pests of sorghums—Sorghum Blight (*Bacillus sorghi*), for instance, has caused considerable damage in some areas of the Union.

KIKUYU (*Pennisetum clandestinium*).

Although Kikuyu under very favourable conditions will occasionally make a sufficiently heavy and upright growth to warrant its being cut for hay, it is essentially a pasture grass.

Description.—It is a perennial grass, making its chief growth in summer. The plant is normally decumbent and has numerous thick rhizomes and runners, by means of which it soon establishes itself in the surrounding soil. On rich soil well supplied with moisture an upright growth of 3 to 4 feet will sometimes be made. If required for hay, this should be cut before lodging, which takes place very readily. Although it apparently does not set seed in the Union—the growing season being insufficiently long—it frequently reaches the flowering stage.

It is best suited to parts having a warm growing season and a summer rainfall, and has been unfavourably reported on in parts having less than 10 inches of rainfall and in colder parts of high altitude. Nevertheless, it is probably the most drought resistant of the grasses commonly cultivated in South Africa. It remains green until severe frosts occur, and commences to grow earlier in the spring than the veld grasses. In the Eastern Province and in Zululand it is said to remain green throughout the year, and in parts of Natal it seems to become naturalised.

Soils.—Kikuyu will do well on moist soils. At the Dry-land Station at Pretoria it has given a growth, on a poor sandy soil, of three feet in height. While it gives very good results on a poor sandy soil, and in some parts often having less than 20 inches of rainfalls, the optimum conditions for its growth are found on rich moist soils. On poor soils it responds readily to kraal manure, and doubtless to phosphates where the latter are deficient.

Feeding Value and Composition.

	Moisture.	Crude Protein.	Carbos.	Fat.	Crude Fibre.	Ash
Kikuyu (Hay)..	8·29	12·36	35·06	1·79	33·08	9·42
Lucerne (Hay)..	8·0	15·5	30·6	2·4	34·8	8·9
Teff(Hay)	8·2	6·0	43·2	1·1	34·8	6·7
Boer Manna	7·1	5·0	42·6	1·5	36·7	6·7

While recent analyses show a variable protein content, in the absence of digestion trials it must be looked upon as very much more nutritious than teff or Boer manna and nearly equal to lucerne. Judging from its chemical analysis, it is outstandingly the most nutritious of grasses grown in South Africa. The experience of farmers who have grown Kikuyu on a large scale bears out this opinion as well.

It is apparently very palatable, as it is eagerly eaten by all classes of stock and is pastured in preference to green barley or rye. It is naturally adapted to grazing, as it is not injured by close grazing and stands tramping well.

Cultural Methods.—It is propagated vegetatively by planting cuttings of culms or rhizomes, which are characteristic for the long time—from 4 to 6 weeks—during which they remain capable of growing after having been cut or dug up. Good soil preparation is necessary. One of the most successful methods of planting is to throw the cuttings or rhizomes into every third furrow opened by a single-furrow plough, and then cover lightly with the subsequent furrow. This should be done during the rainy season. If planted in November or December the ground will often be entirely covered by winter. It is quick-spreading and very aggressive, more so than Quick, when grown in competition with other grasses. It forms a heavy matted growth in a few months.

As its growth is very vigorous, it usually becomes " sod-bound " about the fourth year after planting. To remedy this condition it is necessary to plough it over every four years, after which it soon re-establishes itself. No further cultivation is necessary.

Because of its heavy growth, it is exhaustive on soils, and where economically possible should be fertilised with phosphates and with available kraal or stable manure. From 10 to 20 bags of cuttings or rhizomes are required to plant an acre.

General.—Because of the longevity of the rhizomes or runners when ploughed or dug up, it is likely to prove a troublesome weed, and for that reason should not be planted on land required subsequently for other crops.

It is fast becoming the most popular lawn grass in South Africa, because it remains green longer than Germiston or Bermuda grasses and because of the better colour. However, it soon invades flower beds, and should not be used in close proximity to these.

In rich soil having plenty of moisture it is valuable as a summer soiling crop.

It has proved useful as a soil binder on dam walls, and also on loose sandy soil, and in preventing erosion in dongas. Further, it can be recommended as a grass for planting in poultry runs; fowls seem very fond of the leaves. Owing to its aggressive nature, it can withstand the ravages of the fowls scratching, etc.

Diseases and Pests.—No serious diseases or pests have so far been reported.

PHALARIS BULBOSA (Toowoomba Grass).

This is a perennial used chiefly for winter soiling and for hay. It is probably the best winter grass introduced into the Union. *P. minor*, an annual, is often mistaken for *bulbosa.*

ORIGIN AND DESCRIPTION.—This grass is indigenous to the Mediterranean region of North Africa, and has proved useful under Australian conditions. It was imported by Burtt-Davy in 1903, and for a time was incorrectly described as *Phalaris commutata.*

It is a bunch or tussocky grass, having a bluish tinge, and in general appearance somewhat resembles barley. It grows to a height of about three feet. The analysis of *Phalaris bulbosa* shows a high feeding value, being comparatively rich in protein :—

Water.	Protein.	Fat.	Carbos.	Fibre.	Ash.
21·88	10·06	1·46	34·41	25·98	6·21

This analysis by the Government chemist of N.S. Wales was of grass cut in the flowering stage, and shows a nutrient ratio of 13 : 3·7. It is very palatable.

CLIMATE AND SOILS.—On the Dryland Station plots at Pretoria in 1911 two cuttings and a grazing crop were obtained. It has also given good results in Bechuanaland under conditions of very low rainfall. It is fairly hardy against drought and is frost-resistant. Given plenty of moisture and a good soil, it gives a very fair growth during the winter months. It thrives best on rich moist soil, and many failures are due to the grass being sown on unproductive soils. Heavy clay soils should be avoided.

Burtt-Davy says : " Where conditions suit it, it gives as heavy a cutting as green barley, and, being perennial, one can keep on cutting month after month without having to resow."

PROPAGATION.—The seed costs 3s 6d. to 4s. per pound, and is reported generally to have a low vitality. Sow 6 to 8 pounds per acre in autumn. Because of the high cost of seed and poor germination, the seed is usually sown in well-prepared beds, and when the seedlings have made a good growth the crowns are split up and transplanted in rows $2\frac{1}{2}$ x $2\frac{1}{2}$ feet. It is not an aggressive grass, and competes badly with weeds ; consequently, the land should be clean before transplanting, and the crop should be cultivated to control weeds.

Place in South African Agriculture.—In most parts of the Union it should be planted for soiling and hay on rich soils under moist conditions or under irrigation. Under these circumstances it might take the place of barley to supply green feed in winter. Although an annual barley has a certain advantage in that it requires comparatively little labour in planting. "Its distribution as a farm crop is limited, however, by the fact that it requires rich soil and plenty of water to give thoroughly satisfactory results."[10] To this must be added the large amount of labour required in establishing the grass. It is sometimes subject to ergot.

NAPIER GRASS (Elephant Grass) (*Pennisetum purpureum*).

This is a perennial fodder grass which is receiving increasing interest in the Union and in Australia. It is indigenous to Central Africa and Rhodesia, and was introduced from the latter place in 1912.

Description.—In appearance it somewhat resembles a coarse-growing sorghum. It suckers very freely, giving numerous stout stems, which reach a height of 8 to 10 feet in three to four months when once established. North of Nairobi it is said to reach a height of more than 20 feet. It thrives best in a hot climate on rich soils, but is, nevertheless, fairly drought but not frost resistant. In Australia it has given 25 tons of green fodder after four months' growth. At Hawkesbery College during the season 1917-18 three cuttings yielded 30 tons, and about 50 tons of fodder were obtained for the whole season.

Analysis in Australia gave an albuminoid ratio of 1 : 4·3.[14]

	Napier's fodder.	Green maize fodder.
Water	61·81	79·0
Ether Extract	0·29	0·5
Protein	2·92	1·7
Woody Fibre	14·77	5·6
Carbos	17·29	12·0
Ash	2·92	1·2

While higher than maize fodder in protein, it will be seen that Napier fodder is considerably higher in fibre.

Uses.—Its chief value would be in soiling and for silage. It should be cut for silage when the bottom leaves commence to turn brown. Usually two cuttings for this purpose can be obtained in the Transvaal and Orange Free State. As a soiling crop it should be cut earlier than for silage, probably four to five times during the season.

Propagation.—It does not mature seed in the Union, and is therefore propagated by cuttings and rooted slips or roots. Slips should be taken in April. Cuttings should be taken about the same time, and planted so as to leave one joint above ground. Each cutting should have three to five nodes. If the crown is broken up these roots may be planted out. Plants stool abundantly, and should be spaced three feet in the rows and six feet between the rows. Until well established cultivation should be fairly frequent. Cuttings, slips and roots should be planted out in the spring. Previous to this they should be kept in a bed well watered with good drainage.

For silage it has a certain advantage over maize in that it is perennial. The silage is probably not as valuable as that of maize, because of the large quantity of fibre content. However, it is readily eaten by stock.

CULTIVATED GRASSES OF MINOR IMPORTANCE IN SOUTH AFRICA.

A great many grasses, exotic and indigenous, have been experimented with in South Africa. Some of these have been cultivated by farmers to a certain extent, but for various reasons have proved themselves poor grasses for our conditions, *e.g.*, Timothy; some are unpalatable or of low feeding value; others because of their aggressiveness have become troublesome weeds, *e.g.*, Kweek; while some have developed ergot very readily, and so have become dangerous to pregnant stock, *e.g.*, *Paspalum*.

Among the most important of what may be called the minor agricultural grasses in South Africa are the following:—

(1) *Paspalum dilatatum*.—This is a native of the tropical States of America, and was introduced from Australia. It is probably one of the best known exotic grasses in the Union, and is sometimes known by the names of Water grass or Breed Zaad Gras. It is a summer-growing perennial, having a strong, deep-rooted system, with numerous leaves near the ground, and relatively leafless stems of a weak, spreading character. It is essentially a pasture grass.

Adaptations and Characteristics.—It thrives best in wet localities or on low-lying vlei ground. While quickly injured by frost, it is one of the earliest grasses in spring, and at this stage is readily eaten by stock. When allowed to seed it becomes very coarse and unpalatable. In some localities *Paspalum dilatatum* has proved to be fairly drought-resistant. Sow 10 lbs. per acre.

On account of the following disadvantages, it is becoming less popular every year :—

(1) Only at certain times is it really palatable.
(2) It is extraordinarily susceptible to ergot.
(3) As a weed it is very aggressive. It is distributed and easily propagated by seed, so much so that many farmers who would like to rid their farms of *Paspalum dilatatum* have found it has spread so much that its further distribution cannot be checked. This occurs chiefly in parts of the Union where mists are common, *e.g.*, East Griqualand.
(4) It is of relatively low feeding value.

(2) *Paspalum virgatum* (Erect Paspalum).—This species is a perennial also in very general cultivation. It is erect growing, reaching a height of five to eight feet in a few months after growth has commenced. While it yields very well, the hay is very coarse, because of the thick fibrous stems. It must be considered a hay grass less objectionable than *dilatatum*. Provided the rainfall is heavy, it will give a good growth on the poorest soils. Its feeding value is much lower than that of grasses like the Sudan grass.

It is similar to *dilatatum* as regards frost injury and early growth. It is not so aggressive as water grass, and is therefore not likely to become as bad a weed. While the former is a hay and the latter a grazing grass, a comparison is difficult. On the whole, *virgatum* is a very much better grass, with decided possibilities as a perennial summer grass for hay purposes. Sow 5 pounds per acre.

New Zealand Tall Fescue (*Festuca arundinacea*).—This is a perennial grass making a very good winter growth under moist conditions on good soils. It does not do well on sandy soils. In South Africa Tall fescue (*F. elatior*), a European grass, has been used instead of *Festuca arundinacea*. This grass, not being drought or rust-resistant, does not do well, and many failures of the latter are due to sowing seed of *F. elatior*.

The former grows into tussocks rapidly, is very free from rust, and is not so susceptible to ergot as the paspalums. Young growth is very much liked by stock, but if allowed to grow rank its palatability suffers.

It should be sown at the rate of 30 pounds to the acre in February or March.

It is a native of the Mediterranean region of Southern Europe, was introduced into South Africa from New Zealand, and has possibilities as a winter pasture grass under irrigation or in moist parts on good soils.

Chewing's Fescue (*F. ovina*).—This is a fine-leafed pasture grass, best suited to sandy soils in parts of heavy rainfall, where the climate is not too hot. Sow 15 lbs. per acre. It gives a fair winter growth.

Cock's Foot (*Dactylis glomerata*).—J. Burtt-Davy says: "It is an excellent pasture grass where the conditions favour it, but it is one of the most difficult to establish in South Africa. In a few localities along the Drakensberg, Wakkerstroom, and especially near Kokstad, it appears to do well, but in many localities it seems to die out early and to suffer from drought and rust. Cock's foot is eminently a grass for cool, damp localities." In America it is one of the foremost agriculural grasses.

Italian Rye Grass (*Lolium italicum multiflorum*) is usually a biennial, and has proved fairly successful as a winter grass under irrigation or in the mist belt of the Drakensberg. Seed should be sown at the rate of 30 pounds per acre. It is very frost-resistant and heavy-yielding, but, generally speaking, it is an inferior grass to *Phalaris bulbosa*.

Rhodes Grass (*Chloris gayana*).—"Is a South African summer perennial grass which is now more extensively grown in America and Australia than in the Union. Rhodes grass develops numerous running stems which root at every joint, and after covering the ground with herbage the shoots assume an upright position, finally attaining a height of 3½ to 4 feet." A very palatable grass, good for pasture or hay. The growing period corresponds with that of *Paspalum*. Sow 10 lbs. of seed per acre in summer. The seeds require warm, moist weather for germination. It seeds well, will establish itself if allowed to run to seed, and is fairly drought-resistant.

Natal Grass (*Pennisetum unisetum*) has recently given excellent yields under adverse conditions at the Dryland Station, Pretoria.

Star Grass (*Cynoden plectostachymum*) has been recently tried in the Union, and gives promise of becoming a useful pasture grass.

The following grasses have been tried, and only in exceptional circumstances have any given satisfaction in South Africa, viz. :—

Rescue Grass (*Bromus wildenowii*); Red Top (*Agrostis alba*), may do well in marshy ground; Timothy (*Phleum pratense*); Kentucky Blue Grass (*Poa pratensis*); Canadian Blue Grass (*Poa compressa*); Tall Oat Grass (*Arrhenatherum elatius*); *Bromus inermis;* Perennial Rye Grass (*Lolium perenne*); Red Fescue (*Festuca rubra*); Meadow Foxtail (*Alopecurus pratensis*); Sweet Vernal Grass (*Anthoxanthum odoratum*); Crested Dog's Tail (*Cynosurus cristatus*), and many others, including most of the more common grasses indigenous to the Union.

In Rhodesia, Molasses Grass, a perennial, has given excellent results as a hay grass. At present little experience has been had of the plant in the Union.

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MILLETS (Mannas).

In European agriculture these play a different rôle to that in Asiatic and some African countries. In the latter countries millets have been grown chiefly as cereals, whereas in the former they are cultivated almost entirely as hay crops. It is because of this duality in use that a number of grasses are usually designated "millets," in distinction to the grasses grown for hay or pasture.

The cultivation of millets in South Africa has increased very little, if at all. They are still grown by the natives for their grain, and as a quick summer catch-crop by a fair number of our farmers. All the millets are rapid-growing summer annuals, usually having an extremely low water requirement, and as such they are admirably suited to "dry-land" agriculture.

The following are the principal millets grown in South Africa :—

Setaria italica.—These are the Foxtail Millets, and are those most commonly found in the Union.

Varieties.—(1) Boer Manna or Common.—This is one of the earliest varieties of this group, and is our most popular variety. It is fine-stemmed, leafy, smaller inflorescence than German, with small yellow seeds in a cylindrical, fairly compact head. The variety now called Boer Manna is undoubtedly German Millet.

(2) German is usually about three weeks later than Boer Manna, is much coarser in the leaves and stem, and has a larger, less compact, and distinctly lobed head. The yield is very much higher than Boer Manna, but the quality of hay is not so good. Golden Wonder is a finer strain selected from German.

(3) Siberian.—This variety is finer and earlier than Boer Manna, inferior in yielding capacity, and while still grown in South Africa is by no means popular. It is readily distinguished by its orange-coloured seeds. The ear is smaller and more compact than that of Boer Manna.

(4) Hungarian.—This is a fine-strawed variety, with small, compact heads and seeds mixed in colour—yellow, black and purple. It also is grown in various parts of the Union, but is not receiving much attention.

History.—*Setaria italica* is probably a native of Southern Asia, and is of very ancient cultivation, records showing that it was grown in China, 2700 B.C.

Millets are erect summer-growing annuals, thriving in parts of high summer temperatures, are quicker maturing than the sorghums, and probably more drought-evading. Generally speaking, they do well in all parts where sorghums are cultivated. They are extremely sensitive to frost, and for that reason should be sown late.

Cultural Methods.—The preparation of the soil need not be so thorough as that required for crops like lucerne or wheat. The ground should be in fine tilth and fairly firm. The Foxtail Millets are usually broadcasted, and can be seeded with a grain drill to advantage. About 15 pounds of seed are required per acre. The seed weighs 50 to 55 pounds per bushel. Sowing should take place from November to January. Hay crops can be cut from 7 to 12 weeks after seeding, according to the variety and the time of year when sown. On most farms in the Union millets are usually sown after maize planting is completed.

Harvesting.—(1) Hay.—When cut for hay the plant should just have flowered. It is cut with the ordinary mower. Millet hay is not of very high quality, and if cut late, when nearly mature, causes disorders in horses—" Millet Fever "—a disease of horses found when millet hay forms the sole diet. If mixed with other food little trouble is experienced. Horses seem to be the only animals affected.

Little difficulty is experienced in making hay from this crop.

(2) Seed.—The crop is cut with a reaper and binder or by sickle, is allowed to stand in shocks, and then threshed with the ordinary small-grain threshing machine. It is heavy-yielding, 6 to 10 bags being a good yield per acre.

Of the remaining millets in common cultivation, Japanese Barnyard (*E. frumentacea*), Pearl Millet (*Pennisetum glaucum*) and Japanese Broom-Corn Millet (*Panicum miliaceum*) are the most important in South Africa.

Japanese Barnyard.—This is a coarse-growing millet, suited to moist localities, and does well even on very acid soils, *e.g.*, in East Griqualand. It is prolific and gives good growth on very poor soils. It has probably originated from *E. crus-galli*, a weed very common in America and Canada. It should be sown in November to January at the rate of 25 pounds per acre.

Japanese Broom-Corn or Proso.—This is also a native of Asia, and of very ancient civilisation—dating back to the Stone

Age. In South Africa it is known as Japanese Broom-Corn or Buffel Gras Millet. The panicles may be loose, contracted at the top and dense. The glumes may be red, black or white; in South Africa usually the last-named. In Russia and Asia it is invariably grown as a cereal, elsewhere as hay, and often for bird-seed. It is a lower hay-yielder than the Foxtail Millets, and during wet weather is apt to lodge very badly. It is fairly drought-resistant.

Pearl Millet, N'Youti or Kaffir Millet.—This is probably indigenous to South Africa, where, as in India, it is cultivated by the natives as a cereal. It is a tall, erect, rapid-growing species, reaching a height of 6 to 10 feet in South Africa and 16 feet on rich soils in Florida. The stems are more slender than those of the saccharine sorghums, the nodes shorter, and the pith dry without sugar content. The head is cylindrical, very dense, 4 to 14 inches long, bearing numerous pearly exposed grains. It takes longer to reach maturity than most grain sorghums, but is more or less adapted to the same conditions as these.

The stems are apt to become hard and pithy; consequently, for hay it should be cut before flowering. Two to three heavy cuttings are obtainable in suitable localities in the Union.

It is usually planted in three-feet rows, requiring 3 to 5 pounds of seed per acre; if broadcasted, about 20 to 30 pounds are required. In South Carolina six cuttings have been obtained in one season, giving an aggregate yield of 47 tons of green matter per acre.

At Tweespruit, 1906-7, seed sown on October 5th and harvested February 28th yielded 5½ tons of hay per acre.

It is very badly attacked by birds if allowed to go to seed.

Large acreages of this millet are grown in the native territories for seed, chiefly for the manufacture of kaffir beer.

Diseases and Pests.—Generally speaking, the millets are not subject to serious insect depredations.

The Foxtail and Panicum Millets are both attacked by smut, the former by *Ustilago crameri* and the latter by *Ustilago panici-miliacei*, "both of which infest the individual grains, converting the whole head or panicle into a large black mass, enclosed by bracts in the Foxtail Millets and by a thin, white membrane in the Panicum types."

Seed treated with formalin, as recommended for wheat, will control both smuts.

CHAPTER XVIII

ROOT AND ALLIED CROPS

These crops are grown for human consumption, some often for the manufacture of sugar, but in the Union principally as a foodstuff for livestock. Their present *rôle* in South Africa is a small one; nevertheless, in specialised farming, such as dairying and sheep farming, where climatic, soil, and irrigation conditions are suitable, their cultivation is likely to increase.

The chief field crops belonging to this group are :—

Chenopodiaceæ: Beta vulgaris:—

(1) Sugar Beets.
(2) Leaf-Beets or Chard.
(3) Mangel-Wurzels or Mangels or Mangolds.

Cruciferæ:—

(4) Turnip—*Brassica rapa.*
(5) Swede or Rutabaga—*Brassica campestris.*
(6) Rape—*Brassica napus.*
(7) Kale—*B. oleracea var. viridis.*
(8) Kohlrabi—*B. oleracea var. caulorapa.*

Umbelliferæ:—

(9) Carrot—*Daucus carota.*

Compositæ—

(10) Jerusalem Artichokes—*Helianthus tuberosum.*-

A common characteristic of these crops is that during the first season the excessive nutrients not needed for the immediate use of the plants are stored up in the roots, leaves, or thickened stems.

They are grown most extensively in European countries and in Canada. In the United States maize silage is mostly used to provide succulent feed during winter, though "roots" are often grown for the special feeding of certain classes of stock, as well as for their tonic value as part of the winter rations. Their chief uses in South Africa are to add succulence to the rations and to supplement grazing during the winter and early spring months.

1.—SUGAR BEET.

The sugar beet is the principal sugar producing crop of Europe, for which purpose it is extensively grown, particularly in Germany.

In South Africa, sugar is more profitably produced from sugar cane, and, while having a higher nutritive value than mangels, as a foodstuff for stock, sugar beets are not likely to receive the same attention as mangels, since the latter are heavier yielding and require less labour in harvesting.

When grown as a stock-food the cultural methods are identical with those required for mangels.

Sugar beets are really strains of mangels which have been specially evolved for their high sugar content, and which, by continued selection, have become fixed types. "They are comparatively small, the best weighing from 1½ to 2½ pounds, and of conical or elongated shape. Unlike mangels, the thickened 'roots' are almost entirely buried in the soil. The roots should not be fanged. In good varieties the skin is white, the flesh firm and white, with a large number of close concentric rings of vascular bundles." As the sugar is stored chiefly in the small-celled parenchyma, those having a large number of concentric rings and of a dense consistency are richest in sugar. Beets with upright leaves and long petioles are always less rich in sugar than those with leaves which lie close to the ground and have shorter petioles.

Composition.

Water-content	...	80 per cent.
Cane-sugar	...	15 to 16 per cent. in good varieties.
Woody-fibre	...	1·3 per cent.

Vilmorin's Improved is one of the best known varieties, and has given good growth under cultivation in South Africa.

2.—LEAF-BEET OR CHARD.

The root is not enlarged. The tender leaves and enlarged petioles are used in the same way as spinach. It is supposed to be the progenitor of the mangel, and was known to the Greeks as a vegetable in 300 B.C. In the Union it must be looked upon as a crop of very minor importance. It is of summer growth, affected by frost, and of poor feeding quality.

3.—MANGEL.

The mangel is a biennial of summer growth, grown only for stock-feed. In South Africa, and in most countries, it is the most important of the "root crops." It is a native of the Mediterranean coast and Canary Islands, and has been cultivated in Great Britain for about 200 years.

Comparison between the Mangel and Sugar Beet.—"The root of the sugar beet is fairly uniform in shape, being longest near the crown and tapering gradually to a long tap-root, while that of the mangel is of various shapes in the many varieties. The flesh of the sugar beet is white, while that of the mangel is usually reddish or yellow. The skin of the sugar beet is also white; the mangel may be red, white, golden, purplish, or even black. The sugar beet grows almost entirely below the surface of the ground, while in many varieties of mangel half or more of the root is above the surface, making it much easier to harvest. Well-grown sugar beets weigh from $1\frac{1}{2}$ to $2\frac{1}{2}$ pounds; mangels should weigh 4 to 6 pounds. The sugar beet contains about 20 per cent. of solids, of which about four-fifths is sugar; the mangel contains only about 12 per cent. of solids and not more than 6 per cent. of sugar." In good crops mangels yield from 5 to 8 tons more per acre than sugar beets.

Description and Varieties.—Varieties vary principally in colour and shape. According to shape the types are :—

(1) Long Type.—These are several times as long as broad, and have proved to be amongst the heaviest yielding and most successful varieties in South Africa. Examples : Mammoth, Long Red, and Long Yellow.

(2) Intermediate.—These are intermediate in shape between the long and globe types. Example : Giant Intermediate.

(3) Tankard.—Cylindrical and abrupt at both ends. Roots usually small in size. Example : Golden Tankard.

(4) Globe.—Globular in shape, usually yellow-fleshed. Examples : Yellow Globe and Orange Globe.

COMPOSITION.

	Water.	Proteins.	Fat.	Dig. Carbos.	Fibre.	Ash.	N.R.
Golden Tankard ...	86·24	1·69	·08	9·83	·73	1·41	1 : 5·9
Yellow Globe	88·19	1·76	·11	7·59	·78	1·57	1 : 4·5
Orange Globe	86·91	2·01	·05	9·01	·74	1·28	1 : 4·5
Long Red ...	85·20	1·54	·04	11·22	·76	1·24	1 : 7·3
Giant Half-Sugar White	87·11	1·84	·04	8·60	·85	1·54	1 : 4·7
Sugar Beet ...	67·11	2·80	·05	26·95	1·46	1·63	1 : 9.7

According to feeding experiments conducted in the United States, eight pounds of mangels are equal in feeding value to one pound of maize grain. Calculated on this basis, three times more feeding value is obtained from an acre of roots yielding 20 tons than from one acre of maize yielding 8 bags (26 to 27 bushels). From the above analyses it will be seen that mangels contain a very large proportion of water, and consequently do not contain sufficient nourishment to form the sole ration; the mangel should therefore be supplemented with more concentrated foodstuffs, *e.g.*, lucerne hay, maize meal, etc. Its chief value, however, lies in its tonic effect and succulency during periods when feeds of this nature are scarce. It can be fed to all classes of livestock, but as the cost of production of this crop in the Union is rather high, its use as a feed will naturally be restricted to comparatively high-priced stock.

CLIMATE AND SOILS.—Mangels require a warm growing season of about five to six months, and plenty of moisture, for full development. Maximum yields in the Union are obtained under irrigation in somwehat arid areas. After the first two months of growth the plants are fairly drought-resistant. When grown on land not irrigated (drylands), the early growing period must take place after the regular summer rains have commenced.

Next to the salt-bushes, mangels are probably the most alkali-resistant of farm crops.

They require deep, open, productive, well-drained soils; heavy clays and loose sandy soils should be avoided. They respond well to manures, particularly nitrogenous manures.

The following, taken from Warrington,[2] shows the amounts in pounds per acre of phosphoric acid, nitrogen, and potash, removed by good crops from the soil :—

	Phosphoric Acid.	Nitrogen.	Potash.
Wheat	21·1	48	28·8
Potatoes	21·5	46	76·5
Mangels	52·9	138	300·7

Mangels are looked upon as exhaustive of available plant-food, and that this is correct is to be seen from the above table. They should therefore receive heavy applications of kraal manure, or should follow well-decomposed green manures. On most soils a dressing of 100 to 200 pounds of superphosphate is required. Although the above analysis shows a high potash requirement, and under European conditions the crop responds well to heavy dressings of potassic fertilisers, in the Union 100 to 200 pounds per acre of sulphate of potash is usually all that is necessary.

When farmyard manure or green manures are used these must be allowed to become thoroughly decomposed, as the seed-bed should be compact and finely pulverised.

Cultural Methods.—A good, fine, mellow seed-bed should be prepared by ploughing, cross-ploughing, and harrowing, and, if necessary, rolling to break down clods, to pulverise the soil, and to compact it. Ploughing should be deep and thorough, so as to extend the feeding zone of the roots.

Mangels are grown on ridges or on the level. Under irrigation the former method is employed, on drylands the latter. On irrigated land the seed is drilled in on top of the ridges, which are generally 30 inches apart. On drylands the width of the rows is usually 36 inches.

The seed is put in either by means of a root-crop drill or a single row planter, *e.g.*, Planet Junior, and should not be planted deeper than one inch, except in sandy loams, where the depth may be slightly more. Ridging is necessary for irrigating, and assists in drainage during excessively wet spells.

In South Africa, unfortunately, all the seed used at present is imported, and must be tested for vitality before planting, as poor seed is the chief source of failure in this country. Germination tests often show a viability of only 5 to 10 per cent. of the "clusters." The cotyledons have difficulty in reaching the surface, consequently soils liable to form a crust should be avoided and, if under irrigation, the soil should be kept moist until the seed has germinated. The seed should be soaked and dried sufficiently to allow it to pass through the machine readily, and should be planted only in moist soil.

Ten to twelve pounds of seed are required per acre. When the plants are a few inches high they should be thinned out, first by hoe and then by hand pulling, to about 10 to 15 inches in the row. Wider spacing would result in larger roots; but the feeding quality and quantity per acre is less when too widely planted. For this reason it is preferable to have a larger number of small roots than a smaller number of large roots. When grown without irrigation they should be thinned out to about 15 to 18 inches in the row.

Hand thinning is necessary, as the seed cluster contains one to five seeds, and consequently a number of plants may arise from the same cluster.

On irrigated land, where the soil moisture can be regulated, planting may commence in October, and continued not later than January, but on dry lands it should not start until November, or until the regular rains have commenced.

During the early growth, the crop must be hoed by hand two to three times. Narrow tooth cultivators could be used frequently to advantage to control weeds and to break soil crusts. On dry land, before thinning, a weeder may be used.

Harvesting.—In America and Europe mangels are pulled by hand, the leaves "topped off," and the roots stored in cellars or pits until fed in the winter. Under the relatively high winter temperatures in South Africa this is impracticable, and the best and most satisfactory method is to leave the roots *in situ* in the field. The daily requirement is then pulled and carted from the field each day.

About 25 tons per acre is considered a good yield.

They should be sliced before being fed to stock. If fed heavily when rather immature scouring is often caused.

Seed Production.—Seed can be grown readily in the Union by pulling roots at the beginning of June. Only desirable, disease-free roots should be chosen. These are stored in cool, well-ventilated places until October or November. They are then planted three feet by three feet in the field, and mature seed about April. Individual plants will yield twelve ounces to one pound of seed.

Pests.—Cutworms often destroy young seedlings. The Leaf-Spot Disease, as well as Mangel Rust, often cause a certain amount of damage.

4 & 5.—TURNIPS AND SWEDES.

While grown largely in other countries, particularly in Europe, these are cultivated to a small extent in South Africa, and are limited to the mist belt in eastern parts of the Union. In other parts of the country they thrive very indifferently and are often destroyed by plant lice. Plenty of moisture, dull and cool weather, are required for their best growth. They are often pastured *in situ* by sheep, and are also fed to cattle in the same manner as in the case of mangels. As they taint the flavour of milk they should be fed cautiously to dairy cows. When grown close to towns they are often sold for human consumption.

Description.—Swedes (Rutabagas) can be distinguished from turnips by the " neck " found at the top of the root. The flesh is firmer than that of the turnip, and the keeping quality is better. White, but chiefly yellow-coloured flesh is found, the latter being preferred, as the keeping quality is usually superior. The skin may be green, purple or bronze. They are not so easily injured by frosts as turnips, and are one to two months later in maturity.

The *Farmer's Handbook* (N.S.W.) gives the following composition of Swedes :—

Water.	Ash.	Protein.	Fibre.	Carbos.	Fat.
88·6	1·2	1·2	1·3	7·5	·2

Cultural Methods.—They may be planted on ridges or broadcasted. When ridged in rows 2 feet 6 inches apart, two pounds of seed are required per acre; when broadcasted, about five pounds per acre. The soil preparation is very much the same as that required for mangels. Sandy loams are preferred. The seed should not be planted deeper than one inch. If drilled, they should be thinned by hoe, when a few inches high to about 8 inches in the row. Planting takes place from November to early in January.

About twelve to fifteen tons per acre is considered a good yield.

If fed to cattle they should be sliced before feeding.

6.—RAPE.

This is a quick-growing, broad-leafed, succulent, and palatable plant, somewhat resembling young cabbage, two to four feet in height. It makes its best growth in the cooler months of the year. Rape is grown for soiling and for temporary pasture for cattle, pigs, and particularly sheep.

It is very frost-resistant, and does best under cool conditions on rich, moist, loamy soils. It responds well to applications of barnyard manure. The soil should be prepared in January, and the seed drilled or broadcasted in February and March. It can then be grazed off or soiled during May and June. In the Western Province it is often sown in May or June, and then affords a succulent feed in the dry summer months.

If drilled in rows three feet apart, two pounds of seed are required per acre; if broadcasted, five pounds. Dwarf Essex is the best variety grown in the Union.

In the United States, rape is often planted between the rows of maize at the time of the last cultivation. The whole crop is later grazed off by pigs, sheep or cattle.

Experiments at the Potchefstroom Experimental Farm indicated that soiling was the most economical method of feeding rape to pigs. The advantage to the soil, however, when pastured, should also be considered.

Care must be exercised when grazed by sheep or cattle, as bloating is common. Hungry and thirsty animals should not be put into the fields; the dew should be off, and animals should gradually have their stay in the field lengthened. Twenty minutes twice a day at the commencement, until, after a fortnight, they might be allowed in permanently.

7.—KALE.

This crop resembles rape, and is distinguished from it by having entirely smooth leaves, while those of rape are slightly hairy. Chou Moellier and Thousand Headed Kale are strains of kale.

The soil and climatic requirements, cultural treatment, and uses of this crop, are identical with those of rape.

8.—KOHL RABI.

" The stem is short, much thickened, fleshy, and stands out of the ground. The fleshy part comes from the stem above the cotyledons, hence is not root. The swelling begins at the ground line; there is formed a large spherical body, upon which are very prominent broad leaf scars—white and purple ' balls ' are formed."[3]

It is a crop grown under the same climatic and soil conditions as rape, and is utilised in the same way; when soiled, the " ball " should be sliced.

The composition is similar to that of mangels, but the yield is very much less. If stored, the leaves should be removed first.

9.—CARROT.

Sometimes grown as a field crop for horses. Must be grown under irrigation in the Union. It requires a deep, somewhat sandy, and productive soil. Usually drilled in rows 2 feet 6 inches apart; three to six pounds of seed are required per acre; planted in March and April.

10.—JERUSALEM ARTICHOKE.

This is a native of North America. It is a tall, robust growing plant, reaching a height of six to twelve feet, and in appearance resembles the smaller varieties of sunflower. It produces a large cluster of rhizomes or tubers of special value to pigs, but often used for culinary purposes. The tubers may be red, white, or yellow. It makes its growth in summer. It is a persistent crop when once established and, if grown in suitable soil, is difficult to eradicate; it is wise, therefore, to set aside a field for artichokes permanently. Enough tubers, as a rule, are left in the ground each year to continue the crop. Waste places or fields difficult for ordinary cultivation may be profitably utilised by growing artichokes. (The Globe Artichoke, *Cynara scalymus*, is very different in appearance, but also belongs to the *Compositæ*. The thick receptacle, together with the fleshy bases of the scales of the involucre, is used as a vegetable. Its use as a stock food in the Karroo is advocated by some.)

Climate and Soils.—The plant is extremely hardy, will withstand moderately adverse conditions of soil, moisture, and frost, and will thrive on most soils. However, good potato soils are best. Loose alluvial soils, containing an abundance of organic matter, well-drained, are among the most productive for this crop.

Cultural Methods.—The tubers, planted in September and October, should be dropped in furrows, three feet apart, with a spacing of two feet apart in the row. They are then covered about four inches in depth by turning a furrow-slice over them. About 400 to 500 pounds are required per acre. It responds well to kraal manure. The crop should be harrowed lightly just after the appearance of the plants above ground, and, if necessary, cultivated. It matures in five months, and is ready for harvesting as soon as the plants have flowered and turned yellow. Artichokes do not keep well in storage, and should therefore be left in the ground and lifted as required.

In feeding to pigs, it is best to turn the animals into the crop to root out the tubers. The expense of lifting and carting the crop is obviated, and exercise for the animals is afforded. If the crop is to be continued. the pigs must be taken out before all the tubers have been unearthed. The ground should then be ploughed and harrowed to keep down weeds.

Composition.[4]

	Water.	Ash.	Protein.	Carbos.	Fat.	N.R.
Artichoke ...	79·5	1·0	2·5	16·7	0·2	1 : 7
Potato ...	78·9	1·0	2·1	17·9	0·1	1 : 8·6

The artichoke has a fairly high nutritive ratio as compared with the potato, and is one of the cheapest and healthiest feeds for all classes of livestock, providing succulent feed during late winter and early spring. Inulin takes the place of starch in artichokes. In France, the tubers are distilled for alcohol.

REFERENCES:

[1] Science Bulletin No. 6, Union Dept. of Agriculture.
[2] "Warrington's Chemistry of the Farm."—Dr. Juritz.
[3] "Botany of Crop Plants."—Robbins.
[4] "Farmers' Handbook," New South Wales.

CHAPTER XIX.

FLAX, BUCKWHEAT, SUNFLOWERS AND PUMPKINS

FLAX (*Linum usitatissimum*).

History.—De Candolle says *L. angustifolium*, usually a perennial species, was the first cultivated. It was eventually supplanted by the annual *L. usitatissimum*, which has been cultivated in Mesopotamia, Assyria and Egypt for 4,000 to 5,000 years. This region he thinks was its original habitat. Some of the bandages on the mummies in the British Museum are of linen.

Description.—The crop is grown for the two products, fibre and linseed, and because the best fibre is not produced by the heaviest seeding plants two distinct types have evolved. The fibre type is small-seeded, uniformly straight, has a comparitively unbranched stem 2 feet to 3 feet 6 inches, and a small raceme at the top, which eventually bears capsules having five compartments, containing ten shiny, flat, dark brown seeds.

The linseed type is shorter, 1 foot 6 inches to 2 feet, more branched, has larger and heavier seeds, with numerous capsules. By close planting the tendency to branching is inhibited, and plants can thus be produced resembling the fibre type.

The common varieties have blue or white flowers; red-flowered varieties are occasionally found.

The fibres, which constitute from 20 to 27 per cent. of the stem, occur in small bundles between the cambium and cortex. Each cell is about one inch in length, and the fibre filament one foot to three feet in length.

Production.—Most of the flax grown for fibre is grown in Russia, Austria-Hungary, Belgium, Ireland, and other European countries, Russia's share being nearly four-fifths of the world's fibre output.

	1914 Linseed Crop.
Argentine	39,171,000 bushels
British India	15,440,000 ,,
United States	13,749,000 ,,

In South Africa production is limited entirely to linseed, and as yet no census returns are available, the present output being relatively small. As stable feeding, dairying, etc., become more common, the growth of the crop for linseed is likely to become more important.

Uses.—The fibre is used in cloth for wearing apparel (linen), for matting, "crash" and towelling, while the unretted flax is employed in the manufacture of binding twine.

The linseed is very rich both in protein and oil. Oil-cake, a by-product rich in protein, is left after the oil has been extracted. It is a valuable concentrate for stock feeding. The oil is very valuable, being used for varnishes in the manufacture of linoleum, in patent leather, and medicinally.

The straw has little or no feeding value, and at times is dangerous on account of the nature of the fibre, and the prussic acid sometimes found in the growing plant.

Composition.

Flaxseed and Linseed Cake compared with Wheat (Montgomery).

	Flaxseed. Percentage.	Linseed Cake. Percentage.	Wheat Grain. Percentage.
Water	9·1	10·1	10·5
Ash	4·3	5·8	1·8
Protein	22·6	33·2	11·9
Crude Fibre	7·1	9·5	1·8
Nitrogen F. Extract ...	23·2	38·4	71·9
Fat (Oil)	33·7	3·0	2·1

Climate.—Generally speaking, our climatic conditions are not suited for the production of good fibre, because of our uncertain rainfall. Changing conditions of moisture affect the uniformity of length, fineness, and spinning quality of the fibre. For fibre, a moist atmosphere with frequent showers and a moderately low, uniform temperature, gives the best quality. In favoured South African localities it may be grown successfully for fibre. However, the excessive amount of care and labour required will probably preclude its growth for fibre in the Union.

The requirements for seed production are not nearly so exacting, and although the water requirement of the crop is high, it has been grown in various parts of the Union with good results.

Soil Requirements for Fibre.—Uniformity in length, strength, and thickness of fibre is readily affected by a lack of uniformity in the soil. The soil in individual fields should be as uniform as possible. Uniformity in soil for the production of linseed, however, is not so important. It is a very shallow rooted crop, and if grown on land continuously exhausts the upper layer of soil very rapidly. Because of this it is popularly supposed to be an exhaustive crop. Rotative cropping is essential particularly if Flax Wilt (*Fusarium lini Bolley*) appears as the spores remain viable in the soil for about eight years. Heavy nitrogenous manures must be avoided as well as newly applied barnyard manure, particularly if the crop is to be grown for fibre. The former causes lodging, and the latter uneven growth. In general, soils suitable for the cereals are suitable for the linseed crop; the fibre crop, however, must not be grown on calcareous soils, heavy clays, or peaty soils too rich in humus.

Rotation.—It competes very badly with weeds; consequently it follows cleaning crops best, and is often sown on virgin land. It requires a very firm seed-bed, which is one reason why the crop should not follow a green-manuring crop. Further, as its feeding area is limited, the plant-food should be readily available.

Soil Preparation and Planting.—The land should be as clean as possible, and ploughing should be done some time before planting. The subsequent discing and harrowing preparatory to planting should aim at destroying the first crop of weeds, and to get the land firm with a fine surface tilth.

It may be sown up to the end of December, but early November is considered the best time for the greater part of the Union. It is possible that it may be a profitable winter crop under irrigation. Linseed is often drilled, but more often broadcasted, and should not be planted deeper than threequarters of an inch—consequently, if broadcasted, a weeder or very light harrow should be employed to cover the seed.

For fibre 80 to 100 pounds, and for seed 30 to 50 pounds per acre, should be sown. Before sowing, the seed should be treated with formalin in the same way that wheat is treated for stinking-smut.

Harvesting.—The crop takes 90 to 100 days to mature seed; it does not mature very uniformly, consequently judgment must be used to harvest when the percentage of capsules are ripe at one time. It is generally cut with a reaper and binder, or mower, then stooked, and, when thoroughly dried, threshed.

Harvesting for fibre requires skill and care. The crop is hand pulled as soon as the capsules begin to turn yellow. It is laid out in swaths and allowed to dry, after which the capsules are "rippled off," or may be beaten off with mallets. After this it is graded and bundled for "retting," by the aid of which the fibre is ultimately freed. This consists in steeping the flax in water for five to fifteen days, thereby enabling certain biological processes to hydrolise the tissue surrounding the fibre. It is next dried, and the processes of "breaking," "scutching," and "hackling," follow. In these the fibre is separated from the rest of the stem. It is then sorted, graded, and baled ready for market.

About six hundred pounds per acre is considered a fair yield of fibre, and eight hundred pounds a good yield of linseed from a crop grown for the seed. The fibre crop, in addition to the fibre yield, gives about five hundred pounds of seed, much of which is immature.

Improvement.—The crop in South Africa is likely to develop as a grain- rather than a fibre-crop. In Europe, varieties are distinguished as fibre and linseed types, the latter branching more, being heavier linseed yielders and having larger and heavier seed. For our conditions, however, grain varieties should be chosen, and selection from these should be made for size and weight of seed, allied with high total yield. Disease resistance can be acquired by selecting the seed from surviving plants in badly infested fields, and continuing to do so each year.

Diseases.—Flax-Wilt (*F. lini* Bolley).—The spores are carried over in the soil, on dried stems, and by adhering to the seed. For this disease the formalin treatment and rotation are recommended.

Flax-rust (*Melampsora lini*) is fairly common, but is seldom serious.

The flax plant has no serious insect pests.

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[1] "Flax Cultivation."—South African Journal of Industries, November and December, 1919.
[2] "Field Crops."—Wilson and Warburton.
[3] "Cyclopedia of American Agriculture," pp. 293-302.
[4] "Flax Cultnre."—U.S. Dept. of Agric. Bulletin 274.
[5] "Resistant Seed Flax and How to Get it."—North Dakota Bul. 23.

BUCKWHEAT (*Fagopyrum Spp.*).

Buckwheat has not been in general cultivation so long as the cereals, and in China it was not grown for human consumption until after the Christian Era. It is grown extensively in Europe and North America, and with success in most parts of South Africa. It occurs in the wild state in Manchuria.

Description.—Buckwheat belongs to the Polygonaceæ, a family having angular, three-sided seeds. It has a strong central tap-root, no tillers, but many branches, somewhat triangular leaves, white flowers, and green to purple stems. There are three species in cultivation :—

(1) Common or Japanese (*F. esculentum*). Vars. : Japanese, Silverhull, Gray.

Key to Varieties of Common Buckwheat.

Faces of grain slightly concave; angles extended into very short wings—Common Gray.

Faces of grain flat; angles not extended into wings, grain small and plump—Silver Hull.

Grain large and not so plump—Japanese.

In Silver Hull the plant and seed are very small; the seed is silvery in appearance, plumper, smoother, and heavier in weight per bushel, than Japanese or Gray.

Japanese.—The seed is brown to black in colour, the plants and seed both large, and is generally the heaviest yielding and most commonly grown variety.

Gray.—Is intermediate in character.

(2) Tartary Buckwheat (*F. tartaricum*).—Sometimes called India wheat. It has a rough, wrinkled hull, small seeds, and wavy edges, small leaves and simple racemes. It is not much grown, but will succeed in higher and cooler altitudes than *F. esculentum*.

(3) Notch-Seeded Buckwheat (*F. emarginatum*) is cultivated to some extent in India, but very little in other countries. It is distinguished from *F. esculentum* and *F. tartaricum* in having the angles of the smooth hull prolonged into wide, rounded wings.

Buckwheat Grain.—Has a very heavy hull, which shows a tendency to split along the edges. The endosperm is softer and more starchy than in most wheats, and is low in fat content; the flour is low in protein.

Essential Ingredients of Buckwheat and its Products.
(Hunt.)

	Grain.	Flour.	Middlings.	Hulls.
Water	12·6	14·6	12·7	10.1
Ash	2·0	1·0	5·1	2·0
Protein	10·0	6·9	28·1	4·6
Crude Fibre	8·7	0·3	4·2	44·7
N.-Free Extract ...	64·5	75·8	42·2	37·7
Fat	2·2	1·4	7·7	0·9

50 to 60 per cent. of the grain is recovered as flour, 25 per cent. as middlings, and 15 to 25 per cent. as hulls.

Uses.—The flour is used to a considerable extent as human food in the making of buckwheat cakes in Europe and America.

The whole seed ground is used as stock food, and in those countries where flour is produced, the middlings, on account of their protein content, are looked upon as a valuable concentrate. Cracked grain is used to a considerable extent by poultrymen, and on account of quantity and quality of the nectar in the flowers, it is very often grown solely for honey production.

The straw is of little feeding value. Because of its quick and heavy growth, often on relatively poor land, it is one of the best non-leguminous plants for green-manuring, and, in addition, a good smothering crop.

Climate.—Buckwheat is a summer annual. As a green manure it will give good growth during the summer in most countries. During hot, dry spells, it fails to set seed but, being to a certain extent indeterminate in growth, this feature is often overcome. It is better, however, to plant accordingly, *i.e.*, so that the flowering period does not synchronise with the hottest months of the year. In the greater part of the Union planting about the middle to the end of January is best for seed production; flowering then takes place in February, and continues for several weeks. The seed commences to mature 56 to 75 days after sowing, and thus buckwheat is one of the quickest in maturity of the grain crops. On account of this feature it is one of the most suitable of catch crops, and should be chiefly grown for this purpose in South Africa.

Soils.—It will do well on most soils, but does better than the cereal crops on thin and sour soils. Except as a catch crop, it should not be grown on good soils, as other crops will be found more profitable. On rich soil it lodges very readily, but does well on newly " braaked " soil, *i.e.*, virgin soil.

Cultural Methods.—Fair crops will be grown with less soil preparation than for the cereals, but it naturally responds well to good soil cultivation.

The seed may be drilled or broadcasted at the rate of forty to fifty pounds per acre.

It should be harvested when the majority of the seed has matured, and as it shatters readily, this operation in extremely hot weather should be avoided. If cut in the early morning, when still damp with dew, excessive shattering can often be minimised. As the straw is still green when the crop is harvested, it must be loosely cocked and, on account of heating, it is often better threshed from the field. If stacked prior to threshing great care is necessary to prevent overheating. It can be threshed with an ordinary wheat thresher, having the concave adjusted so as not to crack the grain.

It is a crop apparently little affected by diseases or insect pests.

SUNFLOWER (*Helianthus annus*).

This is a summer annual, grown chiefly for the seed, which is used for feeding to poultry and for the oil contained, and to a limited extent for silage. It is a native of North America.

Varieties.—(1) Common.—Heads 8 to 16 inches in diameter, seed grey, brown or striped.

(2) Mammoth or Giant Russian.—Heads 15 to 20 inches in diamete, seeds about half an inch long, with black or brownish stripes, though sometimes they are all white. Considered one of the best varieties for oil-production.

(3) Black Giant.—Produces heads 16 to 22 inches in diameter, with black seeds $\frac{3}{8}$in. in length.

Soil and Climate.—Its soil requirements are very similar to those suited for maize. It is considered to be a heavy feeder and exhaustive on soils. It requires plenty of sunshine, and is more resistant to drought, alkali and frost, than maize.

Cultural Methods.—The land should be prepared as for maize. Plant the seeds 1 to 3 inches deep in rows 3 feet to 3 feet 6 inches, and 18 to 24 inches apart in the rows; eight to fifteen pounds of seed are required per acre. It is best to sow thickly and then to thin out when the plants are about six inches high; this is, however, only practicable where labour is cheap and plentiful. It has a tendency to branch, and if large heads are to be produced, all lateral branches should be cut off; this should be done when the plants are about three feet in height.

The plants require a long growing season, and should be planted in November, except in the Lowveld, where seed could go in as late as December.

Harvesting.—The heads should be harvested before they are fully matured. This prevents loss through shattering or from birds. If the crop is small, the heads may be harvested as they ripen. They are then dried as quickly as possible in the sun and threshed. Threshing is often done by flail, but where large amounts are handled the ordinary maize thresher, suitably adjusted, can be successfully employed. Small meshed wire netting, suitably stretched on a frame, and the heads rubbed over this, will often prove serviceable.

The seeds are afterwards dried in the sun and then, where possible, run through a winnower.

A bag of seed weighs about 100 lbs., and ten bags per acre is considered a good yield.

Uses.—(1) The seed is used principally for poultry, but forms a valuable part of the ration for sheep, pigs, and other livestock.

(2) Silage.—This has been tried in the United States, and as a mixture with beans and maize is said to give good returns.

In a recent publication[1] Dr. Shutt concludes " that sunflowers make a satisfactory, acceptable soiling and silo crop, in districts in which the season is too short, the nights too cool, and the rainfall insufficient for the best results with maize. . . . The exact stage at which to obtain the largest amount of digestible dry matter per acre is not as yet known, but would appear to be when about 10 per cent. of the plants are in bloom. If left much later, the increase in dry matter appears to be more than offset by the marked increase in fibre content, leading to a decided decrease in the digestibility of the silage."

Composition Maize and Sunflower Silage.

	Water.	Crude Protein.	Crude Fat.	Carbos.	Fibre.	Ash.
Sunflower cut when 10 per cent in bloom...	75.67	3.43	1.24	10.17	6.22	3.27[1]
Sunflower seeds fully formed	52.31	5.06	2.42	24.75	10.16	5.30[1]
Maize	73.7	2.1	0.8	15.4	6.3	1.7[2]

From these analyses it will be seen that sunflower silage cut at the right stage is very similar in composition to maize silage, but contains a slightly higher percentage of crude protein, fat, and ash, than the latter.

The Grootfontein School of Agriculture claims excellent results from ensilaging sunflowers.

(3) The largest production is in Russia, where the crop is grown to a large extent for oil. The oil is said to be superior to both almond and olive oil for table and cooking purposes, and is also used in the manufacture of soap and candles, and for lighting.

ANALYSIS BY TRANSVAAL DEPARTMENT OF AGRICULTURE.

Husk	43·43	per cent.
Kernels	56·57	,,
Percentage oil in kernels	36·72	,,
Percentage oil in seeds	20·77	,,

After pressing out the oil from the seeds, a residue is left in the form of a cake, which is of high nutritive value, and said to be quite equal to that of linseed and cotton-seed cake for feeding dairy cattle.

CONCLUSION.—It is a crop for intensive agriculture where labour is cheap. Whether it would be profitable when grown on a large scale in South Africa is questionable. It thrives in parts where maize succeeds, and is a much surer crop in times of drought.

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[1] "Seasonable Hints," July, 1921.—Dominion Exp. Farms.
[2] "Feeds and Feeding."—Henry and Morrison.

PUMPKINS (*Curcubita pepo*).

KAFFIR AND STOCK WATERMELONS (*Citrullus vulgaris*).

These are grown for human consumption and for stock food. Certain species of the genus *Curbubito*, and all the kaffir and stock watermelons are indigenous to Africa and South Africa.

PUMPKINS.

DESCRIPTION.—Pumpkins are summer annuals, monoecious; of two distinct types.

(1) Table.—Medium size, generally flat, with thick flesh and fine-grained. The seed cavity is small in proportion to the size.

(2) Cattle.—Large size, somewhat spherical in shape, flesh coarse, and sometimes with woody lumps. The seed cavity is large in proportion to the size of the pumpkin. They cross-pollinate readily within the genus, and with some of the other genera belonging to the *Curcubitaceæ*. Cattle pumpkins will weigh up to 120 pounds.

Cultural Methods, Etc.—Pumpkins are very susceptible to frost, and should not be planted until all danger of frosts has passed. Under irrigation they are preferably planted from September to October, and on dry lands in November. They do well on moist soils, except heavy clays. Manuring, particularly with stable manure, is advisable. The manure may be applied in hills or on a large scale in strips across the land, the rows being along these strips. They are planted 10 by 10 feet, four or five seeds ner hill—these are subsequently thinned out to two or three plants per hill. About two to three pounds of seed is required per acre. The crop is better grown alone and not in competition with maize. When well started, pumpkins resist drought fairly well.

The fruit stalk should not be broken off, as this encourages decay. They should be harvested about June, after the killing frosts, and stored in a dry place. To preserve pumpkins for table use they are sometimes stored in pits covered with sand. Properly stored, they keep well until October. Thick-skinned varieties keep best.

Stock pumpkins yield from 40 to 50 tons per acre. Sliced up, they form an excellent addition to the winter feed for sheep, cattle and pigs.

Stock Melons.

Stock varieties of melons have been devoloped in the United States of America, some of which have not yet reached South Africa. These, like the Maketaan and Tsamma (common species found in the dry parts of the Union, *e.g.*, the Kalahari), are non-saccharine. The Tsamma weighs three to four pounds; Maketaan considerably more, while some of the stock melons weigh up to 75 pounds.

The cultural methods are somewhat similar to those required for pumpkins. They are exceedingly drought-resistant, giving heavy yields in very sandy soil and under very low rainfall. "The Maketaan (Mammoth and Fraserdale) are now extensively grown in different parts of the Karroo, where, owing to scanty rainfall, irrigation is needed for all other kinds of crops." They mature about April to May, and if carefully stored will last to the end of September or later.

Dr. Juritz reports a yield of 300 tons per acre!

COMPOSITION (Dried).

	Water.	Protein.	Fat.	Carbos.	Fibre.	Ash.	N.R.
Tsamma ...		9·40	5·77	48·40	27·79	8·24	1 : 6·6
Stock Melon		7·97	3·77	58·90	22·02	7·34	1 : 8·4
Pumpkin ...	90·5	1·3	0·4	5·2	1·7	0·5	

The seed of the Maketaan contains 15 to 19 per cent. protein and 20 to 23 per cent. fat. Four to five per cent. of the melon is seed. The green weight contains 92 to 94 per cent. of water.

Pumpkins and melons must be looked upon as valuable in supplying succulence for winter feeding. They are extremely bulky, and should not be used as a complete ration in themselves.

If maize silage is available, the silage should be kept for September, October, and November, while the pumpkins and melons are being fed during the winter months.

REFERENCES:

[1] "Notes on Some Indigenous and Other Fodder Crops."—Science Bulletin No. 6.—Juritz.
[2] "Botany of Crop Plants."—Robbins.
[3] "The Farmers' Handbook."—New South Wales Dept. of Agric.
[4] Encyclopædia of American Agriculture.

CHAPTER XX.

MINOR CROPS

Since most of the crops dealt with in this chapter belong to the leguminosæ, the following key to the principal genera, given by Robbins,[1] may be of use :—

Plants with tendril-bearing leaves :

Calyx lobes leafy, stipules large, rounded—*Pisum* (pea).
Calyx lobes not leafy, stipules mostly small, pointed.
Style slender, bearded at the tip—*Vicia* (vetch).
Style flattened, bearded along inner side—*Lathyrus* (vetchling).

Plants without tendril-bearing leaves :

Leaves palmately three-foliate—*Trifolium* (clover).
Leaves pinnately three-foliate, rarely five to seven-foliate.
Flowers small, many in a cluster.
Flowers in slender spike-like racemes—*Melilotus* (sweet clover).
Flowers in heads or short spikes—*Medicago* (lucerne).
Flowers medium to large, few in cluster.
Pods smooth, mostly large.
Keel of corolla spirally coiled—*Phaseolus* (bean).
Keel of corolla merely incurved—*Vigna* (cowpea).
Pods hairy, small—*Soja* (soy bean).
Leaves pinnate, with two pairs of leaflets—*Arachis* (peanut).

FIELD BEANS (*Phaseolus spp.*).

Beans belong to the leguminosæ or pea family of plants. They are either annual, biennial or perennial; although most of the common varieties in the Union are annuals. The most characteristic features of this genus are the pea-like flowers, the pods and the nodules on the roots. Because of their beneficial effect on the soil, their cultivation might well be extended.

Climatic and Soil Requirements.—Beans are hot weather crops, and for that reason they should not be planted until all danger from frost is over. Any good agricultural soil thoroughly prepared will produce beans. They seem to thrive best, though, on deep loam soils, not too sandy in nature. Very heavy brak and water-logged soils should be avoided, as these are decidedly unfavourable for the production of these crops. Soils containing too much organic matter, such as are often found in vleis, are also undesirable, as they stimulate vegetative growth at the expense of seed production. When grown on dry lands the preparation of the seed-bed should aim at the production of one retentive of soil moisture.

Cultural Methods.—For successful bean production, the proper preparation of the seed bed is of utmost importance. The land is best ploughed in winter and disced before the beans are planted in the spring. The time of planting will vary with the locality as well as with the variety planted, whether early or late maturing. Under average South African conditions probably the best period for sowing this crop is during the months of November and December, when the heavy summer rains coincide with high temperatures.

The best method of planting beans is with an ordinary maize planter fitted with plates that will allow the beans to pass through regularly. A small grain drill with some of the holes stopped up to get the rows the correct distance apart could also be used advantageously. The rows are generally made about 2 to 3 feet apart and the seeds spaced 6 to 12 inches in the row. On dry lands the spacing must necessarily be wider than under irrigation. In no circumstances should the seed be placed deeper than 2 inches, otherwise the seedlings will have difficulty in reaching the surface. The rate of planting varies with the size of the bean; about 10 lbs. of Tepary beans, 30 to 40 lbs. of sugar, and 50 to 60 lbs. of white kidney beans will be found to be the right quantity to plant per acre. The crop on a well prepared seed-bed will require three to four cultivations. Harrowing is sometimes necessary just before the beans begin to appear to break the soil crusts and to destroy new seedlings that may have germinated. Where a very good stand has been obtained, a second harrowing after the plants are up may be of use; this operation is best carried out when the young seedlings are wilted; otherwise, being too brittle, a large number will be broken off. Cultivation should be commenced soon afterwards, and should continue until the vines meet and thus make inter-tillage impossible. Harvesting should start when the majority of pods have turned colour, and before the oldest have started to shatter. Where there is any danger of shattering, the crop is best cut at a greener stage and the handling done during the early morning hours when the crop is moist from the dew. The crop is generally pulled or cut by hand, but where large acreages are grown, they are most economically harvested with an implement called a bean cutter, the essential feature of which is a pair of sharp knives, about three and a half feet in length, mounted on a sled, from which they should stand inward and slope backward at an angle of 66 degrees. The sled straddles two rows and deposits the plants in a windrow, where they are left until dry enough to be put up in cocks before being threshed. In South Africa threshing is mostly done with a flail or by trampling with animals. Grain threshers have thus far proved unsatisfactory in that too many of the beans get cracked. In America special bean threshers are used and are reported to give every satisfaction.

Being a soil renovating crop, it should, where desirable, be included in rotations. It is undoubtedly one of the best cash crops on dry lands as well as under irrigation. On the former it can precede maize, and on the latter wheat in the rotation.

Production and Yield.—The acreage under this crop in the Union, according to the 1918 agricultural census, was 30,474 morgen, which gave a total production of 256,472 muids of 200 lbs. each. Thus the average acre yield is about three to four bags, though much higher yields are often obtained.

Uses.—Beans are used in large quantities dried, and in the pod as "green beans." They are also to a limited extent used as stock feed when ground, and the straw makes a valuable hay for all classes of livestock. On account of their high protein content, all parts of the plant constitute an important portion of rations which may include them.

Varieties in South Africa.—Beans belonging to the sugar group are those in greatest demand and fetch the highest prices. The best varieties of these are Painted Lady and Port Natal. White varieties such as Large White Kidney, Large and Small Haricot are also popular and sell well. Of the coloured varieties the Red Canadian Wonder is probably the most outstanding.

VELVET BEAN (*Stizolobium deeringianum*).

This plant is often called Florida Velvet Bean because of its early cultivation there. It is a vigorous growing summer annual, having much branched twining stems which may reach a height of 20 feet and upwards. The dark purple flowers are borne on slender pendent racemes. Two distinct types of pods are produced, one covered with a dense black velvety pubescence, as in the Florida and Georgia varieties, and the other type has a white to greyish pubescence, *e.g.*, Chinese and Yokohama varieties. The latter shatters badly. The pods of the commoner types are short, 2 to 3 inches in length, somewhat constricted about the seed, and contain most commonly three to five grey or mottled seeds, although white and black seeded varieties are also known. Early and late varieties are found. The Florida variety is the one commonly grown in South Africa, although a white-seeded variety is found in Zoutpansburg. The velvet bean is considerably later in maturing than cowpeas (kaffir beans) and soy beans usually grown in the Union. An early variety more suitable for many districts might be produced by crossing Florida and Chinese. At present it is so late in maturing that it produces seed only in the Lowveld, where it is grown to a limited extent. It should be sown at the rate of 30 to 50 lbs. per acre when grown for green-manuring or as a smother crop to be harvested for fodder. In America it is sometimes used to smother out quick grass. On account of its entangled growth it is extremely difficult to harvest. The stems are generally cut by means of a spade. If used for hay, the crop must be harvested before any of the pods mature. Its use for silage when grown with maize is advocated by some, and in the United States it is sometimes pastured off for cattle and pigs.

MUNG BEAN (*Phaseolus aureus*).

This is an erect summer growing annual legume introduced from India. In some localities it has given excellent results, promising to replace cowpeas in South African agriculture. In some respects it resembles the soy bean, in others the cowpea. The seed, small and of a green colour, makes an excellent soup, but is very subject to depredations by weevils. Being of an erect growth, the plant can be harvested more easily than the cowpea, and for the same reason can be more readily ploughed under as a green manure.

THE FIELD PEA.

Piper says :—" It is customary to distinguish agriculturally between the garden pea (*Pisum hortense*) and the field or Canada pea (*Pisum arvense*), but whatever characteristics are used, there are all possible inter-grades in the long series of cultivated varieties. In general the term field pea is restricted to those having somewhat angled, brown to black or marbled or speckled seeds and coloured flowers; garden pea to those having white flowers and round, yellow seeds. But several varieties are used both for vegetables and for forage."

In South Africa field peas are looked upon as winter rather than summer annuals, since their growth during the hot months is extremely poor.

They are fairly resistant to drought. Except in the winter rainfall area, however, they must be grown under irrigation.

DESCRIPTION.—They are usually decumbent, pale green and glaucous; the leaves are pinnate, with one to three pairs of leaflets; numerous tendrils; having stout axillary preduncles bearing each one to three flowers. Those seeds, having a very angular form, owe their shape to a higher sugar content and consequently greater shrinkage when drying. " The colour of the seeds when of a single tint may be yellow, pea green, brown or black. Yellow or green seeds may be marbled with brown or speckled with blue, black or brown, or both marbled and speckled. The embryos are yellow in yellow seeds and green in green seeds." Numerous varieties are found. They are best sown with oats, but will do well with rye. In general they do well when used for the same purposes as those described for the vetches. In mixtures a quantity of peas equal to that of the cereal should be used. When grown for seed they must be planted early enough to ensure the setting of pods before the warm summer weather arrives. Unlike the vetches, when grown for seed they are badly attacked by the pea weevil (*Laria pisorum* or *Bruchus pisorum*), which lays its eggs on the developing pod; the larva hatches and burrows into the young seed and remains for a considerable period in the mature seed.

THE CHICK-PEA (*Cicer arietinum*).

This is a bushy, hairy winter annual which has grown well in those parts of South Africa where it has been tried. Although it seeds heavily and the seeds are weevil-resistant, there appears no reason why its cultivation as a field crop should be advocated, since owing to an acid secretion from glandular hairs with which the plant is sparsely covered, it is unpalatable to stock and, moreover, is said to be poisonous to cattle and horses. In India it is known as " gram." The seeds resemble the pea and have a beak-like projection near the hilum.

THE GRASS-PEA (*Lathyrus sativus*).

This has been tried at experimental stations and is another winter annual having no decided characteristics to warrant its cultivation in South Africa. The seeds, which are wedge-shaped, are used for human consumption, but if eaten continuously cause paralysis. The seeds are also immune to weevil attacks. The stems are flattened and more slender than those of the ordinary pea; the leaves consist of one or two pairs of narrow grass-like leaflets and have branched tendrils; the flowers are white and solitary; the pods are about 1 inch long and 1 inch wide, flat and contain three to four seeds, which are generally yellow or yellowish-green.

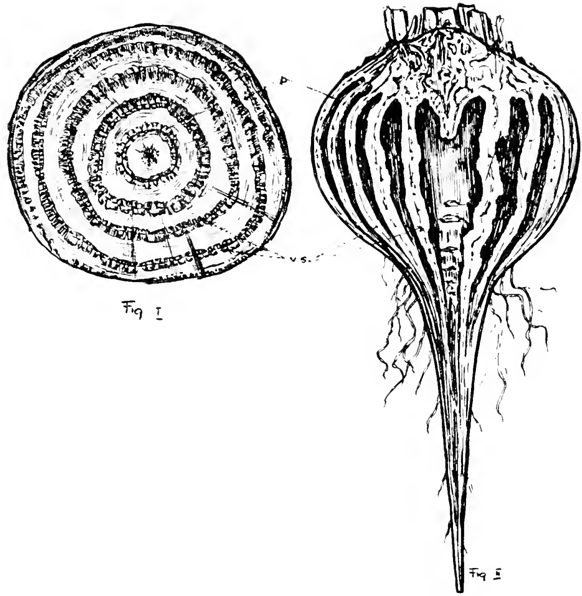
THE VETCHES.

While a number of plants belonging to various genera are called " vetches " in different parts of the world, the term " vetches " should, however, be used only of those plants belonging to the genus Vicia.

There are four species commonly met with in South Africa, viz. :—

V. sativa.—Common Vetch or Tares or Spring Vetch.
V. villosa. Hairy or Winter Vetch.
V. angustifolia.—Narrow-leaved Vetch.
V. fabia.—Broad, Windsor or Horse Beans (Boer boontjie).

As field crops, *V. sativa* and *villosa* are the only ones of importance in the Union. *Angustifolia* is frequently found as a weed and *fabia* is commonly grown in gardens as a vegetable. *V. sativa* is a winter annual in South Africa, having stems 2 to



SECTIONS OF YOUNG MANGEL, SHOWING RINGS OF VASCULAR BUNDLES.

PLOT OF SUNFLOWERS AT THE TRANSVAAL UNIVERSITY COLLEGE FARM.

MUNG BEAN (PHASEOLUS AUREUS).

OLD MAN SALTBUSH (ATRIPLEX NUMMULARIA) AT GROOTFONTEIN SCHOOL OF AGRICULTURE. (COURTESY UNION DEPARTMENT OF AGRICULTURE).

SPINELESS CACTUS. (COURTESY UNION DEPARTMENT OF AGRICULTURE).

3 feet in height, which generally branch from near the base. The plant when unsupported is decumbent in habit. The leaves are numerous and compound, terminating in tendrils. The leaflets are oblong, square at the end and decidedly mucronate. The flowers are in pairs at the base of the leaves, generally purple to rose-coloured, but are somteimes entirely white. The pods are brown, each containing from four to five, usually grey or marbled seeds which are readily shattered at maturity. Vetches are seldom cross-fertilised. This species is indigenous to Europe, Asia and Northern Africa.

V. villosa.—This is also a winter annual, the stems of which reach a length of about 12 feet. It grows from 2 to 4 feet in height, winding and trailing in all directions, like Common Vetch, from which it is easily distinguished, even if no flowers are developed, by its hairiness, the whole plant being covered with long, soft, spreading hairs, which often give it a white woolly appearance. The leaves are compound and the leaflets gradually taper towards the apex. The flowers are purple to pale blue in colour, borne on long peduncles, and are smaller than those of *sativa*. The pods are smooth, pale-coloured, containing two to eight small black globose seeds, velvety when fresh. It is hardier to cold than *sativa* and its early growth is much slower. It has a deep and much branched rooting system. This species is indigenous to Europe and Asia.

HABITS OF GROWTH.—Although closely related, the development of peas and vetches is very different. The main stem of the pea plant grows during the whole life of the plant, but the branches are less vigorous. In a vetch the main stem soon stops growth and strong lateral branches are developed from the base. In this respect their winter annual characteristics are shown, since in the colder parts they start growth later in the season, remain stationary during winter, and complete development during the summer. The seedling stage, particularly in the case of Hairy Vetch, is very disappointing: however, once active growth commences, the ground is soon covered and a dense deep mat is formed.

When used as hay croys they are always grown in conjunction with oats, barley or rye, as without these harvesting with a mower would be practically impossible on account of their prostrate and entangled habit of growth.

In northern countries *sativa* is generally sown in the spring and *villosa* in the winter. In South Africa, however, little difference need be made, except that in mixtures Hairy Vetch should preferably be used with late varieties of oats and barley.

Cultural Methods.—A fairly compact seed-bed is required. They can be sown from the end of February (Hairy Vetch) to the end of July (Spring Vetch). Fifteen to twenty-five pounds of vetch are generally grown with forty to sixty pounds of oats, barley or rye. If the vetch is grown as a green-manuring crop, then thirty to forty pounds of seed is used per acre. Practically all the seed is imported and is expensive. For this reason thinner seedings are advocated. The Common Vetch shatters its seed readily and in consequence is sometimes troublesome as a weed in winter cereals. As a rule vetches prefer sandy and light types of soil to heavy ones. The Common Vetchs like lupines are injured by heavy applications of lime; on the other hand, Hairy Vetch prefers calcareous soils and is quite the most resistant to alkali of all field legumes and is besides fairly drought-resistant. Unlike cowpeas, the vetches may be sown quite deeply without injury, because the cotyledons remain where planted, the plumule becoming much elongated. Two inches, however, is the optimum depth for sowing.

Experience in America points to the necessity for soil inoculation; however, in South Africa on fields where winter cereals have been grown for any period, the necessity does not arise, since inoculation has probably been accomplished by vetches as weeds in these crops.

When grown for seed, both species can be grown, with a variety of oats which takes about the same time to mature. When fully matured, the mixed crop is harvested and threshed with the ordinary grain thresher, which will easily separate the seeds; the straw provides a fairly good feed. If grown for seed purposes, the quantity of vetch seed in proportion to the oats should be reduced and the mixture sown on poor soils in preference to rich soils.

Uses.—Under irrigation and in those parts having a winter rainfall, the vetches and field peas might well play a more important part. When grown alone they make an excellent green-manuring crop of winter growth, and are also very useful as a pasturage. As a hay crop in mixture they are easily harvested, assist in maintaining the fertility of the soil, and, being extremely nitrogenous and palatable, they increase the feeding value of the crop with which they are grown. When grown with oats the yield varies from $1\frac{1}{2}$ to 3 tons of hay per acre.

The vetches are extremely free from insect or fungus pests.

SAINFOIN (*Onobrychis viciæfolia.*)

This is a perennial with a strong tap root and numerous erect stems, which reach a height of 1 to 2 feet. It has compound leaves and an inflorescence that is spikelike, long and thin, with showy pink flowers. Sainfoin has been cultivated in France for 400 years. It prefers calcareous soils of open texture and is very drought-resistant. Piper cites Lawson, who claims that the plant may live for 100 years. It does poorly in competition with weeds and is generally sown at the rate of 60 to 100 lbs. per acre. As a pasturage it is excellent and has not been known to cause bloating. It would appear to have possibilities in South Africa, where calcareous soils are found, to furnish grazing in July, August and September and hay during summer.

SULLA OR SPANISH SAINFOIN (*Hedysarum coronarium*).

This is a perennial legume which has been tried at the various experimental stations in the Union. It prefers much the same soils as sainfoin, but is not so drough resistant and vigorous in growth. The flowers are red and the compound leaflets are less in number than those of sainfoin. The plant is greyish in appearance and the seed is difficult to germinate.

BURNET (SANGUISORBA MINOR).

This is a deep-rooted perennial herb making an excellent winter growth in South Africa. The leaves are ovate and the leaflets deeply toothed. The stem is about 1 foot long and bears a few heads of light green or purplish monoecious flowers. It is sown at the rate of 30 lbs. per acre. Burnet, or Sheep's Burnet as it is commonly called, is fairly hardy and drought-resistant, and, like sainfoin, prefers calcareous soils. It is not very palatable, but is looked upon as an excellent tonic, especially for sheep during the winter months, and will furnish good grazing under very adverse winter conditions. While the sainfoins and Burnet make excellent growth, the stands readily become sparse in competition with weeds or if hard soil surfaces are formed.

KUDZU VINE (*Pueraria thunbergiana*).

A perennial legume indigenous to Japan. It has large leaves with very woody older vines. The purple-red flowers are borne in racemes. The pods are covered with short brown hairs containing numerous speckled seeds. In South Africa it is only now being tried as a field crop, although it has been used as an ornamental plant for some years. The vines will attain a length of 60 feet, and it seems to be drought-resistant and to do well even on the poorest of soils, although clay loams are preferred.

The growth from seedlings is slow, and, moreover, the seed germinates very poorly under ordinary treatment. It is best propagated by roots, obtained from the prostrate vines which root at their joints. These should be planted 9 feet by 9 feet. Heavy crops are obtained only in the third season. The leaves are extremely persistent and little loss is experienced in hay-making, although harvesting is difficult. Its function would seem to lie in grazing, where it can be employed in fields not suitable for other crops.

THE CLOVERS.

Various species of *Trifolium* have been tried privately and at all the experimental stations in South Africa with very meagre success. Species belonging to the genus *Melilotus,* however, grow very well, but have not as yet become popular. Generally the climate in South Africa is unsuited to the clovers, and in parts where the climate is not wholly unfavourable the absence of the specific nodular organisms seems to be the factor limiting their growth, since in one or two localities in the Western Province, where persistence has been shown in soil inoculation, successful stands have been obtained.

Red Clover (*Trifolium pratense*).—Its value in the northern hemisphere is indicated by Piper, who says: "Red Clover is the most important of all leguminous forage crops, both on account of its high value as feed and from the fact that it can be so well employed in rotations." In North America five times as much Red Clover is grown as lucerne; in fact it forms the basis of farming in many countries in Europe and North America, and is also extensively grown in Chili and New Zealand. Red Clover is mainly biennial. In contrast to lucerne, the primary root contracts as it grows older, resulting in a deep-set crown. The stems spring from buds in the crown in a manner very similar to lucerne. The inflorescence is a dense head about an inch in diameter when fully developed, usually red in colour, but may be white. The oblong leaflets are generally marked with a white spot of varying size and shape. It is completely self-sterile; cross pollination is effected by insects, chiefly bumble bees. The pods contain only one seed each and the flowers are persistent. The seeds may be yellow or purple, and some may be bright at one end and dark at the other. Mammoth Red or Cow Grass (*T. pratense var. perenne*) is a coarser perennial variety of Red Clover.

Red Clover is essentially a crop for humid parts where temperatures are not very high. It has poor drought-resisting qualities, and since lucerne can generally be grown on irrigable land which will grow Red Clover, there seems to be no advantage in employing it on such fields. It is, however, not so exacting in its soil requirements as lucerne, and does best on well drained calcareous soils.

It is probable that in suitable areas in parts of South Africa having winter rainfall and on inoculated soils, if sown in February, March and April, it could be grown without irrigation, giving a good hay crop before the hot and dry summer months set in.

Clover should be sown at the rate of 8 to 12 lbs. per acre.

It is often sown with grasses, giving two hay crops during the first season and providing with the grasses, excellent grazing the following year. The hay is easier to cure and handle than lucerne hay. If cut at full bloom and before the heads commence to turn brown, it gives hay of the highest feeding value. When grown continuously in the same soil, the crop eventually becomes unthrifty and the soil is said to be "clover-sick." A great many theories have been advanced to explain this, but none has been proven.

Nearly 50 per cent. of the plant at full bloom consists of roots, which to a great extent explains its remarkably beneficial effect on the soil.

Crimson Clover (*T. incarnatum*) is an annual adapted to somewhat hotter areas than Red Clover. It is very poor in resisting drought and there seems to be no outstanding reason why its cultivation in South Africa should be encouraged. It is distinguished from *T. pratense* by its longer inflorescence of a rich scarlet or crimson colour. The head has a bluish green tint before flowering.

White or Dutch Clover (*T. repens*) is a low-growing, shallow-rooted perennial species having adventitious roots, bearing small pure white flowers on long flower stalks from the lower part of the stem. It is especially adapted to rather moist, warm climates, and does fairly well on comparatively water-logged soils. It is an excellent legume for pasturage and is nearly always included in pasture mixtures in Europe and America. When grown alone poor results have been obtained in South Africa, but Melle has found it to grow excellently in conjunction with kikuyu grass on well limed soils. At the Experimental Farm, Potchefstroom, it is affording good pasturage together with paspalum.

Alsike Clover (*T. hybridum*).—It is a fairly erect growing glabrous perennial, having white to pinkish flowers—white when young, pinkish later on, borne on the terminals of branches. The seeds are small yellowish-green, black and greenish-black in colour. It is shallow rooted, poor in drought-resistant qualities, and will do fairly well on soils too poorly drained for Red Clover. It thrives in cool climates having abundant moisture. Trials at the experimental stations in South Africa have not shown it to be suitable to our conditions.

Berseem (*T. alexandrinum*) is a white flowered annual preferring higher temperatures than the other clovers commonly grown. It is extensively grown as a winter irrigation crop in Egypt, and as such might find a place in South African agriculture.

Subterranean Clover (*T. subterraneæ*) is a perennial grown in Australia, having rhizomes, and which may prove of use in South Africa, since it is supposed to be more drought-resistant than the other species of *Trifolium*.

SWEET CLOVERS (*Melilotus spp.*).

White, Sweet or Bokhara Clover (*M. alba or leucantha*) is an erect biennial, having white flowers. It grows 3 to 4 feet the first year, and may reach a height of 6 to 9 feet the following year when it flowers, the racemes being 3 to 12 inches in length. The stems are coarse and very woody close to the ground.

Yellow Sweet Clover (*M. officinalis*) is a yellow flowered biennial species of earlier and more slender growth than *M. alba;* it is also less leafy and smaller in size.

There are several annual species as well as an annual selection of *M. alba*, namely, Hubham Clover, which makes rapid growth under South African conditions, and has attracted a great deal of attention lately. The Sweet Clovers contain a bitter substance called cumarin, which renders them unpalatable to stock, a fact which has restricted their cultivation. Once accustomed to it, though, stock thrive on it.

Agriculturally, *M. alba* is much the most important. It grows readily on a variety of soils, heavy and light, rich and poor, well drained and poorly drained. In South Africa it enjoys the reputation of doing well on poor sandy soils—a happy fact, since being an excellent green-manuring crop, it might well be utilised in renovating worn-out sandy soils. It is drought and alkali-resistant to a high degree. A fine seed bed is required, and 15 to 20 lbs. of seed are used per acre. American experimentalists consider it, on account of its vigorous root system and quick decay of the whole plant, to be one of the best crops for green-manuring. The young growth is less bitter than the older growth and it makes good grazing for stock that will take to it.

As a hay crop in South Africa it is difficult to see why sweet clover should be superior to the erect growing types of cowpeas. It is highly esteemed by bee-keepers.

THE SWEET POTATO (*Ipomœa batatas*).

The original home of the sweet potato is in the West Indies and Central America. It belongs to the Convolvulaceæ or the Morning Glory family, and is a perennial with very much thickened roots, which constitute the edible portion. It seldom produces flowers and rarely, if ever, matures seeds. When in favoured localities, seeds are produced and planted, new varieties may thus be originated. The classification of varieties is based on the shape of the leaf, which is round, lobed or notched. They may also be divided into two groups upon the basis of the amount of water and sugar present—(1) dry sweet potatoes are ones in which the flesh is dry, mealy and yellow; (2) "yams" are sweet potatoes of which the flesh is watery, rich in sugar, soft and gelatinous when cooked.

Climatic and Soil Requirements.—For maximum production it requires a fairly long growing season, free from frost, such as is found along the southern coast belt of the Cape Province and in the Lowveld areas of the Transvaal Province and

Natal. It is adapted to fairly warm temperature and a medium rainfall, or, in the absence of the latter, a moderate number of irrigations.

Although the crop is grown on a wide range of soils, it seems to thrive best on sandy loams with a clayey well-drained sub-soil. It has the reputation of growing on very poor sandy soils, especially along the coast, but for profitable returns it is best grown on soils of fairly high productiveness. Excessive applications of stable or kraal manure tend to produce too much top growth and too little root formation.

Cultural Methods.—Sweet potatoes are generally grown from slips, from the roots, or more commonly from vines. The latter is the method practised to the largest extent in South Africa. The best practice, though, is to sprout the roots in warm sand and then to remove the sprouts for setting in the field (as they become large enough). As the roots continue to sprout for some time, a comparatively small number of roots will supply sufficient plants for a fairly large sized area. Where the crop is propagated by means of vines, these are cut about 1 foot long.

The crop is ordinarily planted by hand on flat or unridged land in rows two to three and a half feet apart with plants spaced fifteen to eighteen inches in the row. Where the land is not well-drained it is advisable to plant the crop on ridges, as described for potatoes. In the case of vines three-fourths of the cuttings should be buried below the ground and care should be taken to plant them in soil which is fairly moist or otherwise irrigation must be resorted to.

The land intended for this crop should be ploughed some time in advance of planting so as to give it time to settle. It should subsequently receive a cultivation or disc-harrowing, to put it into good tilth before the plants are set out.

Analyses have shown that sweet potatoes take large proportions of potash from the soil, as well as fair quantities of the other elements of plant food, and on that account the crop should not be grown continuously on the same lands for any length of time. Rotative cropping is as necessary with this crop as it is with ordinary potatoes, and when the soil shows signs of exhaustion the necessary elements of plant food required should be supplied in the form of artificial fertilisers: "A fertiliser containing 2 to 4 per cent. of nitrogen, 8 per cent. of phosphoric acid, and 8 to 10 per cent. of potash has given very satisfactory results."[1] It also follows well after a green-manuring crop, especially on poor sandy soils lacking in organic matter.

The cultivation is no different to that given to most other cultivated crops. A one-horse cultivator is generally employed for stirring the soil between the rows and to prevent a hard crust from forming. This operation is discontinued as soon as the vines commence to cover up the space between the rows, and after some loose soil has been worked up towards the plants.

Under normal conditions in South Africa the crop may be lifted any time during the winter months, after the vines have died. Where the winters are very severe and the roots likely to be frosted in the ground, they should be lifted and, as their keeping qualities are poor, graded and sent to the market without delay.

YIELD AND PRODUCTION.—The average annual production of the Union, according to the 1918 Agrciultural Census, was as follows:—

Province.	Acres.	Production.	Yield per acre.
Cape of Good Hope	12,162	46,089,450 lbs.	3,790 lbs.
Natal	3,643	12,290,850 ,,	3,374 ,,
Transvaal	4,411	10,529,250 ,,	2,387 ,,
Orange Free State ..	176	231,600 ,,	1,316 ,,
Total	20,392	69,141,150 lbs.	Av.3,390 lbs.

From the above is seen that the average yield per acre is 3,390 lbs., or, approximately, 22 bags of 153 lbs. each, as compared with 2,200 lbs. per acre of ordinary potatoes.

In the sweet potato belt of the Cape Province—namely, in the Districts of Oudtshoorn, George and Knysna, the yield per acre is considerably higher.

USES.—It is chiefly used as food for man, but in some parts it is considered excellent stock food, especially for pigs. Besides these two uses, alcohol is manufactured from it in certain countries.

CHICORY (*Chicorium intybus*).

Chicory belongs to the Compositæ, or thistle family. It is a perennial, with a fleshy tap-root about one foot in length.

CLIMATIC AND SOIL REQUIREMENTS.—This crop can be grown either as a summer or a winter, dry-land or irrigation crop. It is fairly drought and frost-resistant, although for its highest production, other factors being favourable, it requires a good rainfall, or in its absence a few thorough irrigations. Like other root crops it succeeds best on a deep loam soil, not too sandy nor too clayey. The preparation of the seed-bed should be as thorough as possible as success or failure of the crop often depends on this factor. Deep ploughing, so as to provide a deep feeding zone to the roots, is very essential. If the crop is to be planted in spring, winter ploughing will prove very beneficial. Manuring, especially on soils of poor fertility will prove profitable. About 10 tons of well-rotted kraal manure, ploughed under during the winter months, together with a dressing of 200 lbs. of superphosphate, applied in the row at the time of planting, is advocated.

Cultural Methods.—In areas having winter rainfall, or where the crop is grown under irrigation, March and April are considered the best months for sowing; but where the crop is grown on dry-lands in summer, the spring months are looked upon as the most suitable. About 1 lb. to 1½ lbs. of seed are required to plant an acre. The seed is put in by hand or by means of a small seed-drill, such as the Planet Junior, to a depth not exceeding 1 inch. The rows are made 18 to 24 inches apart. The seedlings are thinned out to a distance of 9 to 12 inches; under favourable conditions and on good soils the spacing is generally a little closer.

Cultivation should commence as soon as the plants appear in the rows, for if delayed weeds are likely to smother the slow-growing seedlings. Hand-hoeing is necessary between the plants in the rows. Three to four cultivations during the growing-season is generally sufficient. The number will, however, depend upon the amount of weed growth.

Harvesting.—Generally speaking, the crop is ready to be harvested when the lower leaves turn yellow. If this operation is delayed ehe roots tend to become too fibrous. Lifting is tion is delayed the roots tend to become too fibrous. Lifting is found in the use of a heavy single-furrow plough, which should cut a furrow deep enough to unearth the roots. In order to prevent sap from exuding, the leaves should not be removed from the roots for a couple of days. After the crop is lifted it is washed, if necessary, and then, as " fresh roots," sent to the factory, or it is cut and dried by the farmer himself.

YIELD.—Yields of 3 to 8 tons of fresh root can be expected per acre, provided the soil and climatic conditions are favourable. "This will result in a gross return of from £15 to £45 per acre at prevailing prices, a nett profit to the farmer of £7 to £30."[2] According to experiments conducted, the Magdeburg variety has so far proved most suitable for our conditions .

USES.—Chicory is used as a substitute for, and as an adulterant of, coffee. It is also employed in the manufacture of chutney and confectionery. In Holland and other European countries it is grown as a pasture plant, for which purposes it is excellent, being both palatable and hardy.

REFERENCES:

[1] Journal of the Dept. of Agriculture, March and April, 1921.—"Field Crops."—Wilson and Warburton.

[2] Journal of the Dept. of Agriculture, August, 1921.—"Chicory as a Farm Crop," by E. Parish and K. M. Johnson.

CHAPTER XXI

DRYLAND FARMING

The term "dryland farming" refers really to water conservation in farm practice, particularly in arid and semi-arid regions, where irrigation is impossible or not practicable. The term is a misnomer and unfortunate, but, because of its general acceptance, is still adhered to.

The following is a rough classification of land according to the average annual rainfall :—

Less than 10 inches—arid.

10—20 ,, —semi-arid.
20—30 ,, —sub-humid.
More than 30 ,, —humid.

This is a very general classification, because factors such as run-off, evaporation and percolation, are not taken into consideration. For example, 15 inches of rainfall will provide moisture for much better crops in a part having an annual evaporation of 20 inches, than in a part having an evaporation of 70 inches.

For a proper appreciation of the subject a brief description of the forms of water found in soils is necessary.

HYGROSCOPIC WATER.—This form of water is held in the soil by the forces of adsorption. It is not capable of moving from particle to particle, and can be completely expelled only by heating the soil to the temperature of boiling water. Soils previously dried, so as to deprive them of all their moisture, and then exposed to moist air, absorb water vapour from the atmosphere with great energy at first: both the rapidity of absorption and the amount absorbed, when full time is given, vary greatly with the nature of the soil. Broadly speaking, sandy soils absorb the smallest amount, while clayey soils, and those containing much humus or finely divided ferric hydrate, take up the largest amounts. The quantity absorbed is almost entirely a function of the total surface exposed, but in no case is it sufficient to make the soil visibly moist.

The percentage of moisture representing the full condensation of water upon soil from saturated air, under given conditions of temperature, is known as the *Hygroscopic Coefficient.*

The hygroscopicity of soils is important in plant growth, because soils of high hygroscopic power can withdraw from the moist air enough moisture to be indirectly of material help in sustaining the life of vegetation during droughts, in that high moisture absorption prevents rapid and undue heating of the surface soil to the danger point, and thus may save crops that would be lost in soils of low hygroscopic power. Except, perhaps, in the case of some desert plants, hygroscopic moisture cannot maintain normal growth.

CAPILLARY WATER.—This form of water is held in the soil by capillary forces, and exists in the form of surface films around the particles. It differs from hygroscopic moisture in that it evaporates at ordinary temperatures, is not condensed again on the soil particles, and may move from one particle to another.

Normally, it not only serves as the vehicle of all plant food absorbed from the soil during the growth of the crops, but also sustains the enormous evaporation by which the plant maintains, during the heat of the day, a temperature sufficiently low to permit of the proper operation of the various growth processes.

Working with fine glass tubes, it is found that the height to which water rises by capillarity is inversely proportional to the diameter of the tube. The rise of water by capillary action, or the "capillary pull," in soils is somewhat analogous to this, being greatest in the finest textured soils. Very fine texture, however, offers considerable resistance to the movement of water, so that the rate of movement is slower than where the texture is coarser. Speaking generally, therefore, the capillary pull is strong in clays and weak in sands, but the rate of water movement in sands is far more rapid than in clays. Granulation of clay will increase the rate of movement, and compacting sands will strengthen the capillary pull.

The quantity of capillary water retained varies greatly according to the nature of the soil, and is also largely a function of the total surface exposed. Thus sands retain the least and clays the most. Compacting the former and granulation of the latter increase the capillary capacity in both cases. Humus greatly increases the capillary capacity of all soils.

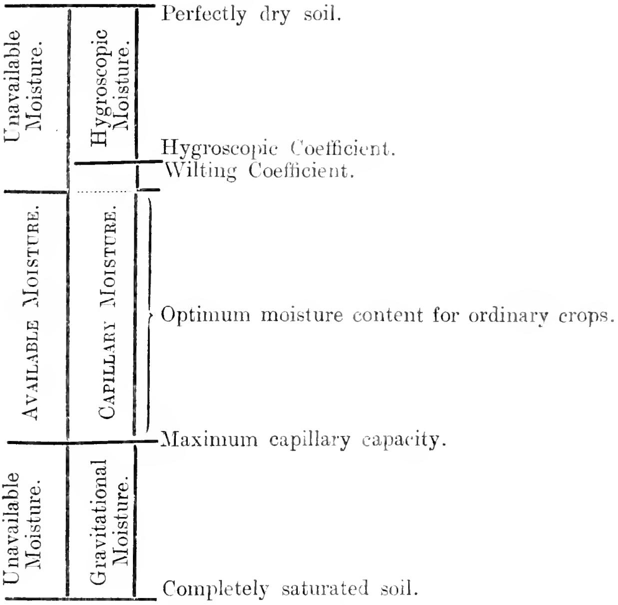
Gravitational Water.—This is free water, removable by drainage. The presence of gravitational water causes a water-logged condition in soils, hence is objectionable if maintained for any length of time. Immediately after rain all soils contain more or less gravitational water. In semi-arid and arid regions, however, the excess of water is rapidly distributed in the lower soil layers, where it assumes the capillary form. The poor growth of plants in water-logged soils is chiefly due to improper aeration, which is dealt with more fully under the subject of drainage.

The Wilting Coefficient.—This is used as a basis for comparison of the capacities of different soils for supplying water to plants. The wilting coefficient of a soil is its total moisture content at the point where plants just wilt. Permanent wilting occurs when the soil still contains a certain amount of capillary water, and is due to the fact that the remaining moisture is either unextractable by the plant, or not extractable at a sufficient rate to meet the demands of the plant. Wilting is soon followed by death of the plant, unless water is added to the soil. The moisture contained in the soil at the wilting point is for all practical purposes unavailable to the plant. The *available moisture*, therefore, is the amount present in excess of the wilting coefficient.

The wilting coefficient varies greatly in different soils; in sands it may be as low as 5 per cent., or even less, while in clays it may be as high as 30 per cent. In general, the finer the texture the higher the wilting coefficient. Under normal conditions, however, the wilting coefficient of a particular soil is the same for all plants.

It will be obvious that the content of available moisture is the only sound basis for comparing the efficiencies of different soils in regard to moisture supply—a sand containing 10 per cent. of water may supply considerably more available moisture than a clay containing 30 per cent.

The relation of the various soil constants, and the different forms of moisture present, is made clear in the following diagram (adapted from Mosier and Gustafson).



Water is lost to plants through the agencies of transpiration, evaporation, run-off, and percolation.

(1) Transpiration Ratio or the Water Requirements of Plants.—During the elaboration of plant structures, while a comparatievly small and practically negligible quantity of water enters into its composition, very large quantities are transpired through the plant. The transpiration ratio is defined as the quantity of water in pounds required to produce one pound of dry matter, or the ratio of the total water transpired to the total weight of dry matter produced in the crops. This ratio is affected by many conditions, chief among which are the average humidity, the fertility of the soil, and the kind of crop grown.

The variation of transpiration ratio according to the crop is shown by the following figures obtained at experimental stations in the Western States :—

Lucerne... ...	1,068	Barley	540
Rye	762	Wheat	507
Rape	743	Maize	368
Potato	636	Sorghum ...	322
Oats	614	Millet	275

Expressed otherwise, one ton of dry lucerne transpired 1,068 tons, or from 9 to 10 inches of water; one ton of rye transpired about 7 inches, and so on, for the weight of one acre-inch of water is roughly 110 tons.

The transpiration ratios given above are not likely to be the same in South Africa, because our evaporation is about 70 inches per annum, while at these stations in America it was considerably less. The relative order, however, would probably correspond.

In practice, a study of the transpiration ratios of plants is important when, for example, we realise that a crop of millet utilises about half the amount of water that is required by a barley crop of equal weight; also, that kaffir corn requires considerably less water than maize, which, without taking into consideration its other drought-resistant qualities, such as dormancy, shows why sorghums can be grown under drier conditions than maize.

The more humid the climate the smaller is the water requirement of plants generally. Thus, in North Dakota, with an annual evaporation of 30 inches, the transpiration ratio of lucerne was found to be 518, while in Texas, with an evaporation of 54 inches, the transpiration ratio was 1,006. This means that twice the amount of lucerne could be grown with the same amount of water in North Dakota as in Texas.

The fertility of the soil has a direct influence on the amount of water lost by transpiration. Hellriegel obtained the following results in pot-cultures :—

Units of $Ca(NO_3)_2$ applied.	Dry matter.	Transpiration ratio.
0	1,111	724
4	8,479	399
8	13,936	347
12	18,288	345
16	23,026	302
20	25.504	292

The amount of water required by the plants was lessened as the plant food deficiency was rectified.

Montgomery, experimenting on Nebraska soils in 1911, obtained the following results with wheat :—

Yielding Capacity.	Transportation ratio. Manured.	Transportation ratio. Unmanured.
Poor (15 bushels)	350	549
Medium (30 bushels)	341	479
Fertile (50 bushels)	346	392

The yield on the manured ground was nearly double that obtained on the unmanured soil. Pagnoul, in France, found the transpiration ratio on fescue grass on fertile soil to be 555 as against 1,190 on an infertile soil.

Widstoe, in Utah, obtained the following results with wheat :—

Soil.	Transportation ratio. Not cultivated.	Transportation ratio. Cultivated.
Fertile sandy loam ...	603	252
Fertile clayey loam ...	595	528
Infertile clay	753	582

Cultivation increases the availability of plant food, and in so doing lessens the transpiration ratio.

All these experiments indicate that the more fertile the soil the less is the water requirement of crops. They show indirectly the importance of ascertaining soil deficiencies in parts where moisture is limited, since deficiency of one of the essential plant foods will sometimes double the amount of water transpired.

The economy in the use of moisture effected by the rectification of a soil deficiency may in practice be responsible for the difference between good crops and crop failures.

WEEDS.—Briggs and Shantz obtained the following transpiration ratios for the various weeds mentioned :—

Amaranth (*A. retroflexus*)	287
Pursland (*P. oleracea*)	292
Gum Weed (*Grindelia squarrosa*)	608
Lamb's Quarters (*C. album*)	801
Ragweed (*A. artemesiifolia*)	948

Thus, for the average weed, from five to eight inches of rainfall is required to produce one ton of dry matter. The loss of moisture through weeds is one of the chief causes of crop failure in South Africa. Moreover, weeds may reduce to a marked extent the amount of plant food available for the use of the crop, and thus increase the water requirement of the crop.

EVAPORATION.—The loss of water referred to under this head is that due to direct evaporation of moisture from the surface of the soil. The "evaporation" of a particular locality is usually stated as the number of inches of water evaporated from a free water surface, and in semi-arid parts is generally considerably higher than the rainfall. From a wet soil surface evaporation occurs at an even faster rate than from a free water surface. Fortier found that a wet soil surface evaporated 4·75 inches per week, while a free water surface evaporated only 1·88 inches per week. The difference is probably accounted for by the soil's highest temperature, higher absorptive capacity for heat, and larger surface exposure.

The rate of evaporation is influenced by a great many factors, chief among which are :—

(1) The initial percentage of water in the soil,
(2) Atmospheric temperature.
(3) Relative humidity of the atmosphere.
(4) Winds.
(5) Sunshine.
(6) Nature of the soil (physical and chemical).

Ordinarily, about 25 to 35 per cent. of the rainfall is lost through direct evaporation from the soil surface. Loss by evaporation is high during the earlier part of the season, but as the crop develops, the increased protection of the surface by the foliage greatly reduces direct evaporation from the soil surface.

The efficacy of preventing evaporation by soil and particularly dust mulches is a much disputed point. It is held that in dry regions the moisture in the upper 6 to 10 inches will be lost through evaporation, whether a soil mulch is present or not. The maintenance of a soil mulch does, however, conserve moisture, because in establishing a mulch, weeds are controlled, improved aeration influences the amount of plant food available, and the soil is made more receptive for rain.

When a crop is growing, a good deal of the moisture that would escape through upward capillary action is utilised by the root-hairs before it reaches the surface.

The Illinois Station, conducting experiments with maize to ascertain the value of mulches, obtained the following results, as an average for nine years :—

(1) Land ploughed, prepared, planted, and receiving no further treatment—7·4 bushels per acre.

(2) Ploughed, prepared and, cultivated—43·4 bushels per acre.

(3) Ploughed, prepared, weeds scraped off with a sharp hoe, and no cultivation—48·9 bushels per acre.

Chilcott states that : " Numerous experiments made in connection with this work have furnished an abundance of evidence that when vegetative growth is restrained the loss of water from a mulched surface is practically the same as from an unmulched one.

The cheapest and most efficient methods of weed destruction necessarily form a soil mulch. The results accruing from the prevention of weed growth have been very generally attributed to the mulch itself, when the mulch is, in fact, only incidental."

Run-off.—In South Africa, on account of our torrential rainfall, this is frequently a very serious loss, particularly in mountainous and undulating parts. The loss may vary from 10 to 75 per cent. of the rainfall, according to its nature and distribution, the topography of the land, the character of the soil, and the amount of vegetation present.

Heavy rainfall on summer fallowed land will often form a relatively impervious layer, over which the run-off is extraordinarily large. Dr. Shantz supplies the following data obtained in the Western States :—

(1) (*a*) Summer tilled plot—48 per cent. retained by the soil.

(*b*) Adjacent plot under grass-sod—86 per cent. retained by the soil.

(2) (*a*) Land covered with wheat stubble—1½- inches absorbed out of 4 inches total.

(*b*) Land summer tilled—$\frac{1}{2}$ inch absorbed out of 4 inches total.

Thus vegetation impedes the flow, and consequently enhances penetration.

Soil rich in humus and sandy soils absorb water much more rapidly than do clay soils.

In practice, run-off can be decreased by keeping the land in a rough state, rather than in a state of fine tilth, and by cultivating along contours.

In connection with this loss, it must be borne in mind that valuable plant food constituents, as well as valuable material in the form of sediment, is also carried away by the "run-off."

PERCOLATION.—Loss from this source is seldom met with in South Africa in dryland areas, since our rainfall is insufficient there.

In semi-arid parts the water table is often so low that the soil moisture is not maintained from below by capillary action. The amount of water available to plants is, therefore, limited to the rainfall, minus :

(1) that evaporated from the soil,
(2) the wilting coefficient, and
(3) that lost by run-off.

The amount, then, at the disposal of crops is very much below the annual precipitation, and in arid regions it is easy to see why normal crops cannot be expected to materialise.

In an area where the rainfall is, say, 20 inches, the following losses are possible, and often probable :—

20 per cent. lost by evaporation, *i.e.*, 4 inches.

20 per cent. lost by run-off, i.e., 4 inches.

1 ton of weeds grown in crop, say 6 inches.

The total loss is then 14 inches, leaving 6 inches on which the crop is to mature ; and since maize requires 8 to 12 inches, or more, in South Africa, the reason for many crop failures is easily understood.

The following conclusions, arrived at by investigators in America,[13] pertain to dry land agriculture :—

"The principal objects which are sought by ploughing and the subsequent preparation of the soil are, to prepare a suitable seed-bed for the germination of the seed and the early growth of the seedling, to make the surface soil more receptive to water falling as rain, and to prevent the growth of weeds.

"The surface should be in such a condition that it will neither blow when exposed to high winds nor puddle when subjected to heavy beating rains. The latter considerations are of special importance when a period of several months intervenes between ploughing and seeding, as in the case of summer tillage or of early winter ploughing for spring sown crops. The surface should be left in a rough, cloddy, or ridged condition, and a fine dust mulch should be avoided.

"Nothing seems to be gained by ploughing deeper than five to eight inches.

"In some cases, particularly in sandy soils, it will probably be of advantage to use listers and cultivate the ridges down level during the growth of the crop.

"Harrowing maize and potatoes after planting, until the young plants have attained a height of a few inches, is usually advantageous.

"In growing small grains the soil surface should be mellow and the soil firm beneath. This can be accomplished by discing and harrowing after ploughing.

"Land for inter-tilled crops requires less tillage between ploughing and planting.

"As forage and fodder crops can often be grown where grain crops will not succeed, they must occupy an important place in dry-land farming. Sufficient live stock must be kept to convert these crops into finished products on the farm, and sufficient forage must be produced and stored during favourable seasons to carry the live stock through specially unfavourable seasons."

In South Africa, in parts having less than 15 inches of rainfall, it is questionable whether it will pay to grow any of the ordinary quick growing fodder crops. Crops under these conditions can be grown by "moisture storage," that is, by keeping the land quite free of weeds and cropping every alternate or every third year. By this method the rainfall occurring during the period of growth is augmented by that conserved in the previous year or years, and so allows the production of a crop. Experiments show that 25 to 45 per cent. of the annual rainfall can be stored in this way.

Regions having a rainfall of less than 15 inches are devoted almost entirely to ranching, and as the chief concern of the rancher is to tide his stock over periods of excessive drought when the ordinary grazing fails, it would appear feasible to meet the emergency by the growth of fodder trees and shrubs widely spaced.

Useful Stock Food Plants for Arid Parts.—A great many trees and shrubs owe their drought-resistance to their extensive and deep root development, which enables them to obtain moisture beyond the reach of shallow-rooted crops. If widely spaced, such trees will thrive under conditions too severe for ordinary crops. Some of the finest olive plantations in Algeria flourish on a rainfall of less than 10 inches per annum, largely because the olive is deep rooted and the trees are widely spaced.

However, there are plants, indigenous and exotic, which with a very small outlay on labour might be found to give sufficient fodder to warrant their propagation on an extensive scale. The following are the chief ones which have already been tried in some of the driest parts of South Africa and have been found useful as stock food, viz. :—

Old Man Saltbush (*Atriplex nummularia*).—An erect perennial shrub, reaching a height of 5 to 8 feet in four years. It is an introduction from Australia, is readily eaten by sheep, and its propagation by cutting or seed is comparatively easy. Its cultivation in various parts of the country is becoming more and more popular, particularly in the western portion of the Orange Free State and in the Karroo, where it has been found to be extremely drought-resistant.

Creeping Saltbush (*Atriplex semibaccata*).—Also introduced from Australia. It is a very decumbent, perennial shrub, easily propagated by simply sowing the seed on the land, followed by light harrows. Once established, it seeds abundantly, young seedlings being produced among the old plants. With careful grazing this species maintains itself with little or no extra care. It gives an abundant, succulent and palatable fodder for sheep and cattle, and is probably quite as drought-resistant as *A. nummularia*.

Both of these varieties of saltbush are very tolerant of alkali, an important feature, since large areas of our arid soils are " brakish."

Spineless cactus (*Opuntia spp.*).—Perennials introduced chiefly from Mexico. These are being distributed by the Agricultural Department, the demand increasing rapidly each year, particularly in the Karroo. Propagation is easy, " leaves " being either planted or simply placed on the ground *in situ*. Their cultivation in Texas, Australia and elsewhere is becoming quite general. The nutritive value is comparatively low, although the large quantity of succulent fodder produced under arid conditions warrants a more extensive cultivation.

Spekboom (*Portulacaria afra.*).—An indigenous perennial found in the eastern parts of the Cape Province. (It should not be confused with the " spekboom " of the Transvaal bush-veld; the latter belongs to the genus *Euphorbia*, a tree never eaten by stock.) Mr. R. W. Thornton, Principal, Grootfontein School of Agriculture, Cape Province, who has conducted some valuable experiments with this and other shrubs, writes: " A shrub that really does well is our spekboom (*P. afra*). By planting cuttings we have been successful in raising these shrubs not only in this country, but in America, and at one time I was informed that the extension of this plant in America was going on at a rapid rate in some of the drier parts of the western and south-western districts of the States."

Mesembryanthemum spp.—Mr. Thornton considers that some of our species of this genus would make excellent experimental material, being valuable as stock fodder. The outstanding work at present in connection with these is to find out the best stock species as well as the best means of propagation. Concerning *M. floribundum*, an indigenous species, von Mueller says: " This succulent perennial, with many allied species from the same part of the globe (South Africa), is a far more important plant than might be assumed, because ' a good stretch of this is worth a dam (Professor MacOwan).' Succulent plants like these would live in sandy deserts where storage of water may be practicable."

Goed Karroo (*Pentzia virgata*) is a small perennial shrub found in the Karroo and highly valued as sheep fodder.

Rechte ganna (*Salsola zeyheri*).—Another perennial shrub found also in the Karroo and esteemed as highly as *Pentzia virgata*.

Mesquite (*Prosopis juliflora*) and Screw Bean (*P. pubescens*) are slow growing perennial leguminous trees, having very nutritious pods. The former is said to be spreading in the South-West Protectorate. Professor J. R. Smith, University of Pennsylvania, cites an instance of a Mesquite tree which bore six consecutive crops of beans of twenty bushels each. In Texas, New Mexico and other dry south-western states it is the chief standby during drought. Mr. Mugglestone, of the Smartt Syndicate, Ltd., Britstown, writes: " I have no doubt the propagation of shrubs in the arid parts of the Karro is practicable if started in favourable spots and allowed to spread by natural as well as by artificial means. I planted seven Mesquite Bean trees about ten years ago and they are spreading all over."

Carob Tree (*Ceratonia siliqua*).—Indigenous to eastern Mediterranean regions. Extremely drought-resistant, yielding very nutritive pods. " Instances are on record of a tree yielding nearly half a ton of pods in a season. The exportation of the pods from Creta for cattle food is very large. In some of of the Mediterranean countries horses, stable cattle and pigs are almost exclusively fed on the pods. The meat of sheep and pigs is greatly improved in flavour by this food, while its fattening properties are twice those of oil-cake."—von Meuller.

The high value of the Mesquite and Carob beans is shown in the following analysis :—

	Protein.	N.-Free Extract.	Crude Fibre.	Fat.
Mesquite	10·3	54·7	28·9	0·7
Carob	8·6	59·5	8·7	0·5
Wheat bran	15·4	53·9	9·0	4·0

The Mexican Aloe (*Algave mexicana*) is being extensively cultivated by some progressive Karroo farmers. It is easily propagated and has been found to furnish a heavy yield of fairly nutritious fodder, readily eaten by cattle, sheep and estriches. The leaves are sliced up before feeding.

To the writer the above trees and shrubs seem to be among the best as a basis for experimental work. The following indigenous to South Africa are some of those known to be eaten by stock, but, for various reasons, are not so suitable :—

Kiepersol (*Cussonia spicata*), Zootdoorn (*Acacia horrida*), Wild Olive (*Olea verrucosa*), Rozyntjebos (*Grewia cana*), Narranarra (*Acanthosicyos horrida*), Vaal Karroo (*Phymaspermum parvifolium*), Vaalbos (*Tarchonanthus camphoratus*), Karreboom (*Rhus viminalis*), Draai-bossie (*Aster filifolius*), and Cape Saltbush (*Atriplex capensis*).[14]

ORDINARY CROPS SUITED TO DRY LAND FARMING.—Many of these are crops having a low transpiration ratio, particularly sorghums and millets, and crops which regulate their growth until maturity on the available moisture—wheat, rye, oats and emmer are among the latter class of crops and should be grown in parts of winter rainfall: the potato is probably one of the best of these crops for dry-land farming.

Maize is not a particularly good crop in these areas. However, the flint varieties are more drought-resistant than the dents, and may do quite well for ensilage purposes.

Cowpeas, soy beans and tepary beans will often make a good growth. Care should be used in green-manuring these crops, as ploughing down a heavy growth may leave the ground very open, and should a dry spell follow, an excessive loss of moisture will take place by evaporation; moreover, decomposition may be very slow. They should be ploughed down when succulent and if possible when the ground is sufficiently moist to ensure their decomposition.

Cotton is fast becoming one of the most profitable and reliable of the crops grown in dry land regions in South Africa.

Conclusions.—The chief points in dry land agricultural practice are:—

1. Kraal or stable manure must be used carefully. Under semi-arid conditions it often causes too luxuriant a growth, resulting in the too rapid depletion of available soil moisture.

2. Keep the ground in as receptive a condition for rain as possible; the surface should be more or less rough and a dust mulch avoided.

3. Destroy weeds.

4. At the time of seeding prepare a good seed-bed to ensure uniform, vigorous and early growth.

5. Use seed from regions as similar as possible to the one in which it is to be grown, *i.e.*, "acclimatised" seed.

6. Grow crops of quick maturity, low transpiration ratio, and those capable of adjusting themselves to the available water.

7. If economically possible, gradually incorporate organic matter in the soil, taking care to plough down the green crop when succulent and when the soil is moist.

8. If economically possible, correct any outstanding plant food deficiency by the addition of mineral manures.

9. Avoid heavy clays, light sands and shallow soils. The most desirable soils are those which combine good depth with strong and rapid capillary action.

10. Plant with a wider spacing than for irrigated crops or for those grown under humid conditions.

11. Drilling should be practised instead of broadcasting.

12. In parts having a summer rainfall, grow sorghums, millets, flint maize for ensilage, potatoes, cotton, cowpeas, soy beans and tepary beans.

13. In parts having a winter rainfall, grow wheat, emmer, field peas and vetches.

14. Where the above cannot be grown, grow the fodder trees and shrubs previously mentioned.

15. Cultivation of the soil increases fertility and thus lessons the transpiration ratio.

16. It cannot be over-emphasised that in parts of limited and erratic rainfall, farming must be considered from the view-point of the livestock farmer. The returns from animal husbandry are not only more certain, but are more profitable than those from field husbandry. The rearing of livestock is of major importance, and cropping must be undertaken to supplement the requirements for foodstuffs. Hence a policy should be pursued which aims at the production of forage, fodder and silage, rather than one where grain production is looked upon as the main source of revenue. The crops cultivated should be grown with a view to supplementing the natural pasturage, and by storage provision should be made for drought.

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