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Memoirs of the Department of Agriculture in India

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E. J. BUTLER, M.B., F.L.S

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THE DISSEMINATION OF PARASITIC FUNGI AND INTERNATIONAL LEGISLATION.

BY

E. J. BUTLER, M.B., F.L.S.,

Imperial Mycologist.

A FUNGUS is a minute plant, composed of a vegetative part (mycelium) and seed-like reproductive bodies (spores). It may be disseminated by the mycelium or by spores, and in no other way.

The mycelium is incapable of independent spread for any considerable distance, except in rare cases : it is usually adherent to the substance on which it grows, often immersed wholly or in part in it ; small fragments detached perish quickly ; and larger pieces, which might preserve their vitality, fall to the ground before long when carried into the air. Just as it is well known that in the higher plants the vegetative body is less able to stand extremes of heat and cold or dryness than the seeds, so also in the fungi the mycelium is generally less resistant to such unfavourable conditions than the spores. Laboratory workers who are engaged in the cultivation of living fungi are familiar with this fact. Furthermore the fungi which cause disease in plants are parasites and for the most part cannot long survive in their vegetative condition (unlike the spores) unless able to obtain living food from the plants on which they grow.

Hence, dissemination over long distances in the mycelial condition only occurs when the substance on which the fungus is growing is itself conveyed from one place to another ; in the case of parasites such dissemination is practically confined to occasions when the plants[1] on which they feed are moved, though a few cases, such as facultative soil parasites, may travel with earth

[1] Living plants are taken to include not only complete plants, but also cuttings, buds, tubers, bulbs, seeds, and any other part that can survive detachment from the plant, even (within limits) cut flowers and green leaves. Some parasitic fungi can also survive in a vegetative and often quite long-lived condition on dead parts of plants.

or the like. Nevertheless several instances of extensive spread in this manner are known—

Phytophthora infestans (the cause of the potato blight) has reached practically all parts of the world, in which potatoes are grown, as an internal mycelium within the potato tuber.

The blister-rust of white pines (*Peridermium Strobi*) has been introduced into the United States as an internal mycelium in the stems of seedling pines obtained in vast numbers from Europe.

The mildew of *Euonymus japonicus* survives the winter in Europe as an external mycelium on the leaves, and doubtless came from Japan or elsewhere in this condition, when first introduced into Europe some 15 years ago.

The spores are, however, the usual means of spread. For this they are much better fitted than the mycelium, being often long-lived bodies, able to stand drying or extremes of heat or cold. The spores of bunt of wheat have been germinated after 8 years, and have been kept in a solid lump of ice for 3 months in Canada, without the slightest injury, though the temperature fell to 20° F. more than once. They are more susceptible to heat : bunt spores can be killed by immersing them in hot water at about 130° F. for 10 minutes and yellow rust of wheat in India by 5 minutes in water at about 120°F. ; the dry spores can stand considerably higher temperatures. So far from being injured by drying they can usually be best preserved in a dry condition and it has often been noticed that thorough drying favours their subsequent germination.[1] Owing to their small size also, often approximating to that of very fine dust, they are readily blown about, and as they are usually detached as soon as ripe, air currents play the most important part in their dissemination. Many spores are provided with arrangements for sticking them to objects with which they come into contact. Thus many rusts and smuts have fine spines on the spore wall, the anthracnoses liberate their spores with a mucilaginous substance which is adhesive on drying, the cilia of *Pestalozzia* serve the same purpose, and so on. Not only, therefore, are spores cast into the air in vast numbers,[2] but their small size and tendency to adhere cause them to attach

[1] There are some exceptions to this, as the 'summer spores' (sporangia) of the downy mildews, which are often unable to survive even after 24 hours' thorough drying.

[2] It has been estimated that a small spore horn of the chestnut bark disease fungus (*Endothia parasitica*) may contain 115 million spores, a bean pod affected with the bean anthracnose (*Glomerella Lindemuthianum*) may produce from 500 to 1,000 million spores during the season, while *Lycoperdon bovista*, one of the (harmless) puff balls, may contain 7,000,000,000,000, and the common edible mushroom can shed spores at the rate of 40 millions per hour.

themselves to neighbouring objects such as other plants, insects which visit plants, and even the person and implements of people passing through infected fields or working in them.[1]

These properties of the spores render them peculiarly suited for dissemination. For short distance spread, currents of air are unquestionably the most important means in the great majority of cases. The splashing of rain, accompanied by the flapping of wet leaves against one another, is the chief means in a few cases, as in the bean anthracnose, and is a secondary means in others, as in potato blight. Adhesion by contact is well known to cause much of the bunt in wheat, when wind-borne spores or broken bunt balls get into the seed grain. Spread by insects takes place in certain well-established cases, and is highly probable in others. The ergots of rye (*Claviceps purpurea*) and other grasses are carried in part by *Melanostoma mellina*, *Rhagonycha fulva*, etc., which are attracted by the sugary secretion that accompanies the *Sphacelia* stage of the fungus, and carry the spores to other grass flowers. Pear blight, [*Bacillus* (*Micrococcus*) *amylovorus*] begins often in the stigma, to which the bacillus is carried by insects (chiefly bees) from infected sap escaping from the bark in spring. In *Sclerotinia urnula* also the sweet-smelling spores are carried by insects to the flowers of *Vaccinia Vitis-idaea* (cow-berry). In many cases insects which cause wounds allow parasitic fungi to enter; larch canker may begin from the wounds of *Coleophora laricella* and *Chermes laricis*; *Ceratostomella pilifera* (a fungus which causes blueing of the wood of *Pinus ponderosa*) from wounds of *Dendroctonus ponderosæ* and so on; while the *Nectrias* which cause canker of fruit and forest trees are said sometimes to be conveyed on the bodies of the insects which cause wounds through which the fungi can enter. Occasionally other animals have been accused of disseminating disease; mice are said to carry the spores of *Fomes annosus*, the cause of a well-known pine disease, and snails those of a fir disease caused by *Cucurbitaria pityophila*. Almost any disease may be carried by farm-workers, but the cases of serious damage from this cause are rare. All soil-inhabiting fungi are liable to be carried by irrigation water or surface wash after heavy rain; *Fusarium* wilts are undeniably carried from field to field by the latter; and there is evidence in India and elsewhere that diseased sugarcane stems thrown into irrigation channels may enable the spores of the red rot fungus to reach crops growing at a lower level. Infected soil may also carry the spores of

[1] In the Southern States it is said that experience has taught the peril of working in the bean fields attacked by anthracnose on wet days, owing to the way the disease is carried on the person and implements of the workers. We have evidence, too, that the Godavari palm disease in India is often carried by those who climb the trees for the leaves, fruit and for toddy drawing

the fungi which cause wilt and allied diseases and may reach other fields in various ways, as on the boots of field-workers and pedestrians. But the majority of these and other minor means of dissemination can only be invoked to account for spread over comparatively short distances and may be at once ruled out as probable causes of extension of disease to distant countries. Leaving out dissemination through the air, all the others require the susceptible plant to be within short range of the source of infection. The normal flight of insects, the flow of irrigation water, or the range of labourers and pedestrians, is through a limited area ; and though we could imagine diseases crossing land frontiers or even passing, say, from Ireland to England in this manner, spread to Europe from America or East Asia would be rare indeed.

For such long-distance spread, for what may be called "discontinuous spread," the methods are much fewer. They may practically be reduced to three : dissemination through air ; dissemination by animals that travel long distances rapidly, as migrating birds and certain insects ; and dissemination on plants and other horticultural produce. The relative importance to be assigned to each has not, so far as I know, ever been adequately discussed and exact data for such a discussion are scanty ; yet they yield results of considerable significance.

To take, what must be of the least importance first, birds are probably the chief animals that could materially contribute to the discontinuous spread of parasitic fungi. The distances to which they travel are remarkable. Richard's Pipit, which breeds in Eastern Siberia from Lake Baikal to the sea of Okhotsk, regularly visits Europe, as far sometimes as England, and passes through Spain even to Western Africa. Several other Siberian birds visit Western Europe, some, such as the Hooded Crow, in enormous numbers. The Knot, which breeds within the North Polar basin, has been found in winter in Australia and New Zealand. Individually marked storks, which breed in Central Europe, have been identified in South Africa in winter. Still it is perhaps possible to show that they cannot be a serious danger. The wanderings of migratory birds which travel long distances are usually between areas of very dissimilar climate ; they pass in a general direction from north to south and back again ; and between the extremes of their journeys the climates and vegetation are so different that the agricultural and horticultural products are usually sufficiently distinct to have very few parasites in common. Where birds pass through areas with partially similar agricultural and horticultural crops, as from south to north Europe and the southern to the northern parts of North America, the parasites which they could convey would sooner or later be able to effect continuous spread by one or other of the methods discussed above; for the most part they have already done so, where not restricted by deficient powers of acclimatisation, and though migrating birds may have enabled them to pass natural barriers such as the Alps or the Channel more rapidly, the present distribution would probably be much the same even if birds did not exist. The parasites of plants long established in southern and northern Europe are, except in the case of those recently introduced, probably as much identical as they are ever likely to be. Where they differ, the explanation is to be sought in the lesser adaptability to differences in climate frequently possessed by the parasites as compared with their (cultivated) host plants.[1] In general it may be said that England, for instance, is little liable to receive new pests from southern Europe except when they have been recently introduced into the latter area. The danger, in England, is primarily from more distant regions where the climate is not too dissimilar, such as North America and to a considerable extent also temperate eastern Asia, and birds or other animals cannot greatly increase this danger.

There is probably an exception in the case of recently introduced pests. Certain classes of these might be rapidly spread within a large part of Europe by birds. Nothing can reduce this danger but we may console ourselves by the reflection that continuous spread through the same areas would almost certainly occur in any case in the long run, and that the remedy lies in keeping such pests out of Europe altogether, by international co-operation.

Exact investigations of the extent to which birds can actually disseminate fungi seem to be very scanty. In the eastern United States some were examined a short time ago.[2] They were shot, and the beaks, legs, etc., scrubbed, the washings being then used to determine the number of spores. On two woodpeckers, 757,074 and 624, 341 spores, respectively, were found and a high proportion of these were the spores of the chestnut bark disease, which is at present exterminating the chestnut in this area. Some of the birds shot were on their northward migration and could no doubt have carried this disease. Yet it is remarkable that though chestnut blight has been in the neighbourhood of New York since 1904, it had not, up to 1913, been able to cross a chestnut-free belt in the Catskill mountains, some 30 to 40 miles broad, running roughly north and south, parallel to and just west of the heavily

[1] Nothing else will explain the absence of *Phytophthora infestans* in potatoes in the warmer and drier parts of the United States and in the centre and west of India, or of wheat bunt and maize smut in all but the most temperate parts of India.

[2] *Journ. Agric. Research*, II, 1914, p. 405.

infected Hudson River Valley.[1] So far as the spread from east to west is concerned, birds can, therefore, have played little part.

The diseases liable to be carried by birds would naturally be chiefly those affecting fruit and forest trees and producing spores on the upper parts of the tree.

Outside birds, the only other animals that might perhaps help to disseminate fungi over large distances are insects. In some cases these have a power of dispersal probably unequalled even amongst birds.[2] That they should carry spores would seem to be a most natural assumption. Possibly they have done so in many cases in the past, and there may now only be a residue of cryptogamic parasites in each land area which, for some unknown reason, is unsuited to dispersal by birds and insects. It is only within comparatively recent times that any record has been kept of the appearance of new fungal diseases in certain parts of the world, and it is quite possible that all or nearly all of these belong to this residue. Since, however, the object of the present paper is primarily a discussion of the means by which parasites hitherto confined to one locality are, at the present time, able to reach areas separated by the ocean or by large tracts with unsuitable host plants, and since there is no evidence that birds or insects are now a considerable agency in effecting this spread, what may have happened in the distant past is not of direct consequence.

A second means of discontinuous spread is through the air. Though it is somewhat difficult to understand why this should not suffice sooner or later to spread most diseases over those parts of the world with suitable climates, yet such evidence as is available points altogether in the opposite direction.

The bulk of the evidence is circumstantial. Direct experiments are few and do not seem to have been framed so as to ascertain how far spores might be carried by the wind in storms or when the spores of, say, oat smut are sent into the air in clouds during threshing. Concordant results have been obtained in Germany and Russia that "spore traps" remained free from smut spores beyond 250 yards from heavily infected fields, though at Pullman, in the United States, the spores may fall copiously at a distance of a quarter of a mile. The area around barberry bushes through which black rust of wheat (which spends part of its life on the barberry) can be disseminated to the wheat is also said to be remarkably low. There are, however, various

[1] *Cornell University Agric. Exper. Stat. Bull.*, No. 347, 1914, p. 545.
[2] Tutt, J. W. "The Migration and Dispersal of Insects," London, 1902.

records in the case of rusts in which there are two hosts, where one appears to have become infected from the other through moderate distances. *Coleosporium Euphrasiæ* seems to reach the islands off the north-west German coast from the mainland[1] and other cases are recorded of the occurrence of one stage of these fungi from 5 to 8 miles from the plant bearing the alternate stage. The general results of the investigations seem to show that the distance to which spores may be carried in the air has often been exaggerated in the past, and that it is much less than might be expected.[2] Even such small bodies fall gradually when in the air and it has been found[3] that the spores of some of the higher fungi fall at the average rate of 0·5—5 mm. per second in still air, and so must come to earth before very long.

On the other hand, it is well established that dust particles (which are of the same order of size as spores) can be carried to great distances under certain conditions. The dust from the volcanic eruption of Krakatao in 1883 travelled thousands of miles, that from Vesuvius and Etna has reached Constantinople, Norway has been strewn with volcanic dust from Iceland. In these cases the dust has been probably thrown up to a great height by the eruption and its lateral spread may be accounted for by this. But dust has also been carried a long way when blown from the ground by storms. From North Africa it is said to have reached a considerable part of southern Europe; while the wind known as the Harmattan, which takes its rise in the Sahara, blows clouds of dust far out into the Atlantic in a south-westerly direction from the Senegambia and Guinea coast. This dust has often fallen on vessels several hundred, and even more than a thousand, miles out to sea, and Darwin collected particles of stone, over a thousandth of an inch square, 300 miles from

[1] This and several other interesting cases are quoted by Klebahn ("Wirtswechselnden Rostpilze" 1904.)

[2] I believe a somewhat similar conclusion has been reached by plant breeders with regard to the distance to which pollen grains may be carried by the wind; and the long controversy with regard to air-borne infection in such human parasitic diseases as scarlatina and cholera has ended in the same way. Indeed the whole of our modern sanitary regulations dealing with quarantine and the restriction or isolation of infectious diseases, are based on the view that it is the living carrier and objects, such as clothing, which have come into contact with infected persons, that constitute the danger. Even the long-lived and minute organism of scarlatina is not believed to be carried in the air to more than a very limited distance and did not reach many parts of the world until long after it had been known in Europe. As would be expected the evidence regarding the dissemination of the seeds of higher plants is to the same effect and even the small spores of ferns have not been of advantage to this group in enabling it to colonise distant areas more readily than the flowering plants (H. Christ, "Die Geographie der Farne," 1910).

[3] Buller, A. H. R. "Researches on Fungi," 1909, Chaps. XV and XVI.

land. These would exceed in size and weight the spores of many fungi. It would seem natural to suppose that spores might equally be carried for at least some hundreds of miles, were it not that there is a great deal of circumstantial evidence against this to support the direct evidence mentioned above.

This evidence is based on the known distribution of the minute plants which cause disease. It may be divided into two classes. The spread of a limited number of diseases has been closely observed and has not been found to be such as would be accounted for by long-distance spread through the air. The geographical distribution of some groups of parasitic fungi has also been worked out and seems equally to exclude this possibility in a certain number of cases.

Amongst the diseases whose spread has been closely observed and is evidently not due to their spores having been carried by the wind over large areas, the following examples may be selected :—

The chestnut bark disease has been carefully watched, since soon after it first appeared in the United States. It is quite well suited for wind dissemination, as the parasite liberates considerable quantities of ascospores into the air. Nevertheless its spread has been continuous in the main and, as already stated, it was unable to leap a 30 or 40 mile belt free from chestnuts in the Catskill mountains, at least up to 1913, though a little further south it spread continuously along the southern border of New York State, where there is a narrow strip of chestnuts, and so reached the large chestnut area of the south-west of the State. In the ten years after it was first observed in New York City in 1904, it had spread from New Hampshire to Virginia and as far west as western New York and Pennsylvania, but had not reached Ohio or Indiana. Where "spot" infections (*i.e.*, isolated attacks not due to continuous spread) have been observed, the majority have been traced to the introduction of diseased nursery stock.

The American gooseberry mildew was introduced into Europe about 1900. There were probably at least three distinct introductions about the same time, into Ireland, into Denmark, and into Russia. In 1905, it is known to have extended to six counties in Ireland, to ten widely separated localities in Russia and also to Finland, to Posen in Germany near the Russian border, to Norway and to Sweden. It attracted so much attention during this period that a close watch was kept for it in the countries hitherto free from it. Yet it was not reported to have reached England until 1906, Austria until 1905 or 1906, Hungary until 1908, Belgium until 1909 or 1910, and France actually not until 1913 (though it has been suggested that France was infected earlier and indeed that the English attack came from France). Had spores from the first outbreak been carried hundreds of miles through the air all the gooseberry-growing countries in Europe would have been equally liable to attack in the first few years. Instead of this we have definite statements that all the early Scandinavian attacks came with plants from a nursery in Denmark,[1] that it was probably distributed all over Austria from a single nursery[2] and that nursery distribution from Denmark and Russia accounts for the whole of the infection of Europe, there being no evidence that Ireland assisted in the spread. Even within England the distribution is not such as would be accounted for by the carrying of the spores for long distances through the air from the first foci of infection in Worcestershire. The fungus is adapted for wind dissemination in so far that it liberates spores freely into the air; and though these spores are not very long-lived, they would doubtless survive the crossing of the Channel or the Irish Sea without difficulty.

Blister-blight has been known on tea in Assam since at least 1868 and is one of the most destructive diseases of the crop. It remained entirely confined, so far as is known, to the north-east corner of Assam until 1908, when it appeared in the neighbourhood of Darjeeling, and spread with alarming rapidity. Though excellently furnished with the means for short-distance spread, it was unable to traverse the gap between north-east Assam and Darjeeling for 40 years, and has not yet entered the still nearer districts of Cachar and Sylhet. It is peculiarly dependent on climatic conditions and has failed to spread continuously along the tea in the middle and lower parts of Assam. It may have reached Darjeeling

[1] Eriksson, J. in *Zeitsch. f. Pflanzenkrankheiten*, XVI, 1906, p. 83.

[2] Hecke, L. in *Naturwissensch. Zeitsch. f. Land u. Forstwirtschaft*, 1911, p. 51.

in the post or on living plants but can scarcely have travelled through the air, otherwise Cachar, with its similar climate to Upper Assam, would certainly have become infected. Outside the two areas mentioned, it is still unknown, if we except a recent report from Formosa.[1]

The Godavari palm disease (*Pythium palmivorum*) probably first appeared about 1890. Where it came from is not known, possibly from some of the islands in the Indian Ocean, possibly from Malabar where it occurs sporadically and sometimes causes minor epidemics in the coconut forests. In Godavari it spread with great intensity amongst the palmyra palms, killing from 50 to 75 per cent. in many parts. Extension was continuous, the rate being about 1 to 3 miles per annum, and was roughly centrifugal from a point on the Godavari river. Over 1,000 square miles were affected in 1905. But no cases have been found that could have been due to air-borne infection for a distance exceeding a few miles and the immense palm areas to the north and south of Godavari have remained free, except where the continuous gradual extension from palm to palm was going on. The spores are sometimes formed in situations freely exposed to the air and fall off when ripe, but they have evidently not been carried through the air for even a 24 hours' journey.

The downy mildew of the vine is probably indigenous in the United States, where it is common on wild native species and has probably existed for a very long time. It did not reach Europe until 1877, by which time American vine stocks were being imported in considerable quantity to replace the vines destroyed by *Phylloxera*. It was in France by 1878, and in the next year was found in the Rhone valley, in Savoy and had reached Lombardy. In 1880, it was found in Algeria and the Tirol, and in 1881, in Greece. It subsequently spread over all the rest of southern and central Europe, to north Africa and parts of Asia; it was recorded in Australia in 1866-67, but did not extend to Cape Colony until 1907 or shortly before. It is believed to have got to Java, where it was collected in 1905, on fresh grapes brought in by the mail

[1] Sawada, *Bot. Mag.*, Tokyo, 1914.

boats. Had it extended through the air, it is remarkable that it did not begin to spread until the collapse of the European vines led to an introduction of living plants from its original home. From Europe, its wider distribution on exported vines and grapes is easy to understand.

The vine *Oidium* is another American species which spread through Europe progressively after its first introduction. It was noticed at Margate in 1845, and two years later was found in the Rothschilds' greenhouses at Suresnes near Paris. In 1848, it attacked other gardens near Suresnes and appeared in Belgium. In 1849, it was all around Paris and next year was in the Bordeaux district, in Spain and in Italy. In 1851, it was all over France, Spain and Italy and was reported in Switzerland, Hungary and all along the Mediterranean shores. It is now known practically wherever the vine is cultivated. As in the last case the species is native to America and did not spread until introduced into Europe, probably on living vines. If it could be blown across the Atlantic we would expect it to have appeared in a number of places simultaneously and probably at a much earlier date.

The oak mildew is a species allied to the last and, like it, is endemic in North America. It was first seen in Europe about 8 or 10 years ago, but once introduced spread continuously (though exceedingly rapidly) over the whole continent. The *Oidium* on *Euonymus japonicus*, which is probably endemic in Japan, is another similar case, which reached Europe about 1900 and is now all over southern and western Europe. In both these mildews the host plant was available to receive air-borne spores long before the disease appeared, and both were probably nursery introductions. Several other instances of the same kind will be found in the detailed list below (see Appendix I).

Of diseases long known in Europe and more recently introduced into the United States, the carnation rust is a good example. It has been known in Europe since 1789, a time when fungi attracted little notice, so that it may have been present long before. It was not seen in the United States until 1890, when it was found in Michigan. It did so much damage that it is not likely to have been overlooked previously. Another case is the blister-rust of the Weymouth or white pine. This tree is a native of the east of North America and was introduced into Europe about 200 years ago. In Europe it was attacked by a rust which inhabits the European stone pine (*Pinus Cembra*) but which was unknown in North America. This rust was noticed in Europe at least 50 years ago. Recently a very large trade in seedling pines sprung up between Europe (especially Germany) and the United States, and since 1903 it is calculated that some millions of diseased pines have reached the United States from Hamburg and elsewhere. The blister-rust was found in the United States for the first time on these pines, and has been detected altogether in more than 230 places, in all but one on imported plants. In Europe the pines are infected by air-borne spores from currant and gooseberry bushes (on which the fungus passes part of its life) and if these spores could traverse the Atlantic in the air, the pine forests of America would have been infected long since.

The coffee leaf disease has been found in east and central Africa on wild and semi-wild species of *Coffea*. It occurs as far west in the Congo as at least longitude 23°E., but has not been seen on the West Coast. The disease became known first in the epidemic outbreak in Ceylon in 1868. Since that date it has spread to every coffee-growing country in the East and far into the Pacific; the spread has been gradual and the latest recorded attacks are in the New Hebrides and New Caledonia, which latter colony was reached in 1911. Yet the great coffee-growing areas in South and Central America and the West Indies are free from it, as also apparently the plantations in Australia and Hawaii. If, as is probable, the parasite is a native of East Africa, the home of the chief coffee plant of commerce (*Coffea arabica*), long-distance wind dissemination would be expected to carry it to West Africa where it would have found host plants on which it can grow, and thence to the West Indies and America. Its spread throughout south and eastern Asia and the Pacific is readily explained by trade movements and the introduction of East African and Arabian coffee varieties into the British, French, Dutch, and Spanish colonies. There is probably little such movement across Africa from east to west and the escape of the New World may be due to the much greater length of time occupied in conveying the coffee seeds or bushes to that part of the world when first introduced, and the comparative rarity of intercourse between the two areas.

The hollyhock rust is an even more striking case of distribution over distant areas before it reached those nearer at hand. It is endemic in Chile and was first collected there before 1831. It is said to have been seen near Melbourne in Australia in 1857 and was certainly collected in 1865. In 1869, it was found in Spain and reached France in 1872 or 1873. In 1873, it was widely distributed in France, had appeared in several places in England and was found in Rastadt in Germany. In 1874, it was all over Holland, in Stuttgart, Erlangen, Nurenberg and Lubeck in Germany, near Rome and Naples and in Denmark. In 1875, it reached the Cape of Good Hope ; in 1876, Austria, Hungary and Russia ; 1877, Switzerland and Greece ; 1887, Sweden ; and 1890, Finland. Up to 1886 it was unknown in the United States but in that year it was found in Massachusetts and soon spread to other States. It was, when first introduced to Europe, exceedingly destructive and even now, though less virulent, little liable to be overlooked. Though not well suited for wind dissemination, as its spores are not set free as readily as in most of the other cases discussed, still they are eventually liberated in considerable quantities with fragments of the plant, and if liable to wind dispersal over long distances it is remarkable that the United States should have escaped so long after the fungus had reached Europe and Australia from Chile. It appears to travel really with seed.

The above cases have been given at some length as they are all noticeable or destructive diseases whose spread has attracted attention. In most of them the parasite liberates its spores into the air, sometimes in great quantity but in none that I have been able to find is there the slightest evidence that the spores can cross the oceans borne by the wind. Several suggest that aerial spread is limited to a few miles, while others are capable of bigger jumps, possibly of 50 miles or (oak mildew) even more.[1]

[1] I have purposely left out of consideration whether we can offer any explanation why the spores of a particular disease are not carried successfully over long distances in the air. The problem is, are they carried or not ; and if not, the reasons why do not concern us.

Another large group of cases could be selected based on the total absence of specific diseases from certain areas, though long known elsewhere. Particular stress is not laid on these cases, since we do not always know the factors which govern acclimatisation to a new locality, and have some reason to believe that they are often more restrictive in their effects where parasitic fungi are concerned than in respect to the host plants. It seems better, therefore, to rely more on cases like those quoted above, where subsequent experience has proved that the more or less prolonged absence of a disease from a certain locality was not due to any want of ability on the part of the parasite to live in that region when introduced.

One of the most remarkable of this group of cases is the absence of the common yellow rust of wheat (*Puccinia glumarum*) from North America, Australia, and South Africa. The other two wheat rusts (*Puccinia graminis* and *Puccinia triticina*) occur practically wherever wheat is cultivated, though in India, *P. glumarum* has actually a wider range than *P. triticina*. Why yellow rust, which stands the extremes of climate in all the wheat-growing parts of India well, should fail to attack wheat in the United States, Australia or South Africa is a mystery, unless indeed we accept the simple explanation that its spores have not yet reached these areas.[1]

The lilac is attacked by two diseases of restricted distribution. In Germany and Holland a blight caused by *Phytophthora Syringæ* has been prevalent during the past few years; in the United States a mildew (a form of *Microsphæra Alni*) is very abundant on it; neither of these have been recorded elsewhere, at least up to 1914 for the former and 1908 for the latter.

There are two serious diseases of tobacco in the Dutch Indies. One, the bacterial disease caused by *Bacillus solanacearum*, attacks several other plants, including the potato. It is of very wide distribution in most tobacco-growing countries of the world and can readily be conveyed in potato tubers and on other living plants. The other, caused by *Phytophthora Nicotianæ*, is not known on anything but tobacco and has not extended beyond the Dutch Indies. It is probable that living tobacco

[1] Since the above was written yellow rust of wheat has been reported in the United States (*Phytopathology*, VI, 1916, p. 96). The area affected is as yet limited, and it is probably a recent introduction.

plants are never exported, and in the absence of this means of spread, the latter fungus has failed to reach other countries. It has two spore forms, one suited admirably for wind dissemination but only capable of living for at most a few weeks ; the other long-lived and resistant but only set free in the soil when the diseased plants decor pose.

Many other cases similar to these could be instanced, belonging to every group of fungi and with every type of spore. It is difficult to believe that they can all be due to deficient powers of acclimatisation, and many of them are probably to be accounted for by the limited distances to which the spores can be carried in the air in a living condition.

Of the large groups of fungi whose geographical distribution opposes the view that living spores can be borne for long distances in the air, the rusts afford some intresting examples. In the genus *Uromyces* there are 119 species in Europe, of which 70 are endemic (recorded up to 1911). Yet of these Europe has only transmitted three (*Uromyces Betæ*, *U. caryophyllinus* and *U. Trifolii*) to North America, while two (*Uromyces striatus* and *U. Fabæ*) are doubtful. In turn it has only received a single species (*Uromyces appendiculatus*) from North America, though the genus is very well represented there and no less than 249 species have been recorded in North and South America combined, of which 221 are endemic. It is worthy of note that all the exchanged species are parasitic on cultivated plants. Australia, which has 32 species, of which 22 are endemic, has only received six from outside and these six are the same as those which have traversed the Atlantic.[1] Another rust genus, *Phragmidium*, which is parasitic on plants of the N. O. *Rosaceæ*, is also of interest in its distribution. Over 60 species are known, but none are endemic in South America (though there is one in the Falkland Islands) and only one has been introduced, *Phragmidium disciflorum* on roses.[2] Though there are many species in southern and eastern Asia, only 4 (or perhaps only 2) are known in Australia and only one of these has been introduced, the same one as to South America, also on roses. These rusts are not, so far as is known, more exacting than many other parasitic fungi in their climatic or other requirements ; their spores are numerous and the least resistant type can often live for several weeks, while the durable spores, that are set free as the host plant withers (or sooner in *Phragmidium*), live for months ; and though they are strictly parasitic and

[1] The above details are mostly on the authority of P. Dietel (*Ann. Mycol.* IX, 1911, p. 160) who has given special attention to the geographical distribution of rusts. McAlpine (1906) gave a seventh species (*Uromyces Polygoni*) as having been introduced into Australia.

[2] Dietel, P. in *Ann. Mycol.*, XII, 1914, p. 93.

confined to definite hosts, this would not be sufficient to account for so markedly restricted a distribution if they were capable of wind dissemination for long distances.

From this consideration of the evidence available the conclusion to be drawn is that in devising methods to prevent the introduction of new diseases of the type of those contained in the detailed list attached (which includes a considerable proportion of the destructive diseases introduced within the 70 or 80 years during which we have reliable records, and represents practically all the classes of parasites likely to spread extensively in the future) infection by spores carried through the air from remote centres is not a contingency which needs to be taken seriously into account.

There remains the third method of the discontinuous spread of parasitic diseases which depend on spores for their transmission—dissemination on plants and other horticultural produce. The recognition of this as an important means dates from a comparatively recent period and it is doubtful if it is even yet fully realised.

There is an abundance of evidence, both direct and indirect, that the spores of most of the great groups of fungi are readily transmitted in a living condition, from one part of the world to another, on plants or parts of plants.

All economic mycologists have probably had direct experience of the transmission of living spores on plants or parts of plants ; many use it as a means of exchanging material for study with more or less distant countries. I have personally sent Indian parasitic fungi to workers in Europe, through the post, with success on several occasions. The infective powers of the mildew of wheat in India have been compared with that in England by means of living ascospores, thus sent on withered wheat stems, and several of our Indian wilt parasites of the genus *Fusarium* have been sent for purposes of study to Berlin on the roots and base of the stem of their host plants. I have also found living spores of two parasites of sugarcane on cuttings of American varieties of cane received at Pusa from Louisiana, through the United States Department of Agriculture, for trial in India. Quite recently I have received from the same Department cultures on sterilised cotton stems of the American cotton wilt *Fusarium,* and found the spores still living after the long journey to India. Indeed cultures of fungi on nutrient material are now sent out all over the world and there is a central bureau in Amsterdam for the supply of such cultures ; a parasite on its host plant is very often in at least as favourable circumstances for travelling as under these conditions. Presumably because of its very familiarity few seem to have thought it worth while to record their experiences in this direction, but it is unnecessary to labour what probably all mycologists would consider a well-known fact.

Of cases where the importation of plants has been followed by the appearance of fungi conveyed by them to a new locality there are many. None are of greater interest than those disclosed by an enumeration of the fungus flora of the great botanic gardens, such as those of Kew and Berlin. In these gardens a number of foreign species appear from time to time and are unquestionably introduced on plants purchased or presented from abroad and on their packings. Kew, for instance, has a much larger recorded fungus flora than any other area of its size in the world. In the same way parasitic fungi are introduced with foreign varieties of plants by experimental farms and departments of agriculture. In Australia two grass rusts appeared for the first time on the young plants grown from seed imported by the Victoria Department of Agriculture from the United States.[1] In India the only occasion on which the crown rust of oats has been seen was at Pusa, shortly after the experiment farm was started and when Canadian oats were being tried. The race of the parasite *Melampsora Lini* which grows on cultivated flax has also only once been recorded in India, on an experimental crop of recent introduction in the Nilgiris, while, on the other hand, the race of the same parasite which grows on the botanically allied linseed and which is common in India, is said to have reached Australia with seed from Calcutta.[2] Nurseries and florists' establishments must have played a considerable part in disseminating fungi of all sorts, from the very nature of their trade. Settlers, planters, and missionaries have doubtless also been responsible at times for the introduction of fungi on imported plants and other agricultural produce.

It is, however, when we come to consider the spread of specific diseases of economic plants, that the close connection between their movements and those of the living plants on which they are borne becomes most evident. Many instances will be found in the detailed list below and only a few need be referred to here.

The group of vine diseases of North American origin, the appearance of which was the outstanding feature of the history of viticulture in Europe during the nineteenth century, followed on the shortening of the voyage between the two continents due to the introduction of steamships, and two of the worst, the mildew

[1] McAlpine, D. "Rusts of Australia," 1906, p. 43.
[2] *Agric. Gaz. New South Wales,* II, 1892, p. 157.

and the black rot, are ordinarily held to have been introduced on American vine stocks which were extensively imported during the struggle against *Phylloxera*. The mildew is common but only moderately destructive on the wild American grape vines; against black rot, too, some of the American species, such as *Vitis rotundifolia*, are highly resistant; while the oidium has never been known in America to cause such appalling losses as it did in France from 1852 to 1854, when it reduced the yield to one-tenth or one-twentieth of the normal. But for 300 years all attempts to acclimatise *Vitis vinifera* in the United States failed, and it was only by improving the native species, which resist these local diseases, that success in viticulture was ultimately attained.

The great coffee "boom" in the East during the second and third quarters of the nineteenth century led to the rapid extension of cultivation of the bush throughout all the eastern colonies of European states. It is practically certain that this was accompanied by some importation of the berries from the older coffee-growing localities, such as Arabia and possibly East Africa, where (in the latter at least) the coffee leaf disease was probably long established, as it has since been found widely distributed on indigenous East African varieties. The first recorded outbreak was in Ceylon in 1868, and the following are the dates on which it was found elsewhere:—Mysore 1869; Sumatra and Java 1876 (when was still confined to the western part of Java); Natal probably 1878; Fiji Islands 1879; Mauritius about 1880; Réunion 1882; Philippine Islands 1885; Madagascar before 1886 (said to have been first introduced by a Ceylon planter in 1872 or 1873, during a visit to examine into coffee-growing in that Island)[1]; Tonkin 1888; Malaya and Borneo reported in 1888; Samoa 1894. Owing to the commanding position of the Ceylon industry, it is probable that most of these places were infected from that colony; thus it is said to have reached Samoa direct from Ceylon,[2] and the Fiji Islands seem to have been infected by means of a box of seeds packed in earth, received from the same source

[1] Fauchère. *L' Agric. Prat. d. Pays Chauds*, 1907, p. 509.
[2] Reinecke, F. *Tropenpflanzer*, VI, 1902, p. 632.

early in 1879.[1] It has been proved that the uredospores can live long enough to stand such journeys, as they have been germinated in Germany after coming from Mauritius through England. Spore production is very copious and all parts of the plant, as well as the ground and packings, would readily become contaminated on an infected estate.

Citrus canker (*Pseudomonas Citri*) was introduced into the United States about 1912, when it was first seen in South Alabama and Florida. It came from Japan on stocks of Satsuma orange or *Citrus trifoliata*. Its dissemination throughout the Gulf States, where it is at present causing considerable alarm, was effected on nursery stock, perhaps from centres in Texas.

The chrysanthemum rust reached Australia in 1904 on cuttings imported from England. It was carried in the uredo stage, which alone occurs in England, and only this form had been found in Australia when McAlpine published his "Rusts of Australia" in 1906. Probably it owes its spread from its original home in Japan entirely to the trade in living plants. Cuttings have also been accused of carrying several other diseases.

Probably a large number of parasitic fungi can be carried on the seed of their host plants. A packet of purchased seeds examined in Kew some years ago was found to contain spores of several of the diseases of the plants to which the seeds belonged.[2] The leaf spot of celery is spread largely by the use of infected "seed," not less than 90 per cent. of samples of commercial celery seed examined having been reported from Wisley to be contaminated in 1914.[3] The hollyhock rust is another example. It has been proved capable of living through the winter on the persistent carpels, etc., around the seed. Oats are said to have carried the crown rust of this crop to Ecuador and the introduction of the same disease to Pusa has already been referred to. Straw packing is, however, an alternative possibility in this case.

[1] Thiselton-Dyer, W. T. *Q. J. M. S.*, 1880, p. 119.

[2] Massee, G. "Text-book of Fungi," 1906, p. 221.

[3] Chittenden, F. J. "A note on celery leaf-spot-disease," *Ann. Applied Biology*, 1, 1914, p. 204.

The fungi which cause rotting of ripe fruit are readily conveyed on consignments of fruit. A recent case reported[1] was on oranges from Brazil, the sea passage being about 18 days. Other cases known are on pineapples and bananas from the West Indies and citrus fruits from South Africa.

The diseases of such crops as cacao and rubber, the cultivation of which has been started in many tropical countries in comparatively recent times, should furnish interesting instances of the spread of fungal parasites through the agency of man. Rubber is often sent considerable distances as young cut-back plants, known as "stumps," and the first Para-rubber sent to Ceylon and Singapore from Kew in 1875 was in the form of seedlings. In cacao also the large fleshy pods would be an excellent medium for conveying living fungi. Unfortunately we are as yet by no means fully acquainted with the parasites of these crops in different countries and several of their worst diseases are caused by species which attack a number of other plants and which there is no reason to think are introduced. The canker fungus, however, is only known on these two crops (and possibly the bread fruit), and as it is now found in most countries of both the eastern and western hemispheres where they are grown, it seems to be highly probable that it has travelled with the host plant.

There are several diseases that from their very nature are unlikely to be carried in any other way than on their victims, in soil, or in packing. The warty disease of potatoes is a case in point; if we could keep potatoes from infected localities out of those still free, it is scarcely possible that the fungus could spread more than a very limited distance indeed. This is because the spores are confined to the tubers and are only set free into the soil when the latter decompose. The finger-and-toe disease of turnips, cabbages, etc., is a similar case; it is still unknown in India, though reported in Ceylon as an introduced disease. Other instances are the diseases of lucerne caused by *Urophlyctis Alfalfæ* and the grass disease caused by *Cladochytrium graminis*. The latter disease was recorded in Great Britain for the first time in 1908 and appeared in every instance where portions

[1] Rushton, W., in *Ann. Applied Biology*, I, 1915, p. 365.

of a consignment of Continental grass seed had been sown. The parasite was found in the seed-coats of 5 per cent. of the seed that had produced a diseased crop and was clearly introduced in this manner.[1] The Harper Adams Agricultural College has reported a case where a single consignment of potatoes from a crop infected with warty disease spread the disease over a district with a 5-mile radius.

How far packings are responsible for carrying the spores of parasitic fungi is uncertain. Smut spores would no doubt travel readily in this way, but most of the destructive diseases of this class are already widely distributed and they would be carried still more easily as a rule on seeds. Soil is unquestionably dangerous, as many soil-dwelling parasites are long-lived and resistant to unfavourable conditions. But in a general way there does not seem to be sufficient evidence available to decide how far dry packings can serve as a means of transit for parasitic fungi.

An analysis of some of the Australian rusts to show the probable means of introduction of foreign species to a geographically isolated part of the world may help to an estimation of the part played by man in disseminating parasitic fungi by means of their transmission on plants or packings.

In Australia, 90 species of *Puccinia* had been recorded up to 1905. Of these 22 were considered by McAlpine ("Rusts of Australia," Melbourne, 1906) to have been introduced. I have classified them as follows :—

Thirteen are on cultivated agricultural or horticultural plants, presumably introduced by settlers, gardeners or the trade.

P. Chrysanthemi on chrysanthemum.
P. Cichorii on chicory.
P. graminis, *P. triticina*, *P. simplex* } on wheat and barley.
P. Helianthi on sunflower.
P. Lolii on rye grass.
P. malvacearum on hollyhocks, etc.
P. Maydis on maize.
P. Menthæ on penny-royal.
P. Pruni on peaches, plums, etc.

[1] Massee, G. *Kew Bulletin*, 1913, p. 205.

P. purpurea on sorghum.

P. Thuemeni on celery.

Two are on grasses imported by the Department of Agriculture, Victoria, from the United States, in 1903, the rusts first appearing in December to March, 1903-1904.

P. Impatientis on *Elymus condensatus.*

P. Beckmanniæ on *Beckmannia erucæformis.*

Three are on field grasses and probably came with the seeds of their hosts, in grass packing, or were introduced by settlers.

P. Anthoxanthi on *Anthoxanthus odoretum* (sweet vernal grass).

P. Festucæ on *Festuca ovina* and *F. rigida* (fescues).

P. poarum on *Poa annua.*

One (*P. Cyani* on cornflower) is on a garden flower and field weed and was probably introduced by florists, but may have come in packing.

One (*P. Arenariæ* on chick-weed) probably came with the seeds of its host in packing.

While **two** are doubtful, *P. Prenanthes* on *Lactuca* sp. and *P. Hypochoeridis* on *Hypochoeris radicata* and *H. glabra.*

The genus *Uromyces* is the second largest Australian genus of the rusts. Dietel[1] says that of the 31 species recorded up to 1911, five have been introduced.

U. Fabæ on beans (*Vicia Faba*).

U. appendiculatus on cowpea.

U. Betæ on beet and mangel.

U. caryophyllinus on carnations.

U. Trifolii-repentis on clover.

These are all on cultivated plants whose introduction can be readily understood. McAlpine gives *U. Polygoni* on knot-weed as well, and thinks this might easily be carried with the seeds in straw-packing or in hay. More recently[2] *U. striatus* on lucerne has been found and doubtless came in with imported seed from Europe or America.

To sum up this discussion of the three principal methods by which the "discontinuous spread" of parasitic fungi, which rely on spores for their transmission, may be effected, the evidence available from cases sufficiently

[1] *Ann. Mycol.* IX, 1911, p. 160.

[2] Second Report, *Bureau of Microbiology*, N. S. W., 1912.

recent to have been recorded points to the preponderating part played by man. Probably at no period in the history of the world has the movement of plants of economic worth, to and from distant countries, been carried on so extensively as at the present day. The time taken in transit has been continually shortened since the introduction of steam; and whether the parasite is best fitted to travel as spores or as mycelium, there is no doubt that there are few parts of the world that have not been brought near enough to allow the great majority of the fungi that cause disease to reach us, with their host plants, in a living condition.

For continuous or short-range spread, parasitic fungi make use of a number of different methods, the chief of which have already been enumerated. Few travel in the mycelial stage, most having spores suitable for the purpose. In a general way these spores are disseminated chiefly by the wind, but each case must be considered individually, as there are some quite unsuited for air transit and no general statement would cover all groups. For discontinuous or long-range spread, on the other hand, the parasites, whether they travel in the mycelial condition or as spores, are bound up with the ovements of their host plants, and the general statement may be made that, if we can secure the absence of parasites from imported or exported plants, we can control the discontinuous spread of the great majority of parasitic diseases.

With these conclusions in mind, the possibility of controlling the dissemination of diseases caused by parasitic fungi may be considered. Three cases may be distinguished: (1) where the disease has succeeded in gaining a footing in the country; (2) where it has only reached neighbouring countries not separated from us by natural barriers; (3) where it is still confined to areas isolated by the ocean or by large tracts with dissimilar climate and vegetation.

Diseases already present in the country can ordinarily make use of the methods of continuous spread, which are mostly uncontrollable. There have been attempts in the past (and several are in progress at the present moment), to exterminate newly introduced parasites in various parts of the world. It is doubtful if any have succeeded, while some, such as the campaign against black rot of the vine in France and coffee leaf disease in Fiji, have failed completely. The American gooseberry mildew is still spreading in England, in spite of restrictive measures. The Godavari palm disease campaign has been more successful, for it has kept the attack confined practically to the same area, but it has, so far, failed to stamp it out within that area. In the United States very active measures are at present in force against several diseases of recent introduction, such as citrus canker and the blister-rust of the white pine. In Ireland one of the most hopeful efforts as yet undertaken is directed against warty disease of potatoes, which was introduced into one small area. On the whole, though it is as yet too soon to speak definitely, it is clear that treatments of extinction are extraordinarily difficult to apply successfully, and that it would be much easier and more effective to keep the disease from getting a footing in the country.

Against the second class of cases, where the disease has not yet reached us though known in neighbouring countries, India is peculiarly well situated. It is almost completely isolated by the sea or the impassable barrier of the Himalaya. Only along the coastal tracts around the Bay of Bengal and possibly through Baluchistan are there routes by which continuous spread might occur, and there are few cultivated plants which extend along these tracts between India and the countries outside. From Ceylon we might perhaps get infected, as it is possible that such agencies as the wind or contaminated insects could carry spores across the narrow gap from that colony. With these exceptions, however, India is practically immune from foreign diseases unless they are allowed to come in on their host plants. Such countries as are not geographically isolated from their neighbours are in a less favourable position, since they are exposed to attack by parasites that can use the methods of continuous dissemination and there is, as a rule, little chance of keeping these from spreading across the frontier, except in the few cases, such as warty disease of potatoes, where the parasite cannot ordinarily travel unless on its host.

The third class includes all those diseases which can only reach us by the methods of discontinuous spread, which, from the evidence given above, may be practically reduced to dissemination with horticultural produce or packings. If all imports of plant produce could be checked there would be little chance of such diseases entering the country.[1] So drastic a measure is not required provided that we can ascertain what diseases should be guarded against. For this it is important to know: (1) from what parts of the world we might receive dangerous diseases, and (2) what diseases exist in each area that could be imported and might prove injurious.

There is no direct evidence to indicate from what parts of the world India might import dangerous diseases. The country is so large, the variations of

[1] It is scarcely necessary to mention that fungus diseases can escape detection and disinfection at the port of entry, in so many cases, that this method of attempting to obtain security has been abandoned.

climate are so great and there are so many different crops grown, that there is scarcely any considerable area without some parasite liable to attack a valuable economic plant in India. Further there are as yet few exact records of introduced diseases to suggest where danger may be looked for. We have probably received the potato blight and vine mildews from Europe ; chrysanthemum rust may have reached us direct from Japan or through Europe, the downy mildew of maize (*Sclerospora Maydis*) perhaps from Java, and that of cucurbits possibly from Ceylon. Most of the recently introduced diseases in Europe seem to have come from North America, East Asia or the temperate parts of South America, but no such well-defined danger zones can be suggested for India. Hence in order to secure ourselves against the introduction of exotic diseases, there seems to be no alternative at present but to take each of our important economic plants and examine the records of the parasites that attack it in other countries and that are not yet known in India. In this way it may be possible to draw up lists of the dangerous diseases that should be prevented from entering India on their host plants. Fortunately India is as yet largely self-contained as regards seed supply and nursery produce; comparatively few living plants or parts of plants are imported ; and from the lists furnished by the Customs authorities it would appear to be a fairly easy task to decide what produce enters the country, through private agency, of a kind likely to bring in dangerous plant diseases.

In preparing a list of the diseases that should be guarded against, certain difficulties arise. In the first place the diseases that occur in many countries and colonies are not well known. Even in Great Britain no complete plant disease survey has been made and it is consequently sometimes difficult, or even impossible, to ascertain whether a particular disease occurs in that country or not. This is still more the case with other areas, such as China, from which there may be a danger of diseases being imported into India. In most of the discussions on international problems of phytopathology in recent years, reference has been made to the need for establishing a plant disease survey in each country. At the least a card index should be maintained in some central location, in which all diseases of economic plants are entered under the parasite and under the host plant ; and all new diseases should be recorded as they are reported, together with the localities affected as far as known. The maintenance of an index of this nature requires no great amount of work and enables any country desiring it to receive a list of the diseases and the plants affected which would greatly help it in deciding what imports should be kept out. Only one word of warning is necessary. Such an index cannot be prepared in the laboratory or office alone ; the knowledge required must be gained largely by "field" work, as it is generally useless to rely on the chance notification of diseases; and the "field mycologist" is the only person who can undertake this work.

Then in deciding whether a disease is likely to prove dangerous or not the problem of variation in virulence in different localities has to be taken into account. There is unfortunately abundant evidence that diseases that are relatively mild in one continent may prove exceedingly virulent in another.

The vine mildew and oidium are cases already referred to above. The chestnut bark disease, perhaps the most completely destructive fungus disease at present under observation, is another, since in its original home in East Asia it is comparatively innocuous. That a parasite introduced to a new home, where conditions are to its liking, may develop accentuated virulence is now well known; the rule holds equally for animal diseases; and small-pox, for instance, is known to rage with exceptional violence when first introduced into a new community, as amongst the North American Indians. An American phytopathologist[1] has recently brought together some cases observed during a tour in Europe of diseases whose destructiveness differs in the two continents. He found the brown rots of fruit (*Sclerotinia* or *Monilia*) did much more damage in Europe than America, as also the strawberry mildew and some others. On the other hand, the black rot of apple (*Sphæropsis malorum*) does little injury in Europe (where it is known from Italy to England) while it is a widespread and destructive disease in the United States, and this is true also of the bitter rot of the same fruit (*Glœosporium fructigenum*) and asparagus rust. While it is tempting to think that these differences are due to the diseases being comparatively recent introductions to the country in which they are most destructive (as is true of the asparagus rust), there is no evidence whatever that this is the case with the brown rots, the strawberry mildew or the two apple diseases. Whatever the causes, the fact remains that the virulence of a disease in one continent is no safe guide to its destructiveness if introduced into another.

The preparation of lists of diseases, which it is desired to exclude from each country, was accepted as an essential part of the scheme for securing international co-operation in checking the spread of plant diseases and pests, drawn up at the International Phytopathological Conference held at Rome in February, 1914. The object of the Conference was to frame a Convention to control the inter-state circulation of horticultural produce. The meetings

[1] Shear, C. L. "Some observations on phytopathological problems in Europe and America." *Phytopathology* III, 1913, p. 77.

were attended by delegates of some 30 States and Colonies, and the Convention, as finally drafted, secured unanimous support, subject to ratification by the Governments of the countries concerned. The outbreak of war has delayed ratification in most cases and as some differences of opinion regarding certain clauses of the Convention were becoming apparent in several countries,[1] it is doubtless an advantage that further time has been gained for discussion. Since the question of the adherence of India is not yet decided, it may be useful to examine the leading features of the Convention in the light of the conclusions arrived at in the earlier part of this note, for it is evident that any restrictive measures of the kind proposed should be based on the known facts regarding the dissemination of plant parasites.

The Rome Convention (See Appendix II) proposes to control the inter-state circulation of horticultural stock (living plants, cuttings, grafts, flowering bulbs and cut flowers), with certain exceptions mentioned below. Each adhering State pledges itself not to admit such stock without a certificate that its sanitary condition is satisfactory and also (where required) that it is free from certain specified diseases.

In order to be in a position to grant such certificates, each State undertakes to set up a Government Service of Phytopathology, the duties of which will be to supervise nurseries and other establishments engaged in trade in living plants (with the exceptions referred to) and to inspect cultures or consignments (or both) intended for export.

There must be one or more Government research centres in each country; the appearance of diseases and pests and the localities infected ought to be recorded (but this information need not be notified to other adhering States); measures ought to be taken to prevent or check plant diseases; and there ought to be control of the transport and packing of the plants destined for export that come under the Convention. Each State must take legislative and administrative steps necessary to give effect to these requirements and to punish breaches of the regulations.

To enable each adhering State to know what specific diseases must be mentioned in the certificates given within that State to nursery stock intended for export, every adhering country will prepare a list of the diseases against which it wishes to guard itself. These lists will all be furnished to the Government Phytopathological Service of each country, and when a consignment

[1] See *Gardeners' Chronicle*, 3rd Ser. LVI, 1914, pp. 94, 338, 350; *Proc. 3rd International Congress of Tropical Agriculture*, London, 1914, pp. 109-117 & 388-391; *Trans. ib.*, I, 1916, p. 125. *Ann. Applied Biology* I, 1914, p. 113; *Journ. Economic Biology*, X, 1915, p. 42.

goes out of any adhering country, the certificate with it must state that it is free from such diseases (mentioned by name) as are on the list of the country to which the plants are going, and which could be in the consignment.

No country may put on its list common diseases already widely distributed, or those whose ordinary host plants are absent from the country. The diseases mentioned must be (1) of an epidemic character, (2) destructive or at least very harmful, and (3) easily disseminated by living plants or parts of living plants.

The Convention does not apply to the vine,[1] to seeds, to edible tubers, bulbs, rhizomes, and roots, to fruits and vegetables, and to roots and produce of field cultivation. Living plants of any kind are also excluded from control if intended for scientific institutions authorised by Government to introduce plants for scientific study. It is clear, therefore, that no certificate is required by the Convention with imports of any of these.

What is not clear is whether a certificate is required with imports of wild plants or plants not coming from a nursery. Article 5 of the Convention states that the adhering countries pledge themselves not to admit living plants without a certificate (except as noted in the last paragraph). The fact that countries such as England import for horticultural purposes wild plants from parts of the world whence certificates cannot possibly be got (as Tibet) was either overlooked, or it was intended that such imports should cease, or it was intended (but not expressly stated in the *Acte Finale* of the Convention) that wild plants should be altogether excluded from the regulations.

There is nothing in the Convention to prevent countries making any other regulations they like, provided they do not constitute a breach of the principles of the Convention. The latter stipulation is not expressly mentioned but, I take it, is implied in any international agreement of the kind.

These are the essential parts of the Convention. Their effect on India may be considered (1) as concerns imports, (*a*) from adhering countries, (*b*) from non-adhering countries, (2) as concerns exports.

The trade in importing plants seems to fall into two main categories: plants already in wide cultivation are imported chiefly from nurseries; plants not already in wide cultivation (including novelties and wild plants) often do not come from nurseries or trade establishments at all.

For the first class, the application of the Convention to imports from adhering countries presents few difficulties, and the mycological requirements

[1] Covered in part by the Berne Convention.

should not cause more restriction in the trade than is likely to be profitable to the trade itself in the long run. All imports of the sort covered by the Convention must have a certificate, whether there are any listed diseases that could be carried or not. This certificate will guarantee that the nurseries from which the plants have come are subject to inspection and that either the crop or the particular consignment (or both) is in a satisfactory sanitary condition. In addition, the Indian list will show what specific diseases (if any) the consignment must be certified free from. The exporting nursery or nurseries will be inspected and if clean from the specified diseases (if any) and the produce or consignment in a healthy condition, the certificate will be given. All that is necessary is for the Indian list to be prepared in such a way that no disease will figure on it which is likely to be so widely present in the exporting country that there will be a difficulty in getting clean certificates, unless India is prepared to stop the import of the host plant from that country. If we wish to continue to import pears from countries in which pear blight is widely prevalent, this disease should not figure on our list. It must not be forgotten that the Convention is drawn up in the interests of the adhering countries themselves and it would be for the Department of Agriculture to consider whether the country is likely to lose or gain by listing a particular disease. In some cases it may be better to keep a disease outside the Convention and to deal with it in a more elastic manner, if necessary.

Imports of nursery stock, of the sort covered by the Convention, from non-adhering countries must cease, unless the exporting country can and will give certificates signed by "competent official agents" in the same form as those required from adhering countries. The adhering countries undertake not to give non-adhering countries more favourable treatment than those adhering. The effect of this part of the Convention is to enable pressure to be brought on other States by the adhering countries and will presumably result in forcing all that have important export trade of the sort mentioned, with adhering countries, to enter the Convention. In the beginning there will be difficulties but they will probably disappear as soon as exporting countries realise where their interests lie.

For plants which do not come into India from nurseries, the difficulties are much greater. As already pointed out it is not clear whether we must refuse admission to all living plants (with the exception of those specifically excluded from the Convention) unless they have a certificate. If so, then we should refuse entry to orchids, flowering bulbs and the like from many tracts outside the British Indian Customs frontiers, including much of the Himalaya, since it is generally impossible to obtain a certificate in such cases. It seems incredible that this could have been intended and probably plants not coming from nurseries or other trade establishments, and therefore not capable of carrying a certificate (since only nurseries and the like are to be inspected) are meant not to be covered by the Convention at all. If this interpretation is wrong (and the point should be made clear as soon as possible) the Indian Customs will be confronted by a most difficult problem, since it seems impossible to close our frontiers to such plants, and every effort should be made to get the Convention abolished and a new one set up, to which India can adhere. There is little danger to be feared from the wild plants that enter India from the Himalaya and other neighbouring trans-frontier tracts, and standing out may render us liable to heavy penalties from adhering States.

There seems no need to go into the legislative and administrative measures that will be required to deal at the points of entry (which must be specified) with imports under the Convention. Some are laid down in the Convention, others are matters of internal administration. There may be difficulties in deciding who is to bear the cost of consignments refused admission, but such questions are outside the scope of the present discussion.

For the effect of the Convention on exports, much will depend on the modesty of the requirements of other adhering States. The Convention lays down that the lists prepared by each country, of the diseases which it wants to exclude, should be as limited as possible. But, since each country will have a separate list, the total number of diseases which must be watched for in an exporting nursery may be considerable. It will be necessary to scrutinise the lists of the various countries with care to see that they come within the bounds prescribed by Article 10. Even so, there may well be listed diseases which are so prevalent in India that a clean certificate will be difficult to get. As I have already suggested, in some cases it may be wise to attempt to get other countries to withdraw a particular disease from their lists, so as to be able to deal with it in a more elastic manner. Still as a general rule it will be better to have the specific diseases of Indian plants listed by the countries we export to, as they would then be bound to accept our certificates in any case in which they might be correctly given. Although the Convention does not prevent an adhering State from making other regulations, it does, I assume, prevent any regulation which would nullify its provisions. Hence no adhering State could well refuse admission to a properly certified consignment from another adhering State, since this would be to go behind the central principle on which the Convention was based.

The inspectors of the Indian Government Phytopathological Service will have the complete lists of all adhering countries. When a nursery wishes to export stock which comes under the Convention, it must apply for inspection. Presumably it will be necessary for Government to maintain a list of the inspected establishments, and any wishing to export to adhering countries must apply to be placed on this list. It will then be inspected.

The Convention leaves it open whether the inspection is to be made on the growing crop or on the consignment for export or on both. The double inspection was proposed but was judged difficult to apply in some cases. It was also stated in the discussions that inspection of consignments need not be parcel by parcel but that the whole stock which is to form the consignment may be inspected at once.

Not only must the stock (whether growing or ready for export) be inspected for the diseases in the list of the country to which the consignment is going, but its general sanitary condition must be pronounced satisfactory. It is open to the inspecting staff to interpret this latter requirement loosely or strictly, but it is certain that no consignment can safely be pronounced absolutely free from every disease, and the interpretation should, in my opinion, be a broad one. Well kept gardens need not fear it, unless they are struck by an epidemic or something of the kind, when they must expect their exports to be restricted.

To be effective a single inspection in the course of the year will frequently not suffice. As proposed at the Conference (but not adopted) it would be of advantage to inspect the crop at the period of its growth when diseases are most evident (usually as it approaches marketable condition) and also to inspect the consignment when ready for export. It was clearly with a view to making the conditions of inspection as little onerous to the grower as possible, that the double inspection was not insisted on. It seems to have been admitted that as a general rule it is better to examine the consignments ready for export but that in certain cases one must be content with the examination of the crop. From the strictly mycological point of view the examination of the crop can be of great assistance, and if made shortly before the despatch of the consignment would frequently suffice. If made much before the plants were reaching saleable condition, or any considerable time before they were lifted, I would consider a subsequent examination during the period of their preparation for export to be necessary.

In addition to the visits of the inspectors for the purpose of granting certificates, Government ought (under Article 1 of the Convention) efficaciously to supervise establishments engaged in the trade in living plants, make provision for the notification of disease, and take measures to prevent and combat diseases. A Government which interprets this as an encouragement to any extensive system of official control of the hygiene of nurseries will get little support from experienced plant pathologists. It is generally impossible to standardise remedial measures against any particular disease. The soil, climate, water conditions, and other external circumstances of any locality frequently have a most important bearing on the remedial measures to be applied and the way to apply them. Also the varieties grown, and the period of the year when the attack develops, differ from place to place. Even in such a well-established treatment as seed disinfection against wheat bunt, there have been cases of failure due to local conditions and varieties grown, in India, Canada and the United States, and the same is likely to be true for certain diseases of nursery stock also. What Government can do is to provide information of the best available kind; its application to local circumstances requires local knowledge; and I would be sorry to enter into competition with an experienced and *well-informed* nurseryman in trying to check a disease in a locality of which I did not know the conditions.

Thus for the first time an attempt has been made to secure general recognition of the fact that the spread of plant diseases is largely due to human agency. To check this, the Convention goes as far as was perhaps to be expected in a first step. At the same time it is obvious that it does not go far enough to provide complete security, and in one or two respects it does not seem to take sufficient account of the facts regarding the dissemination of parasitic fungi, discussed above.

The Convention wholly fails to make any distinction between continuous and discontinuous dissemination of parasites. It has been shown that diseases that can make use of the methods of continuous dissemination to cross our frontiers cannot ordinarily be kept out, and there is little advantage in listing them. Fortunately India is not exposed to any appreciable danger from this class of disease. We have already, no doubt, received most diseases of neighbouring countries that could reach us in this manner; they are probably very few in number owing to our geographically isolated position; and except in the case of diseases newly introduced into Ceylon, which might spread to South India, or into the Malay Peninsula, which might reach Burma, it is hard to imagine our getting infected from outside in any other way than by means of conveyance on imported plants. To prevent danger from Ceylon and the Malay Peninsula is not easy, especially in such newly introduced crops as rubber, and we can only hope that new diseases will be kept from entering these areas as far as possible, or that, if they do enter, the natural barriers to their spread will prove sufficient to protect India against them.

It follows from this that India should be prepared to list parasites at the reasonable request of Ceylon or the Federated Malay States, even though their host plants are not of importance to India. We might be asked to list a cacao disease, though the plant is but little grown in India, because it is a valuable crop in Ceylon. In such cases it might save trouble to stop cacao imports altogether, since they are probably quite unimportant. We should, of course, list any rubber disease that these colonies wanted to keep out, and would expect them to reciprocate by listing any diseases we did not want to get.

The proviso that only such diseases may be listed as are destructive or at least very harmful, leaves out of account the known facts of variation in virulence already referred to. Under it, it is probable that the chestnut bark disease could not have been listed, since it is said to do relatively little damage in China and Japan, whence it came. In preparing lists it will be wise to include all such diseases as there is reason to fear, from experience with allied parasites, may develop accentuated virulence if transferred to a new area, even though they are not very harmful in their original home. For the present, special regulations to deal with such diseases outside the Convention would have to be made, but it is to be hoped that they will ultimately be allowed to come under its scope. When a new crop, such as rubber, is introduced, there should be no hesitation in attempting to keep out every disease that it suffers from in its native home, which has dangerous potentialities, even though it may not actually be known to cause appreciable injury.

It has already been mentioned that certain diseases can be introduced on seed. Seed is frequently conveyed by post and there is no machinery for restrictive measures which could prevent dangerous importations by this road; seeds are expressly excluded from the Convention. In the United States Quarantine Act of 1912, nursery stock which is subject to restrictive legislation is defined to include seeds of fruit and ornamental trees or shrubs, but field, vegetable and flower seeds are exempted from the regulations, though it is provided that the latter may be extended to include exempted articles by the Secretary of Agriculture in case of need. Also the United States Post Office Order of July 1st, 1913, renders nursery stock unmailable in the international Parcels Post, unless addressed to the United States Department of Agriculture. Hence the United States has gone further than the Rome

Convention was prepared to go, but still allows the uncontrolled importation of most seeds, bulbs, and roots. This and the suggestion that a particular disease must be new and dangerous to justify inclusion in the schedules, are the chief weaknesses of the United States regulations, which otherwise seem to be well adapted for the purpose in view. Still the Secretary of Agriculture has power to extend these regulations to meet specific dangers, and has exercised them in the subsequent restrictive orders against warty disease of potatoes (tubers not having been included in the original definition of nursery stock), and against corn (maize) from India and Java, which might convey *Sclerospora Maydis.*

Botanic gardens and agricultural experiment stations are as liable to introduce exotic diseases as nurseries or any other agency which imports plants. A disease so introduced is not likely to be rapidly disseminated by infected plants being distributed throughout the country, as may happen where a nursery is concerned. Also there is somewhat less danger of diseases of valuable economic plants, widely grown in the country, being introduced, at least into Botanic gardens. Nevertheless there is considerable risk in giving differential treatment to such institutions on any considerable scale ; and in the United States, for instance, only the Department of Agriculture may import nursery stock independent of restrictions except such as are prescribed by the Secretary of Agriculture, other institutions desiring to import plants for scientific or experimental purposes being subject to the same regulations as private firms.

It is clear that the Convention does not cover all classes of plants that might bring in disease. In particular it excludes produce of field cultivation (*produits de grande culture*). Potatoes, sugarcane, tobacco, many planters' crops, and our ordinary field crops are not protected. Hardly any of the diseases scheduled under the existing Destructive Insects and Pests Act in India come within its scope. This was perhaps inevitable, as only a very limited start could have hoped to secure unanimous support at the Conference. As it stands, the Convention is far from satisfying the requirements of most tropical countries and colonies, where horticulture is only a very small part of the agricultural industry. The majority of the dangerous diseases of foreign origin that should be prevented from entering India cannot find a place on its official lists. Still there is no reason why any country should not insist on certificates with imports of other plants besides those covered by the Convention. Once the machinery is in working order there will be no very great difficulty in obtaining these certificates from countries with adequate

Phytopathological Services. The newly organised French service appears to be prepared to give certificates for such produce as tubers, roots, and seeds of field crops, though these are outside the Convention. If this example is followed we may expect to be able to get certificates with most of our imports; under the present Indian Act we require them for potatoes from certain countries, for sugarcane and for rubber; and now that Europe is practically committed to the certificate system and the official agency for the purpose has been defined, it should not be long before certificates can be obtained, if needed, for most of our imported produce.

It remains to examine the restrictive clauses of the Convention, to see whether they go further than is justified in the interests of the country. They are chiefly contained in Articles 1 and 5, and deal with the supervision of nurseries, the control of transport and packing, the notification of diseases, the measures to be taken to prevent and check disease, and the granting of certificates after inspection. In all but the last a certain amount of latitude in interpretation is, I think, essential.

In considering how far the official supervision of nurseries and other establishments engaged in trade in living plants should go, a good principle to follow is that adopted at the Rome meeting, namely, that the object should be to facilitate trade while checking the dissemination of disease. A nursery engaged in the export trade must be kept as free from disease as possible, so that it may fulfil the requirements of the Convention, or of other regulations requiring certificates. To do this it must clearly not lay itself open to infection by continuing to purchase stock from other non-inspected nurseries. It would be best to cease to buy from such nurseries altogether; failing this, the only other course is to arrange for a very early inspection of the newly purchased stock and meanwhile to keep it as isolated from the rest of the stock intended for export as possible. It will be readily seen that the latter is not free from risk, as spores from newly introduced infected plants may easily reach other parts of the nursery through the air or otherwise. For nurseries engaged in internal trade only, the same restrictions are not so necessary. I have several times referred to the generally excellent means which fungi have for continuous spread outside human control, when the distance to be covered is relatively short; and as the spread by nursery stock within the country is only one of several ways by which the fungus can reach plants within, say, the same Province, we cannot often hope to do much good by severe restrictions on internal trade. It is difficult to foresee all cases, but it is fairly certain that the gradual spread of the great majority of diseases of which accurate records exist, from infected areas to neighbouring districts, is largely independent of nursery trade. Hence there is not the same inducement to keep nurseries only engaged in internal trade free from infection, as there is when dealing with nurseries which trade with countries which the parasites can only reach if carried with the host plant. Naturally it is (or ought to be) the interest of every nursery not to sell diseased stock in the country, but it need not be the same pre-occupation of Government to keep up the good name of a nursery engaged in internal trade, as with an exporting nursery where the trade must inevitably cease under the international regulations when the stock for export becomes infected. An exception should be made with new diseases on their first appearance. Any nursery found infected might well be quarantined in such a case, and as it is often not in any way the fault of the nursery that it becomes infected, the question of compensation would arise. But once the disease has got a footing in several different parts of the country or has extended widely in a particular district, it seems to me that the Government service should concern itself chiefly with keeping exporting nurseries free from infection.

The control of transport and packing is probably less important (or perhaps it would be better to say, its effect is less accurately known) in the case of fungus diseases than with insect pests. In a general way there is relatively little danger of a fungus parasite, in a reasonably well packed consignment, escaping during transport. When it is present in the neighbourhood during packing (not necessarily on the plants packed), there is probably a danger of the packings becoming contaminated. Unfortunately there is little information on this point, but it seems undoubtedly to be possible. When the consignment is unpacked, spores thus carried might sometimes get loose. Hence it would be a wise precaution to pack and unpack away from growing plants or their débris, and preferably in sheds or other enclosed spaces, and also to burn all used packings very carefully.

The notification of disease can very easily be overdone, and there ought to be less rather than more need for it as time goes on. This is because at present many States require certificates stating that a particular disease does not exist near the locality from which the plants have come, whereas for all plants subject to the Convention nothing of the kind can well be demanded by one adhering State from another. In the discussions during the meeting at which the Convention was signed, it seems to have been generally recognised that the certificates should be passports to free entry (provided naturally that they are not found to have been wrongly given), and it might be advisable to make this clear by adding a statement to this effect in the body of the Convention. Further, compulsory notification of diseases is only of value with new diseases and for them only until the disease has reached a moderately wide distribution, unless it is proposed to adopt compulsory treatment. In the present backward state of the knowledge of the occurrence and distribution of diseases in many countries, notification may appear important, but it seems probable that this state of affairs will not last long and then notification can only serve three purposes. It may be required to enable certificates to be given for plants not under the Convention or going to non-adhering countries, where the importing country requires the certificate to state that a certain disease does not occur near the exporting nursery; it may be required in order to restrict circulation of diseased stock in the country under the limits discussed above; and it may be required if compulsory treatment is adopted.

The question of compulsory treatment has been already referred to in part. I am not greatly in sympathy with any regulations of the kind, except for new diseases, and for so long as there is a reasonable chance of preventing their spread—generally for a few years only. My experience has been that it is impossible to "administer" a disease out of existence, though sometimes possible to confine it to a restricted area for a time. There have been exceptional chances of testing this in India and some of the colonies, and they have not been sufficiently successful to make it a hopeful line of treatment. In general I think the "measures to check and prevent disease" which Governments ought to take under Article 1 of the Convention, should not be in the direction of compulsory treatment or any other "standardised" methods, so much as in seeing that the best information is at the service of those who require it, and in giving advice and frequent practical demonstrations of the best ways to deal with a particular disease.

From the above it will be seen that there is nothing in the Convention which insists on any rigorous control of nurseries, or which should not be capable of being applied effectively without interfering unduly with such establishments, if administered in a common-sense fashion. Some points require modification or elucidation, but none of these touch the central principle, that the certificates of the Convention should be the passports to free circulation of nursery stock, and none is of such a nature as to prevent the adhesion of India, except the obscure point regarding the exclusion of wild plants without certificates. It is highly probable that other countries will press for a new Convention after the war, but the modifications required are not likely to be considerable and may be expected to remove some of the weaknesses indicated above. It is unfortunately true that a Convention, once signed, cannot be altered, but the same procedure will probably be followed as in the Berne Convention of 1879, dealing with *Phylloxera* of the vine. In this case the modifications indicated by experience were incorporated in a new Convention bearing the date 1881.

If, therefore, the Convention is regarded as being primarily concerned with the control of inter-state circulation of plants; if wild plants from neighbouring areas are excluded from its scope; if the clauses which require that the stock to be exported should be in a satisfactory sanitary condition and that the Government service should supervise nurseries and take steps to prevent or check diseases, are broadly interpreted; and if the Government service is a good one; then I think there are obvious advantages in adhering to it, while pressing for the modifications suggested above and any others that may become evident in the next year or two in the working of the system in those countries that have already ratified it and set up the necessary machinery. To keep India free from the diseases of economic plants of importance, the Convention is only a first step, but after a few years' experience and as soon as other countries have established the organisation required if they wish to adhere, there seems to be a good prospect of a much more efficient control of the dissemination of fungus diseases to distant countries, than has ever been thought possible in the past.

PUSA,
July 19*th*, 1916.

APPENDIX I.

Distribution and extension of some parasitic bacteria and fungi, chiefly those causing diseases of cultivated plants.

THE records below contain the brief history of the spread of most of the important cryptogamic diseases of cultivated plants whose extension has attracted notice during the past 70 years, before which there is little information available. It has been impossible to verify all the references with the facilities at my disposal, and in any case it must be understood that the published record of the appearance of a disease often does not occur for a year or more after the parasite has actually been introduced, even in the more advanced countries, while for much of Asia and Africa the date of record gives no indication of when the parasite was introduced. A thorough search through herbarium specimens would doubtless result in putting back the date of the appearance of several of the diseases referred to in different countries, but even then we would not always have an exact date for the introduction of the parasite. Hence the records must be taken usually as giving an approximate picture of the spread of a disease and are open to correction on further enquiry.

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(1) Pear blight (*Micrococcus amylovorus*, Burr.)	Pear, Apple, Quince, Hawthorn and some other wild allied plants.	Probably eastern United States where it has been present for many years, probably over a century.	First attributed to bacteria in 1877-78 (Burrill), by which date it was prevalent in many parts of the United States, east of the Mississippi. Later reached the far west and south-west. Not known in Europe or Asia, except for a recent record (by Ferraris) in Italy (quoted by Shear in 1913). Has attracted little notice in Italy so far, possibly because of recent introduction or possibly has been incorrectly identified.	Chiefly by insects, some of which carry infected sap to the stigma, others (as *Scolytus rugulosus*) inoculate through wounds in the stem, others (Aphids) by punctures caused when sucking. One of the worst is *Lygus pratensis*. Also carried on pruning tools. Probably does not spread through air, as the bacterial masses are sticky. Was once thought to live in garden soil and to be blown with dust, but this is not now believed. Can be conveyed by cuttings or stocks for long distances.	
(2) Black rot of Cruciferæ (*Bacterium campestre* Erw. Sm.).	Cabbage, Cauliflower, Turnip, Radish, etc.	? Possibly Old World.	Probably first reported in Kentucky in 1889. Studied in Iowa by Pammel in 1893. All over eastern United States and west at least to Colorado. It is said to be not unlikely that it reached the United States from the Old World, and has spread greatly during the past 20 years.	Usually enters through the water pores on the leaf. Not believed to be commonly due to aerial borne germs, though is probably carried in dust at times. Often spread by leaf-eating and other insects. Perhaps can also infect from the soil, through wounds below ground.	

			Canada. Possibly Cuba and Porto Rico. All over north and central Europe; Russia; not seen in Italy. Demonstrated to be common in Europe in 1899-1900. Reported in England in 1903. Reported from New Zealand. Possibly in Japan. Formosa, 1914. India, 1914-15. Stated in 1916 to have been in South Africa since at least 1906.	Has been found on the seed of plants left for seed-bearing and shown to be able to survive for at least 13 months. Hence it can travel readily on seed, and it has been suggested that it reached the United States in this manner.
(3) Crown gall (*Bacterium tumefaciens*, Erw. Sm.).	Peach, Apple, Raspberry, Blackberry, Grape, Rose, Hop. Radish, Tomato, Beet, Poplar, Willow, Chestnut, Paris daisy, etc.	?	References in United States from about 1892, but certainly present long before. Now widely distributed in United States where has been chiefly studied. References in Europe (chiefly on grape) from about 1885 but the European records are considered to be doubtful by United States authorities, except that in Italy (Cavara 1895-97). What seems to be the same disease is widely known in Germany, France (1885), Austria (1905 and earlier) and England, but the cause has not been determined in these countries. Reported from Peru in 1910. South Africa (1910, but said to be long present). Said to occur in Chile.	Local spread occurs readily, as a single diseased tree in an orchard may suffice in a few years to infect most of the other trees. The attack is just below the surface of the ground and the soil may become infected. Possibly carried by dust. Has been widely distributed throughout the United States with nursery stock from infected nurseries, and this is the chief means of long-distance dissemination.

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(4) Bacterial blight of Beans (*Bacterium Phaseoli*, Erw. Sm.).	French beans ..	? United States ..	Known in the United States since at least 1892: New England to Louisiana and Nebraska. Not yet recorded elsewhere, unless the disease known as *graisse*, described from near Paris in 1899, is the same.	Attacks the seed within the pod and could doubtless be distributed for long distances with the seed.	
(5) Citrus canker (*Pseudomonas Citri*, Hasse).	Citrus fruits (Orange, &c).	Japan ..	Introduced into the United States before 1912, when found in South Alabama and Florida. Has been widely distributed throughout the Gulf States. Found in Japan, China and the Philippines in 1915. Cause ascertained in 1915. Reported in South Africa in 1916 and traced to a single importation of grape fruit trees from Florida in 1905-06.	Came from Japan on stocks of Satsuma orange, or *Citrus trifoliata*. Has been distributed on nursery stock in the United States, probably from centres in Texas.	Stated in 1916 to be "the most dangerous enemy to citrus as yet known." An attempt is being made in Florida on a huge scale to exterminate it by burning.
(6) Spongospora scab of Potatoes (*Spongospora subterranea*, John.)	Potato ..	Believed to be indigenous on the eastern slopes of the Andes, where it is found on native varieties near the upper limits of potato culture.	Said to have been long known in Europe and seems to have been mentioned by several authors between 1841 and 1846, especially by Wallroth in Germany in 1842. The true nature of the disease was established by Brunchorst in 1886, from Norwegian material. Common in Quito in 1892.	Carried in same way as warty disease (No. 7). Certain United States investigators believe it to have been recently introduced from Europe. An outbreak in Florida has been traced to the use of seed potatoes from Maine.	

			Is perhaps widely distributed in potato-growing countries, but in some (Denmark, Holland) was overlooked until specially searched for recently, and is probably not common. Reported from Sweden in 1908. First recorded in United States (Maine) in June 1913, and believed to be a new introduction, but may have been overlooked previously. Found in Canada in early spring of same year.		
(7) Warty disease of Potatoes (*Synchytrium endobioticum*, Perc. =*Chrysophlyctis endobiotica*, Schilb).	Potato ..	?	First recorded from upper Hungary in 1896. Reported to have occurred in England (near Birkenhead) in 1901; In Cheshire and Wales (Dolgelly) 1902; Lancashire 1903; Scotland 1907; Ireland (Co. Down) 1908; Germany (Westphalia, Rhine Provinces and Silesia (Breslau) 1908; Newfoundland, October, 1909. Sweden (near Stockholm) discovered in 1912 but found to have been present since 1910 or 1911 and was introduced by empty sacks from a seedsman who dealt in German potatoes. Russia 1911. Belgium reported in 1913.	Chiefly by means of tubers, in which it is hard to detect in mild attacks or early stage. Also in manure from animals fed on diseased potatoes. Also on boots, implements, etc., of workmen and by infected soil. Said to live several years in soil, and so will infect succeeding crops direct from the soil.	

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(8) Grass blight (*Cladochytrium graminis*, Büsg. =*Physoderma graminis* (Büsg.) Fisch.).	*Dactylis glomerata*, *Festuca* and other small-leaved grasses.		First described by Büsgen in 1887 in Germany, where it occurs from Hamburg to Baden and Triglitz. In England was first reported in 1908, and was found in several widely separated parts in the south in 1913. Introduced from the Continent.	With seed. Appeared in 1908 in England in every instance where portions of a consignment of Continental grass seed had been sown. Found in the seed coats in 5 per cent. of seed that had given a diseased crop.	
(9) Warty disease of Lucerne (*Urophlyctis Alfalfæ* (Lagerh.) Magn.).	Lucerne ..	?	First observed in Ecuador in 1892, or shortly before. Switzerland (near Basel) reported in 1902; Alsace (Colmar) collected in 1902; Italy recorded in 1905; England (near Herne Bay) 1905-06; Bavaria seen in 1907; United States first recorded in 1909 in California; in 1910 observed in Oregon and became serious disease in 1911; found in Utah more recently. India collected in Punjab in 1911; Holland 1913. Not yet recorded from south-west Asia, the home of the host plant.	The resting sporangia are set free in the soil from the rotting tissues and can survive for several years (allied species for 7 years). The means of spread will, therefore, be much the same as in warty disease of potato, except that the seed is not known to be directly infected as potato tubers are. Long-distance spread is probably by contaminated soil or plant débris mingled with the seed as dirt.	
(10) Potato blight (*Phytophthora infestans* (Mont.) de B.).	Potato, Tomato and some allied wild plants.	Andes ..	First attracted general notice in Europe in 1845, when a violent epidemic extended from Norway to Bordeaux and from Poland to the Atlantic. Perhaps the first trustworthy	Can only be spread for relatively short distances by the spores. Long-distance spread entirely due to mycelium in diseased tubers.	

			observation of it was at Liége (Belgium) in 1842; but there were notes of potato diseases, which may have been in part this, in France, Belgium, and Germany in 1840 and 1841; in Norway, Denmark, and the United States in 1841-42; in Canada and Italy in 1844. It was epidemic in Canada and the eastern United States in 1845. The Island of St. Helena was ravaged by a potato disease for several years prior to 1844, which was probably the same. No evidence that it was known before 1840.	Following on the introduction of steamers, the rise of the Guano trade, and the use of ice at sea, diseased tubers are believed to have successfully crossed the zone of high temperatures which isolate the Andes, without having the internal mycelium killed. It would be of interest to ascertain if St. Helena was visited by South American steamers about 1840.
			Subsequently it was found attacking wild Solanums at Quito in the Andes, near the home of the potato, and it is generally accepted that the disease spread from this area, where it has probably existed from time immemorial. The fungus cannot stand a high temperature for long and remained isolated till quick transport came in.	
			Reached the hills of South India perhaps between 1870 and 1880. First introduced to North India about 1883 with English potatoes; spread rapidly along Himalaya and reached Khasi Hills in 1885. First reported in plains of Bengal in 1902, but died out from heat. Appeared again	

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(10) Potato blight (*Phytophthora infestans* (Mont.) de B.).—*Contd.*	Potato, Tomato and some allied wild plants.	Andes ..	in 1912 but none since. Reported in every State in Australia in 1909, the earlier record in New South Wales in 1846 being doubtful. Is now practically everywhere that the potato is grown, except certain hot and dry regions.		
(11) Lilac blight (*Phytophthora Syringæ* Kleb.).	Lilac ..	Old World ..	First recorded in Germany (Hamburg) in 1905. At Geisenheim on the Rhine in 1910. Reported in Holland (Schoevers) in 1913. Not yet known elsewhere, though an allied fungus was described as *Ovularia Syringæ* Berk. in England in 1881 (*Gard. Chron.* II, 16, 1881, p. 665; II, 20, 1883, p. 439; and II, 26). This does not, however, seem to be identical.	Spores suited for rapid dissemination are rarely formed, the chief spores being resting oospores buried in the tissues. Could be conveyed in living plants or cuttings.	
(12) Vine mildew (*Plasmopara viticola* (B. & C.) Berl. & de Toni).	Grape vine ..	United States ..	The fungus is common but only moderately destructive on the wild American grape vines and is probably indigenous in the United States. It was first observed in Europe, in Hungary, in 1877. France, observed by Planchon, in 1878; extended to the Rhone	Is well supplied with spores for short distance spread. Has also resting oospores buried in the tissues. Reached Europe as a result of the importation of American vine stocks introduced to replace those destroyed by *Phylloxera*.	

			and Savoy districts in 1879. Italy (Pavia) 1879; Algeria and South Tirol 1880; Greece 1881; Alsace 1882; Recorded in Australia (McAlpine & Robinson) 1898; Recorded in Java (Breda de Haan) 1905, and believed to have been imported on fresh fruit on the mail boats. Reached Cape Colony in 1907 or shortly before, the previous record by Schroeter in Engler's "Pflanzenfamilien" being unsupported by evidence (Lindau, *Notizblatt K. Bot. Gart. Berlin*). Recorded in China 1913, Japan 1913 or earlier, Formosa and Uruguay 1914. Collected in India in 1910, but not known when introduced.	Has travelled to other areas chiefly with vine stocks but possibly at times with the fruit.
(13) Downy mildew of Cucurbits (*Pseudoperonospora cubensis* (B. & C.) Rost.).	Melon, Cucumber, Marrow, Gourds and allied plants.		First described from Cuba in 1868; collected in Japan in 1888; United States (New Jersey) 1889, and spread rapidly over eastern and southern States. England observed in 1899; collected in Brazil in 1900; Russia and Java 1902; Hungary, Italy, and East Africa 1903; Austria 1904; China 1908; India 1910 (newly introduced to Pusa); Australia 1910-11; Russian Manchuria 1914; Formosa 1914.	Is well supplied with spores for short-distance spread, but only these short-lived, "summer spores," are known with certainty, the record of resting spores (oospores) in Russia being very doubtful. If they occur they are certainly rare. The fungus is not known to reach the seed. The long-distance spread of this fungus presents one of the greatest mysteries of any known parasite and no explanation can yet be offered to account for it.

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	REMARKS
(14) Sedge mildew (*Kawakamia Cyperi* Miyabe).	*Cyperus tegetiformis.*	East Asia ..	First described in Japan in 1904. Recorded in Formosa 1914. Recently introduced into the United States (Texas) in an attempt to establish the grass mat industry of China and Japan.	Is well supplied with spores for short-distance spread. Was introduced into the United States by an emissary of the U. S. Department of Agriculture who obtained large quantities of the host plant from Japan. Travelled in the living plants.	
(15) Vine oidium (*Uncinula necator* (Schw.) Burr.).	Grape vine ..	United States ..	Long known in the United States where it is probably indigenous. Appeared first in Europe in a greenhouse at Margate (England) in 1845. Seen in one of Rothschild's greenhouses at Suresnes, near Paris 1847. On vines in gardens round Suresnes, and in Belgium 1848. All around Paris 1849. Bordeaux, Spain, and Italy 1850. All over France, Spain, and Italy; in Switzerland, Hungary, and along the shores of the Mediterranean (Greece, Syria, Asia Minor, and Algeria) 1851. In 1854 reduced French harvest to between 1/10 and 1/20 of the normal. Australia 1866-67. Is now found practically wherever the grape is cutilvated. It may be taken to have reached every vineyard in Europe by 1851.	Has enormous numbers of "summer spores." In the United States has also a durable "winter stage" (perithecia) but this was not found in Europe until 1892 and is formed only rarely in Europe. Introduced either as persistent mycelium, patches of which have been shown to develop in autumn and to remain dormant on the twigs till the following season, when they bear summer spores; or perhaps may have come over as perithecia. In either case it travelled with living vine stocks imported from the United States. Its subsequent long-distance spread was probably in the same manner.	

(16) Euonymus oidium (*Oidium Euonymi-japonici* Sacc.).	*Euonymus japonicus.*	Japan ..	First recorded in 1900 in Livorno, Italy, but subsequently found had been collected at Florence in 1899. England (Sussex) 1903 but it is said to have been seen at Seaford on the coast in 1902. Austria (near east Italian frontier and in south Tirol), and at Padua in Italy 1903. Naples, and at Avignon, near Paris and elsewhere in France 1904. Now throughout southern and western Europe.	Only the summer stage of this fungus is known, but it is believed that it is the same as an endemic form of ***Erysiphe Polygoni*** D. C. which is known in Japan on the same host. It lives through the winter as persistent mycelium and doubtless travelled from Japan on living plants or cuttings in this manner.	
(17) American Gooseberry mildew (***Sphærotheca*** *mors-uvæ* (Schw.) Berk.).	Gooseberry, Currant and some wild species of ***Ribes***. Also said to attack Raspberries sometimes.	United States ..	Known in the United States since 1834 on wild species of *Ribes*, and probably indigenous. First reported in Europe from north Ireland in 1900. Reported in Russia in 1902, but was probably present from 1900 or even earlier, and the foremost Russian authority (Jaczewski) thinks may have been introduced to the southern districts from the U. S. as far back as 1890. Specimens were collected in Russia in 1901. Reported in Denmark in 1904, but there is evidence that it was present in 1900 and reached Sweden and Norway with plants bought from a nursery at Korsör (Denmark) in 1900,	Is abundantly provided with summer conidia. Was not spread over long distances in Europe by the wind as the records in many countries show. Has numerous "winter spores" (ascospores) formed in the mycelium on the bushes, within durable perithecia. Travels readily by means of these for long distances on living plants and (as they become dislodged fairly easily) probably also in packings. Eriksson, the well-known Swedish mycologist, thinks it was chiefly distributed from Russia and Denmark,	In the United States, ***Ribes*** ***aureum***, currant and raspberries are either immune or only attacked under exceptional circumstances. For this and other reasons some believe the parasite has developed accentuated virulence in Europe. American gooseberries (chiefly *Ribes oxyacanthoides* and ***R.*** *cynosbati*) are not much injured but ***R.*** ***Grossularia*** cannot be grown successfully though its hybrids

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	REMARKS
(17) American Gooseberry mildew (*Sphærotheca mors-uvæ* (Schw.) Berk.).—*contd.*	Gooseberry, Currant and some wild species of *Ribes*. Also said to attack Raspberries sometimes.	United States ..	the disease being observed in Sweden in 1901, though not reported until 1905. It is believed to have reached Denmark direct from the U. S. Finland 1904 (imported from Russia). Germany 1905 (Posen, probably from Russia) but it is said to have reached Sweden on German plants in 1904. Austria 1905 or 1906, and spread to many places from one nursery. England 1906 on wild *Ribes aureum* stocks from France and shortly after on gooseberries near Eversham, where for several years previously plants had been imported from the Continent. Hungary 1908. Belgium 1909 or 1910. Reported in France for first time 1913 but must have been present since 1906 if the record under England is correct. Recorded from Russian Manchuria 1914 but has been prevalent since 1912. Not known in Japan up to last year (verbal communication from Yamada at Kew, 1915). By 1915, no European country that grows gooseberries was free.	there being no evidence of its distribution from Ireland. There is no evidence that it over-winters in the mycelial condition or could travel long distances in this form.	with the other two can.

(18) Oak mildew (*Microsphæria Alni* (Wallr.) Salm. a specialised form).	Oak and other species of *Quercus*.	United States ..	Common on species of *Quercus* in the United States, where it is probably indigenous as an endemic form of this common mildew. First noticed in Europe in the west and centre of France in 1907. Spread with phenomenal rapidity and in 1908 was known to be in most countries except Russia, Roumania and perhaps the rest of the Balkans and Scandinavia. In 1908 (end) also in Algeria. In 1909 reached Riga and the Caucasus in Russia, and also Turkey, Asia Minor, and Madeira.	Produces great numbers of summer spores and its rapid spread throughout Europe suggests aerial dissemination through comparatively long distances. In this it differs from most of the other diseases recorded. Winter fruit (perithecia) first found in France in 1911, but seem to be produced only under exceptional circumstances. Usually passes the winter in the mycelial condition more or less dormant until spring when new summer conidia are formed. Ornamental species of *Quercus* are said to be sometimes imported to Europe from the United States and no doubt the fungus travelled on these in the dormant condition. Perithecia may also have come on such plants.	The virulence is said to be declining in places, as in France in 1912 and in Croatia in 1910-11, though, there was a recrudescence in the latter area in 1912, associated with an epidemic of a leaf wasp.
(19) Mildew of Rue (a specialised form of *Oidiopsis taurica* (Lèv.) Salm. described under the name of *Ovulariopsis Haplophylli* (Magn.) Trav.).	Rue and *Haplophyllum*.	South-West Asia..	Collected in Palestine by Bornmüller in 1897 on *Haplophyllum* sp. (a section, according to many, of *Ruta*). Found in Italy on *Ruta graveolens* (rue) in 1913. Does not seem to be known elsewhere.	Has the usual summer spores and winter fruit of the mildews but there is no evidence to show how it reached Italy, or even if it is a new introduction or had merely been overlooked.	

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	REMARKS
(20) Black rot of the Vine (*Læstadia* (*Guignardia*) *Bidwelli* (Ellis) Viala and Rav.).	Grape vine ..	United States ..	First signalled in the United States in 1848, but was certainly present long before. Found first in Europe in France (Hérault) in 1885. Did much damage in le Lot, l'Aveyron, and le Lot-et-Garonne, 1887. A few years later was all over south-east and south-west France. Its present distribution in Europe is difficult to ascertain. It had not been found outside France up to 1907. It was not in Italy at least up to 1913 (the former record having been found to be due to confusion with another parasite). In Spain, it was first recorded in 1914 in the region of Valencia. Algeria seems to be free at present. There was an outbreak reported in the Caucasus in 1896, but subsequent investigations showed this to be due to an allied species. First recorded in South Africa in 1911.	Is abundantly supplied with summer spores and winter fruit. Is said to have been introduced into France on American vine stocks. It is very closely dependent on special weather conditions to cause epidemic outbreaks.	Though the fungus does much damage at times in the United States there are certain American species as *Vitis rotundifolia*, which are highly resistant to its attacks.
(21) Tomato, Melon, and Cucumber spot or canker (*Mycosphærella citrullina* Gros.).	Melon, Cucumber, Tomato.	United States ...	Was probably observed in the United States (Delaware) in 1890 but the cause was not accurately determined. First fully studied in New	Is abundantly provided with Summer spores and has also winter fruit (perithecia). It is not clear how it reached England, if it	

			York State in 1907-08. First record in Europe in England in 1909, as quite recently received at Kew on tomatoes from Waltham Cross and on cucumbers from Gloucestershire. On tomatoes from Guernsey and Kenilworth, 1910.	came from the United States, as it is said that living melon plants (on which it chiefly occurs in the United States) are not imported to England from America. It might, however, travel with seed to which spores have gained access.	
(22) Chestnut bark disease (*Endothia parasitica* (Murr.) And.).	Chestnuts (*Castanea dentata; C. vulgaris, C. pumila, C. crenata*); also Oaks (rarely).	East Asia	First seen in Bronx Park, New York, in summer 1904, but said was certainly at that date scattered in 3 or 4 of the neighbouring counties. In a few years had exterminated the chestnuts in New York and Brooklyn. Eight States infected in 1908. New Hampshire to Virginia and west to the borders of New York State and western Pennsylvania, but not yet in Ohio or Indiana in 1914. Found on two single trees imported from Pennsylvania in two localities in Nebraska towards end of 1914. In 1908, loss estimated at 5 to 10 million dollars in and around New York city. In 1911, 25 million dollars was considered a conservative estimate. In 1912, the total loss to date was said to be about 50 millions. Up to 1912, no case reported of a tree or grove once attacked having been saved by any method.	The summer spores (pycnospores), formed in enormous quantities, are extruded with mucilage and remain adherent till well wetted. They spread the disease on the tree but are not well suited for wind dissemination. Great numbers of ascospores are also produced, and as they are shot out into the air, they are suitable for wind dissemination. Birds and insects might carry the pycnospores, which have been found in quantity on woodpeckers. The most dangerous means of extensive (discontinuous) spread was found to be on living plants from nurseries. Pycnospores separated out in water and then dried on glass slides may live up to two weeks; ascospores up to 35 days. If not dried first from water live longer, and this	Some American workers early suggested that the disease was of Asiatic origin, on the ground of the relative immunity of Japanese, Chinese, and Korean varieties. This opinion was triumphantly vindicated in 1913.

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(22) Chestnut bark disease (*Endothia parasitica* (Murr.) And.).—*contd.*	Chestnuts (*Castanea dentata; C. vulgaris, C. pumila, C. crenata*); also Oaks (rarely).	East Asia ..	Early noticed that the Japanese chestnut (*C. crenata*) was more resistant. Japanese, Chinese, and Korean varieties had been introduced for growth in the United States, especially Japanese. Hence a search was made for the disease in East Asia and it was discovered in Northern China by an emissary of the United States Department of Agriculture (Meyer, reported by Fairchild) in 1913. The parasite was proved by cultures in the United States to be identical. Quite recently (1915) it has been found on wild and cultivated trees in Japan.	is also the case with spores liberated on the bark or leaves. A strip of mountain, 30 to 40 miles broad, free from chestnuts, west of the heavily infected Hudson valley, kept the disease from spreading across it for at least 10 years.	
(23) Black knot of Plum, &c. (*Plowrightia morbosa* (Schw.), Sacc.).	Plum, Cherry and some wild American species of *Prunus*.	United States	Described in 1821 in the United States where has probably been for very long, as there is a record of an epidemic in cherries in Pennsylvania in 1790. It is probably indigenous on wild species of *Prunus*. Occurs throughout the eastern States from New England to Alabama, and west beyond the Mississippi. Not yet known in Europe.	Spore production very copious, both summer and winter forms being produced. Well suited for wind dissemination. It is said that the import of living plants subject to this disease is not likely to have occurred from the United States, as they (especially the plums) are inferior to the European varieties	

(24) **Bamboo smut** (*Ustilago Shiraiana* Henn.).	Bamboos ..	Japan ..	Imported from Nagasaki, Japan, to the Chico Experiment Station, California, in 1909, and detected on the imported plants in 1910.	Came with the living plants.	
(25) Coffee leaf disease (rust) (*Hemileia vastatrix* B. & Br.).	Coffee and the wild and semi-wild African species of *Coffea*.	Probably eastern or central Africa.	First seen in Ceylon in 1868; Mysore 1869; Sumatra and Java 1876; Natal probably 1878; Fiji Islands 1879; Mauritius about 1880; Réunion 1882; Philippine Islands 1885; Madagascar since at least 1886 but is said to have been first introduced in 1872 or 1873 by a Ceylon planter who came to examine coffee growing in the island. Tonkin 1888; reported in Malaya and Borneo 1888; Samoa 1894 (said to have come direct from Ceylon); New Hebrides about 1909; New Caledonia 1911. Is widespread in Africa near the great lakes and has been found as far west as long. 23° E. in the Congo. In this area grows on wild or semi-wild species of *Coffea* and is probably indigenous.	Uredospores produced in vast numbers and can survive for some weeks, having been germinated in Germany after coming from Mauritius *viâ* England. Durable spores (teleutospores) rare and have only been seen by one observer (in Ceylon). Would travel readily for comparatively long distances as living uredospores which had reached the seed or packings. Was probably introduced into the Fiji Islands with a box of Ceylon seed packed in soil. Could also be carried readily on living plants and it is on record that such living plants of the newer African varieties have been sent to Java and possibly elsewhere from Brussels. Whether living plants were moved long distances as far back as 1860—70 is doubtful.	Many of the more recently introduced African species of *Coffea* are relatively immune, which supports the idea that the disease is of African origin.
(26) Rusts of orchids (*Hemileia americana* Mass.) *H. Phaji* Rac., *H. Oncidii* Grif. & Maubl., and probably other allied forms.	*Cattleya*, *Phajus*, *Oncidium*, and probably also *Epidendrum* and *Lycaste*.	Tropics ..	*H. americana* was imported to England from Costa Rica on leaves of *Cattleya Dowiana* in 1899. The spot was single when received, but falling spores infected other leaves. The rust was previously un-	Have reached Europe with their host plants. Can spread, if conditions of temperature, humidity, &c., remain favourable, by means of spores, from plant to plant.	

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	REMARKS
(26) Rusts of orchids (*Hemileia americana* Mass.) *H. Phaji* Rac., *H. Oncidii* Grif. & Maubl., and probably other allied forms.—*contd.*	*Cattleya*, *Phajus*, *Oncidium*, and probably also *Epidendrum* and *Lycaste*.	Tropics ..	known. *H. Phaji* was found on *Phajus Wallichii* in the Botanic Garden, Dublin, in 1911, and there is a specimen in the Kew Herbarium probably from some British source. The fungus was first described in Java in 1900. *H. Oncidii* was imported by Messrs. Stuart Low & Co., from San Paulo, Brazil, in 1909, on *Oncidium varicosum*, and probably the same fungus was seen in the Botanic Garden, Dublin, on this host and also *O. Forbesii*. It has also been imported into France, where it was first described. Other similar rusts seem to have been observed on *Epidendrum vitellinum* and *Lycaste Skinneri*.	Grove (" British Rust Fungi," 1913) remarks that these tropical fungi " might easily become dangerous parasites in Orchid houses, if allowed to spread." Each is, however, probably confined to a single genus, if not species, of host plant, and so far there seems to be no record of much damage.	
(27) Carnation rust (*Uromyces caryophyllinus* (Schrank) Schrœt).	Carnation, Dianthus, Gypsophila.	Europe ..	Known in Europe since 1789. First reported in the United States (Michigan) in 1890. Spread rapidly and was exceedingly virulent for the first few years, but by 1896, was reported to be doing less harm.	As with most other rusts, local spread during the growing season is secured by the uredospores which are relatively short-lived but have been shown in many cases to survive for several weeks, or even, sometimes, for some	

			Does relatively little damage in Europe. Has reached Australia and other parts of the world.	months. A second spore form, the teleutospore, is more resistant and in many species carries the fungus over to the following year. Long-distance spread has probably occurred on living plants or cuttings.	
(28) Euphorbia rust (*Uromyces Euphorbiæ* Cke. & Peck).	Euphorbia ..	America ..	A case has been recorded where this rust was introduced into upper Italy on *Euphorbia Presslii* from America. It is mentioned merely as a recorded example of the introduction of a parasite which does not cause an important disease of a plant of economic value, but which accompanied its host plant. There are a good many similar cases on record, and probably most large herbaria could show one or more examples of exotic parasites thus introduced. The two grass rusts on *Elymus* and *Beckmannia* imported to Australia from the United States have already been mentioned (p. 29). Yet, because such plants of little or no economic value are rarely imported, the proportionate number of their parasites that have become widely distributed is much less than in the case of cultivated plants. For instance, Massee has	It has been demonstrated by Carleton that this rust can be carried on the seed; plants from such seed became rusted unless the seed was disinfected before sowing (*Euphorbia dentata*).	

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(28) **Euphorbia rust** (*Uromyces Euphorbiæ* Cke. & Peck.)—*contd.*	Euphorbia ..	America ..	recently stated (*Jour. Econ. Biology*, X, June 1915, p. 47) that there are no less than 30 species of *Puccinia* on wild plants in Scandinavia, Belgium, France and other neighbouring countries, not yet recorded in Britain, though their host plants grow wild in this country; while about an equal number of British species are absent from these countries, though their host plants are found there.		
(29) **Hollyhock rust** (*Puccinia malvacearum* Mont.).	Hollyhocks and many other *Malvaceæ*.	Chile ..	First collected on marsh mallow (*Althæa officinalis*) in Chile by Bertero prior to 1831, and described by Montagne in 1852. Observed in Australia (near Melbourne) in 1857; collected in Australia in 1865; collected in Spain for first time in Europe in 1869. In several parts of France, various places in England, and Rastadt in Baden in 1873. All over Holland; Stuttgart, Erlangen, Nurenberg and Lubeck (Germany); on Fünen (Denmark); near Rome and Naples (Italy) in 1874; Erfurt (Germany); Switzerland; Cape of Good Hope 1875. In New Zealand since at least	Has only the teleutospore stage. The spores can germinate as soon as formed and give small short-lived "sporidia," which infect new plants and are disseminated by the wind. The teleutospores themselves do not fall off readily but remain mostly *in situ* till the plant withers and disintegrates. They are therefore carried on living infected plants or cuttings. According to Taubenhaus (*Phytopathology*, I, p. 58) the fungus overwinters in three ways; (1) As	Massee remarks (*Kew Bulletin*, 1913, p. 345) "when the hollyhock disease first appeared in Europe it rendered the cultivation of that plant well-nigh impossible. To-day hollyhocks are again in cultivation, and although the rust is present it does no material harm."

			1875. Münster, Bremen, Greifswald (Germany); Linz and in Krain (Austria); Hungary; Lombardy 1876; Brandenburg, on the Rhine, on the Elbe (Germany); near Athens 1877. First recorded in the United States (Massachusetts) 1886, introduced on seeds of imported *Malope*. Near Stockholm 1887. In 1889 was spreading in the United States, found in a nursery and in the Experiment Station at Geneva (New York), later in New Jersey and North Carolina. Finland 1890. Is known in Siberia. Probably Venezuela (as *P. Sidæ* Pat. 1888). Not yet seen in India.	developing mycelium in the tender young leaves, leaves infected in late autumn giving ripe teleutospores in early April; (2) As mature, hibernating teleutospores in living or dead parts of the plant; these spores are formed in late autumn and remain on the plant; (3) With the seed. The actual seeds are usually free from the fungus, but the enclosing bracts and sometimes also the persistent carpels bear spores. Infected fruits and carpels of *Malva rotundifolia* collected in November and planted with the seed in April caused the infection of the young plants and the formation of ripe teleutospores. Blaringhem in France holds that the seed carries the fungus in the obscure form known as "mycoplasm." It was undoubtedly spread by the trade in living plants and seeds.
(30) Sunflower rust (*Puccinia Helianthi* Alb. & Sch.).	Sunflower and other species of *Helianthus*.	America ..	First recorded in Carolina, United States, in 1822. Appeared in epidemic form in the sunflower cultivation of south Russia from 1866 to 1869. Spread westward from Russia, reaching Hungary soon after 1869, then Austria, and was	All the known spore forms of the rusts are found on the host plant, though the æcidial stage does not seem to have been found except in America and Russia. The teleutospores may germinate as

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	REMARKS
(30) Sunflower rust (*Puccinia Helianthi* Alb. & Sch.)—*contd.*	Sunflower and other species of *Helianthus*.	America ..	found in Silesia in 1874 and in Italy about the same time. In 1875, had not yet been recorded from Germany outside Silesia, from France or from England. Sydow's Monograph of the Uredineæ (1902) states that it occurs throughout most of Europe but does not give France or Britain. It is not mentioned in Grove's "British Rust Fungi" (1913). Recorded in Australia from 1887; China 1912. Known in Japan in 1913.	soon as ripe or may remain over the winter and germinate in the following spring. Spores would be likely to get on the seed and could be conveyed in this manner for long distances.	
(31) Chrysanthemum rust (*Puccinia Chrysanthemi* Roze.).	*Chrysthemum indicum* and *C. chinense.*	Japan ..	Probably indigenous to Japan, where it is very common. First European record in England in 1895 (though the chrysanthemum was introduced more than a century ago). France 1897; Italy, Denmark and Germany 1897 or 1898; Switzerland 1900. Reported in the United States (Massachusetts) in 1897; and in Indiana in 1899. Reached Australia (New South Wales) in 1904. New Zealand 1904. Collected in India (Nilgiris) 1904.	In the warmer coast region of Japan it is found only in the uredo stage, but in the colder parts in the interior the teleutospores are regularly produced. In Europe the teleutospores are rarely found but have been seen in France when first introduced. In Australia and India only the uredo was found. The uredo stage persists on the young shoots which come up at the end of autumn, and can remain on these shoots through the winter even in the open air.	

				Long-distance spread is on living plants or cuttings. It is believed to have reached Germany on new English varieties, and was imported into Australia on cuttings from England.	
(32) Asparagus rust (*Puccinia Asparagi* DC.).	Asparagus ..	Europe ..	Has been known in Europe for over a century, and is widely distributed. First observed in the United States in 1896, when spread rapidly in New Jersey and was found on Long Island, New York State. By 1901 had reached the Pacific coast, causing everywhere serious injury. In 1906, was said to be in every State in which asparagus was grown. It has been collected in Abyssinia. Not known in Australia (up to 1905) nor India.	All the spore forms occur on the host plant. The teleutospores which are formed in the autumn remain on the plant or fall to the ground, where they remain till the following spring and can infect the new crop. It is stated to have been introduced into the United States, no doubt on its host plant, from Europe.	It proved more destructive in the United States than in Europe, and English varieties that resist the disease have been introduced into America and their hybrids with local varieties were recently stated (1914) to be giving good results.
(33) Maize rust (*Puccinia Maydis* Béreng.).	Maize and Teosinte (*Euchlæna mexicana*).	America ..	Is not mentioned in European records up to 1815 (Frank) or 1837 (Schroeter). Herbarium records of Desmazières (? France) and from Holland in 1837; Italy 1815 or 1844 (when first named); Austria 1861: Baden (near Rastadt) about 1875. Is now practically wherever maize is grown. Is believed to be indigenous to the United States or Central America and was included with the sorghum rust under the name of *P. Sorghi* by Schweinitz ("N. Amer. Fungi") in 1831.	Like the other cereal rusts this fungus probably travels on or with the grain, or in straw packing, for long distances. It has an alternate stage on species of *Oxalis* in America, Europe, and South Africa, but can evidently dispense with this stage.	

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(34) Vine rust (*Phakopsora Vitis* (Thuem.) Syd.).	Grape vine, also *Vitis inconstans*, *V. flexuosa*, *V. lanata*.	? United States ..	First collected by Ravenel in the United States (Thuemen, "Pilze des Weinstockes," 1878, p. 182). Jamaica 1890 (Lagerheim); also known in Trinidad and St. Vincent. Java 1899. Japan 1899. Formosa 1914. Said to have caused the entire loss of the crop on affected plants in Jamaica. Not known in Europe. An allied species (*Phakopsora cronartiiformis* (Barc.) Diet.) occurs in great profusion on *Vitis himalayana* in the Himalaya, where the leaves are often smothered in spores. It is not yet known elsewhere.	Is known chiefly in the uredo stage (*Uredo Vitis* Thuem., *U. Vialæ* Lagerh.). The teleuto stage was first described from Japan in 1899. The life history of this genus of the rusts is quite unknown, the teleutospores not having as yet been germinated. Said to have been introduced into the West Indies from the United States. Would doubtless travel readily on living plants.	
(35) Rust of *Peltandra* (*Aecidium importatum* Henn.).	*Peltandra virginica*.	United States ..	This fungus developed on the stems and midribs of the host on plants grown from rhizomes imported to Germany from North America in 1894. It was not previously known, but presumably occurs in the United States. This seems to be a similar case to No. 28 above.	Is believed to have been carried in the rhizomes of the host plant.	

(36) Blister rust of white Pines (*Peridermium Strobi* Kleb. = *Cronartium ribicolum* Dietr.).	Five-leaved Pines, *viz.*, Stone Pine (*P. Cembra*), Weymouth Pine (*P. Strobus*), Sugar Pine (*P. lambertiana*) also *P. monticola* and possibly *P. excelsa*. The perfect (*Cronartium*) stage is known on Currant, Gooseberry and over 20 other species of *Ribes*.	Old World (possibly interior of Russia).	The fungus was first described from the southern shores of the Baltic in 1859 (collected about 1855). It caused an epidemic in Finland between 1869 and 1875. It was found in north Germany in 1872; Denmark 1872; Holland 1882; Sweden 1888; France 1890; Austria 1890; England 1892 (but the *Peridermium* stage had been seen some time before). Belgium 1894; Norway 1896; Switzerland 1898. Most of these records were on the Weymouth pine, which had been introduced to Europe from America (its native home) about 200 years ago. That the fungus had an alternate stage on currants and other species of *Ribes* was first established in 1888. Neither of the two forms of the fungus seem to have been seen in the United States until 1892, when the uredinal form was found on *Ribes longiflorum* in Kansas. This stage was again found at Geneva (New York) in 1906, and has since appeared in several localities (chiefly on currants). The *Peridermium* stage has been frequently introduced into the United States since 1903, several million diseased seedling pines having been sent chiefly from Hamburg. Over 230 localities have been found	Local spread takes place by means of the æcidiospores (*Peridermium* stage) from pine to *Ribes* only, not from pine to pine. In the same way the winter spores (*Cronartium* stage) can only spread from *Ribes* to pine, not from *Ribes* to *Ribes*. There is, however, another spore form (uredo) on *Ribes* which can spread from *Ribes* to *Ribes*. For long-distance spread, the stage on *Ribes* can travel in dormant *Ribes* stocks or cuttings in the bud scales and young twigs. The *Peridermium* stage is conveyed in the interior of the stem in the mycelial condition, in which it could escape even expert inspection. After infection there is a long incubation period (from one to several years) before the first spores are produced, and during this period there may be no symptoms until a few months before spore formation, when the bark thickens at the infected part. On the other hand the incubation period on *Ribes*, after infection from the pine, is only about 12	Has rendered the growth of the Weymouth pine almost impossible in parts of Europe (Denmark, Holland) and often kills from 15 to 100 per cent. of young trees.

Disease	Host plant	Probable country of origin	Distribution and extension	How spread	Remarks
(36) Blister rust of white Pines (*Peridermium Strobi* Kleb=*Cronartium ribicolum* Dietr.)—*contd.*	Five-leaved Pines, *viz.*, Stone Pine (*P. Cembra*), Weymouth Pine (*P. Strobus*), Sugar Pine (*P. lambertiana*) also *P. monticola* and possibly *P. excelsa*. The perfect (*Cronartium*) stage is known on Currant, Gooseberry and over 20 other species of *Ribes*.	Old World (possibly interior of Russia).	growing diseased imported Weymouth pines and recently it has been found on large native pines in Vermont (1914). In all cases except the last, *Ribes* were fortunately absent, and as spread from pine to pine cannot occur but only through *Ribes*, the disease is not believed to have become widely established yet in the United States. It was found (introduced) in Ontario, Canada in 1909, and was well established in both its stages by 1914, over a considerable area. The present distribution is all Europe except the Balkans and Iberian Peninsula ; Siberia, Japan, Sakhalin, and perhaps the Himalaya.	days, when uredospores are formed, the teleutospores appearing 1½ months or more after the uredospores. Though common in England in recent years, it was first observed in Ireland in 1915, apparently newly introduced on nursery stock.	
(37) Blister rust of Scotch Pine (*Peridermium Fischeri*=*Coleosporium Sonchi-arvensis*).	*Pinus sylvestris*. The perfect stage (*Coleosporium*) occurs on *Sonchus arvensis* and other species of *Sonchus*.	Europe ..	Long known in Europe. Was introduced into the United States and first seen in 1912 in a single nursery in Wisconsin. The perfect stage (*Coleosporium Sonchi-arvensis*) was found in the neighbourhood on *Sonchus asper*, so it has probably become established. Not known elsewhere in United States up to 1914.	Much the same as the above, except that there is not such a long incubation period on the pine. The damage caused is also less.	

(38) **Rusts of Chinese juniper (*Gymnosporangium Photiniæ* (P. Henn.) Kern = *G. japonicum* Syd.; and *G. koreænse* (P. Henn.) Jackson = *G. Haræanum* Syd.).**	*Juniperus chinensis.* The alternate stages, *Ræstelia Photiniæ* and *R. koreænsis*, occur on *Photinia* (*Pourthiæa*) *villosa* and on *Pyrus sinensis*, *Cydonia vulgaris*, and *C. japonica*, respectively.	Japan ..	Collected first in America (Connecticut) in 1911 on stock of Chinese juniper just imported from Japan. It was subsequently found that both the fungi mentioned were mingled on the specimens. *Ræstelia koreænsis* was first found in the United States (California) in 1913 on *Pyrus sinensis*, in a nursery run by Japanese, and it is assumed that infected trees of *Juniperus chinensis* must have been previously imported in the neighbourhood. It was again found in Oregon in 1914 on the same host and the following year *Gymnosporangium Haræanum* was found on Chinese junipers near by. *Gymnosporangium Photiniæ* was found again at Seattle in May 1915, no doubt as a separate importation, since practically all the examples of chinese juniper are imported from Japan.	These rusts have reached the United States on the juniper, and subsequently spread to the Japanese pear in the case of *G. Haræanum*, which has thus become established in the United States.	As in all species of *Gymnosporangium*, the infection of the teleuto-bearing host (the juniper in these cases) occurs in the summer, and the spores do not appear in maturity until the following spring or even a year or more later. Several species are perennial. Hence it is easy for these fungi to escape detection and they could readily travel in the mycelial condition within the host.
(39) **Blister Blight of Azalea (*Exobasidium* sp.).**	*Azalea indica* ..	Probably Japan..	This fungus was first seen in Europe in Holland where it was recorded in 1906. Italy (near Rome) 1907; Germany, England (Cornwall) 1908. Reported in Belgium (near Ghent) in 1913. The identity of the parasite is still doubtful but it is believed in Germany to be either *Exobasidium japonicum* or *E. pentasporium*, which occur in this plant in	The spores are probably, as in allied species, relatively short-lived but suited for wind dissemination. It could travel readily on living plants and is believed to have been distributed in Europe by the horticultural trade of Holland.	

Disease	Host plants	Probable country of origin	Distribution and extension	How spread	Remarks
(39) **Blister Blight of Azalea** (*Exobasidium* sp.).—*contd.*	*Azalea indica* ..	Probably Japan..	Japan, while in England it has been referred to *E. japonicum.* This species was described by Shirai in 1896 in Japan.		
(40) **Tomato leaf spot** (*Septoria Lycopersici* Speg.).	Tomato ..	South America ..	First described from South America (the native home of the tomato) by Spegazzini in the Argentine in 1884. Is believed to have appeared in Europe shortly after the introduction of the tomato into cultivation. It was known in Italy between 1888 and 1891; Hungary 1902-03. France and Germany (Hamburg) 1905. It was first reported in England in 1908, when it was said that it had damaged the crop in Gloucestershire the previous year. In the report it is said that there is little doubt it was introduced from abroad with cultivated tomatoes. Noted first in the United States (New Jersey) about 1893 and Ohio in 1896. Is now a destructive disease east of the Mississippi. Reported in Australia 1910-11.	Is abundantly provided with spores. Could travel on living plants and very probably also in packings. The spores might perhaps also get mingled with the seed and travel with it. It does not seem to be known how long they live, but several allied species have fairly long-lived spores.	
(41) **Celery leaf spot** (*Septoria Petroselini* Desm. var. *Apii* Br. & Cav.).	Celery ..	Old World ..	The fungus was first described in 1890 from the Botanic Garden, Pavia, Italy. It was recorded in 1891 in the United	Is well provided with spores for short-distance spread. Has been widely disseminated on seed, as abun-	

			States (New Jersey and Delaware). Probably recorded in Bavaria as *Phlyctæna Magnusiana* (All.) Bres. in 1891. Elsewhere in Germany in 1895, and spread rapidly. Belgium 1898; Norway from at least 1899; England 1906. Also known in France. South America as *Septoria apiicola* on *Apium australe*, (Spegazzini "Fungi Fuegiana") 1882. Australia, 1910-11. Formosa, 1914.	dantly established in the past few years. Was found on wild celery in Ireland in 1913 and suggested that it originally spread from the wild to the cultivated plant. Wild celery is found in Europe, North Africa, Western Asia and North-West India, so that spread to the cultivated plant might have occurred throughout a wide area.
(42) **Anthracnose of Melon, Cucumber and Vegetable Marrow** (*Colletotrichum oligochætum* Cav.).	Melon, Cucumber, Vegetable Marrow, *Lagenaria vulgaris*, &c.	?	First described under this name from Lombardy in 1889. It is, however, very doubtful whether the fungus is not identical with *Glœosporium Lagenarium* (Pass.) Sacc. & Roum., which has been long known on the same hosts and attracted notice in England in 1876 (*Gard. Chron.* 1876, II, pp. 175, 269, 303, 336, 400, 495). *Colletotrichum oligochætum* was next recorded in France in 1894. In 1912, it was reported as a new disease in England (*Journ. Board of Agric.*, XVIII, p. 670). The anthracnose due to *Glœosporium Lagenarium* is widely distributed in Europe and the United States, and has been recorded from Formosa in 1914.	Only summer spores are known. In America conflicting results have been obtained in cross-inoculations with this fungus and that found in bean anthracnose (*Glomerella cingulata* (Stonem.) S. & v.S.). The most recent workers regard them as probably distinct species, but if they are proved to be identical then the parasite is of practically world-wide distribution. *Glomerella cingulata* can attack a very large number of plants in all parts of the world, and there is no evidence that it has been recently introduced into Europe, Asia or America. There is, therefore, much doubt whether this is really a new disease in England or indeed anywhere else.

APPENDIX II.

International Phytopathological Convention of Rome.

Article 1.—The contracting States agree to take the necessary legislative and administrative measures to ensure common and efficacious action against the introduction and extension of enemies of plants.

These measures should especially have regard to: (1) the efficacious supervision of nurseries, gardens, green-houses, and other establishments engaged in trade in living plants (plants, cuttings, grafts, flowering bulbs, and cut flowers); (2) the recording of the appearance of diseases of plants and of injurious animals with the localities infected; (3) the means of checking and preventing the diseases of plants; (4) the regulation of the transport and packing of the plants and parts of plants mentioned above; (5) the measures to be taken in case of a breach of the regulations.

Article 2.—There shall be created in each State adhering to the present Convention a government service of Phytopathology intended to secure the execution of these measures.

The government service of Phytopathology will comprise as a minimum: (1) the creation of one or more establishments for study and for scientific and technical research; (2) the organisation of effective supervision of the growing plants; (3) the inspection of consignments; (4) the issue of phytopathological certificates.

Article 3.—The measures indicated in paragraphs 2, 3, and 4 of Article 2 shall be already in force at the moment of ratification of or of adherence to the present Convention.

All other measures indicated in Articles 1 and 2 shall be taken in each State within a period of two years from the date of ratification of or of adherence to the present Convention.

Article 4.—The present Convention shall not apply to the vine, to grains and seeds, to edible tubers, bulbs, rhizomes and roots, to fruit and vegetables, to roots and produce of field cultivation.

Article 5.—In order to protect contracting States against the introduction and the extension of plant enemies, these States pledge themselves not to allow the importation of living plants (plants, cuttings, grafts, flowering bulbs, and cut flowers) unless they are accompanied by the Phytopathological certificate issued by competent official agents of the exporting country.

Article. 6.—The importation of the plants referred to in the preceding Article can only take place through Custom Houses of which a list shall have been drawn up by the importing country and communicated to the exporting country.

Article 7.—Each country reserves its right to inspect plants or fresh debris imported.

In case the consignment of plants is found to be infected contrary to the indications of the certificate, the importing country shall immediately advise the Government of the exporting country, which will take the measures provided in its regulations.

The infected produce will be returned to the point of departure at the expense of the proper persons or destroyed by fire if required by the importer ; in this last case, a report shall be transmitted to the Government of the exporting country.

Article 8.—The certificates shall be in the form appended to this Convention and drawn up in two languages : that of the exporting country and French.

Article 9.—Notwithstanding the above stipulations, the importation of living plants is permitted in the interest of scientific research, even without a certificate, on condition that their destination is a scientific institution duly authorised by the Government of the importing country and that the state of the consignment offers every guarantee against the escape of parasites.

States with adjoining frontiers may make mutual arrangements to facilitate the exchange of plants in frontier zones.

Article 10.—The several contracting States are invited to furnish to the International Institute of Agriculture, Rome, at the moment of ratification of or of adherence to the present Convention, a list as restricted as possible of the enemies of plants against which they wish to protect themselves and which must appear on the respective certificates. These lists will be compiled according to the following principles :—

A.—In the enumeration of the enemies of plants common species of long-standing dispersion extending to nearly all countries will be excluded.

The same will be the case with enemies of plants whose ordinary supports do not exist in the importing countries.

B.—In specifying the enemies of plants which are to figure on the lists, the choice will be limited to those presenting—

(1) An epidemic character.

(2) A destructive or at least very harmful action on cultivated plants.

(3) An easy propagation by living plants or parts of living plants.

Article 11.—The creation of the government service of Phytopathology shall be notified by each contracting State to the International Institute of Agriculture, Rome.

Article 12.—The contracting States recognise, from the time of signing the present Convention, the International Institute of Agriculture, Rome, to be the official international centre for all questions relating to the enemies of plants.

The Institute shall collect statistical data as well as administrative, scientific, and practical information concerning all diseases and enemies of plants, through the medium of documents which shall be communicated to it as soon as possible by the government services of Phytopathology and the establishments for Phytopathological Research placed under the authority and control of the several Governments.

Article 13.—The International Institute of Agriculture shall publish, at least once a month, the administrative, scientific, and practical information transmitted to it.

Article 14.—Any proposal from a contracting State tending to modify or amplify the present Convention shall be communicated by that State to the Institute and referred by the latter to a meeting of special Delegates of the contracting parties which shall be called together on the occasion of a General Assembly of the Institute.

The proposals studied by these special Delegates will then be submitted by the General Assembly for the approval of the States which have adhered to the present Convention.

Article 15.—In case of disagreement between two or more contracting States as to the interpretation of the clauses of this Convention, and in case of practical difficulties in its application, the parties concerned undertake to submit their differences to the examination of a special joint Commission appointed from their Phytopathological services so that measures calculated to settle these differences may be proposed.

Article 16.—States bound by the present Convention shall not treat non-contracting States more favourably than contracting States.

Article 17.—The present Convention shall be signed and ratified as soon as possible and the ratifications shall be deposited with the Italian Government as soon as at least three contracting States are in a position to do so.

Each ratification shall be communicated by the Italian Government to the other contracting States as well as to the International Institute of Agriculture.

Article 18.—States which have not signed the present agreement shall be allowed to adhere on their request.

Colonies shall be permitted to adhere on the same conditions as independent States, at the request of the States of which they are dependencies.

Article 19.—Adherence shall be notified through diplomatic channels to the Italian Government and by the latter to the contracting Governments as well as to the International Institute of Agriculture.

Article 20.—Ratification or adherence shall be accompanied by a formal declaration that the State possesses at least the services indicated in paragraphs 2, 3, and 4 of Article 2.

The present Convention will become effective: for the first three States at least which shall have ratified it, in a period of three months from the date of ratification; for other States, in a period of six months from the deposit with the Italian Government of their ratification or adherence.

Article 21.—If it should happen that a contracting State wishes to denounce the present Convention, either for the whole of its territories or only for all or a part of its colonies, the denunciation shall be notified to the Italian Government which shall immediately communicate a true copy of the notification to all the other States informing them of the date on which it has been received.

The denunciation will only have effect in regard to the State which shall have notified it or of such colonies as are indicated in the act of denunciation, and that only one year after the notification shall have been received by the Italian Government.

FORM OF CERTIFICATE.

* INTERNATIONAL PHYLLOXERA CONVENTION OF BERNE AND INTERNATIONAL PHYTOPATHOLOGICAL CONVENTION OF ROME.

Certificate for consignments of horticultural plants. (Each statement on the Certificate to be accompanied by a translation in French.)

Name of Exporting Country.

I.—DECLARATION OF THE EXPORTER.

The undersigned (1) ....
declares :—

A. That the plants (2)...
contained in (3)..................packages, marked (4)..............
.... addressed to (5)...............................
in (6) ....have been produced entirely from his establishment or from other establishments under inspection by the Phytopathological service ;

*B. That this consignment contains no vines ;

*C. That the plants are packed (7)...............................
earth.

(8)..................the .....day of.....................19

Consignment from (9)...............

* Establishments entered in the list compiled in conformity with Article 9, §6 of the Berne Convention on Phylloxera, under the No. . . . . . . (10)

†II.—ATTESTATION OF THE ADMINISTRATIVE AUTHORITY.[1]

The administrative authority attests :—

A. That the above consignment of plants comes from ground separated from any vine plant by a space of at least 20 metres,

(1) Name, firm, profession and address ; (2) Kinds and quantity of plants ; (3) Number of packages ; (4) Mark and number ; (5) Complete address of the consignee, name, profession, domicile ; (6) Name of the importing country ; (7) Mention if the plants are packed *with* or *without* earth ; (8) Place of departure ; (9) Signature of the exporter ; (10) Enter the number under which the establishment is entered in the general list.

*Only required for States adhering to the Berne Convention.

†This certificate is only required for countries adhering to the Berne Convention and then only in case the establishment does not figure on the list published in virtue of Article 9, § 6 of the Berne Convention.

[1] Burgomaster, Mayor, or other competent authority according to the country.

or by an obstacle to the roots judged sufficient by the competent authority ;

B. That this ground does not itself contain any vine plants ;

C. That no deposit of vines has been made on this ground ;

D. That there has never been an infection of Phylloxera in the plantation or enclosure ;

E. If there have been any phylloxerised vines, that radical extraction has been done and that poisoning and repeated investigation during three consecutive years, have assured the complete destruction of the insect and of the roots.

......the (Date)...................

Seal of the competent authority.

....

(Signature.)

III.—Certificate of Phytopathological Inspection.

The undersigned, Inspector of the Phytopathological service (1)........ ....certifies that the consignment indicated in the declaration of the exporter (2).. of.................................and coming from cultures situated at...................................is according to the results of the inspection (3) $\frac{\text{of the growing plants}}{\text{of the transported produce}}$, in a satisfactory sanitary condition and that it is free from the enemies of plants enumerated below (4)

(Date)................

Seal.

....

(Signature.)

(1) Name in full, official designation and address of the inspecting officer.

(2) Name in full and domicile of the exporter.

(3) Delete where necessary the mode of inspection not employed.

(4) Complete by the list of the enemies of plants, enumerated in the official list of the importing country, which could exist in the consignment.

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I. INTRODUCTION.

The existence of an extraordinarily large number of well marked varieties is a striking feature of cultivated rice. It would be possible to collect many thousands of differently named varieties cultivated in India. Many of these are probably identical, though bearing different names, whereas in many cases the same name is applied to several different varieties. It is probable that the genetically distinct varieties would number several thousands.

The characters in which the varieties differ from each other are extremely varied. On the one hand are morphological characters affecting the colour, size, shape, etc., of various parts of the plant; on the other hand are such physiological characters as determine water-requirement, length of duration, vigour, etc. The variations shown in some of these characters are described by several authors who have proposed systems of classification of rice. The most recent work of this nature is by Graham[1] in India and Kikkawa[2] in Japan.

The present paper deals with the method of inheritance of some of the simpler characters. The material from which the results were obtained

[1] Graham, R. J. D., *Mem. Dept. of Agr. in India, Bot. Series,* vol. VI, no. 7.
[2] Kikkawa, S., *Journal of the College of Agr., Imperial University, Tokio,* III, 2.

consisted very largely of natural crosses resulting from the cultivation, side by side, of a large number of different varieties.

In 1913, when this work was started, an examination was made of about one hundred varieties growing on the Government Farm at Coimbatore. Some of these were almost pure, containing very few plants differing from the type, whereas others were so much mixed that it was impossible to distinguish a definite type for the variety. In each variety a few type plants were selected, together with any variations which were to be found. In selecting the latter such plants as appeared to be unrelated to the type, due to accidental mixture of other varieties, were neglected.

Almost all these selected plants were selfed in the manner described below. Their progeny, grown in 1914, showed that a large proportion of the aberrant plants were heterozygous. The segregating families gave Mendelian ratios for various characters and these were followed up in further generations. For the sake of convenience the original aberrant plants which proved to be heterozygous will be referred to as F_1 and their progeny as F_2, F_3, etc.

In addition to this material a few definite crosses were made between pure strains.

II. PRELIMINARY CONSIDERATIONS.

(*a*) Pollination.

From the accounts published by observers in different places it would seem that the details of normal pollination vary considerably for different localities.

Knuth[1] states that dehiscence of the anthers does not take place till they are fully extended and in a pendent position. Akemine[2] has found that in a variety of North Japan self-fertilization takes place immediately before the flowers open. Fruwirth and Van der Stok[3] conclude that in Java cross-fertilization occasionally takes place between neighbouring plants.

Farneti[4] reports that in Italy rice is cleistogamous, the glumes remaining closed throughout flowering. A number of freshly introduced and old acclimatized varieties gave the same result and he concludes that cross-fertilization is impossible.

[1] Knuth, P., *Hand-book of Flower Pollination*, vol. III, 1909, page 521.

[2] Akemine, M., "Ueber die Blute und das Bluhen von *Oryza sativa*," *Landw. Ztsch. Nogyo-Sekai*, 1910-11.

[3] Fruwirth, C., and Van der Stok, E., *Die Zuchtung der Landw. Kulturpflanzen*, Bd. V, p. 36.

[4] Farneti, Rodolfo, *Atti dell Istituto Botanico dell Universita di Pavia, Series II*, vol. XII, 1913, p. 351.

Hector[1], working in Lower Bengal, finds that dehiscence of the anthers normally takes place at the moment of opening of the glumes whilst the stigmas are still enclosed. He estimates, provisionally, that cross-fertilization may take place to the extent of about 4 per cent.

Graham[2] states that in five years' work at Nagpur, during which many different varieties were grown in adjacent lines, no case of natural crossing was detected.

McKerral[3] shows that in Lower Burma a certain amount of crossing undoubtedly takes place. His figures in connexion with the crossing of white rice by red (*l. c.* p. 326) indicate about 4 per cent. of total cross-fertilization.

Thompstone[4] notes that in Upper Burma "pollination takes place before the glumes open, or at the moment of opening—seldom afterwards." He finds that ".... hybrids are quite common among the numerous rogues to be found in nearly every field of ordinary paddy ...."

Observations made at several places in the Madras Presidency show that there is some difference between different varieties. Most commonly dehiscence does not take place till the glumes are well open and the anthers are partially extruded. Very exceptionally dehiscence takes place immediately before or during the opening of the glumes, whereas occasionally it is postponed till some seconds after the anthers have assumed a pendent position. In some cases it has been found possible to perform successful emasculations, for crossing purposes, by allowing the glumes to open naturally and removing the anthers as they emerge.

The amount of cross-fertilization taking place naturally was estimated for several varieties. In each case a variety was chosen which normally possessed a purple tip to the grain, but in which occasional plants altogether lacking in purple colouring were to be found. It will be seen later that such green plants are pure recessives, so that any purple-tipped plants in their progeny must be due to crossing. A few of these pure green plants, surrounded by the purple-tipped type, were picked out and allowed to set seed naturally. Their progeny contained a small number of purple-tipped plants which were counted and calculated as a percentage of the total number as shown in Table I.

[1] Hector, G. P., *Mem. Dept. of Agr. in India, Bot. Series*, vol. VI, no. 1.
[2] Graham, R. J. D., *l. c.*, p. 214.
[3] McKerral, A., *Agr. Jl. India*, vol. VIII, 1913, p. 317.
[4] Thompstone, E., *Agr. Jl. India*, vol. X, 1915, p. 26.

TABLE I.

Amount of natural cross-fertilization.

Variety	District	Total progeny	Purple-tipped crosses	Per cent. crossing
Sadai Samba	Coimbatore	2,491	72	2·9
Dodda Biru Bhatta	do.	2,019	2	0·1
Swarnawari	do.	2,039	18	0·9
Do.	South Arcot	2,888	20	0·7
Rasangi	Godaveri	3,794	92	2·4
Rascadam (1)	Coimbatore	1,435	21	1·5
Do. (2)	do.	3,350	46	1·4

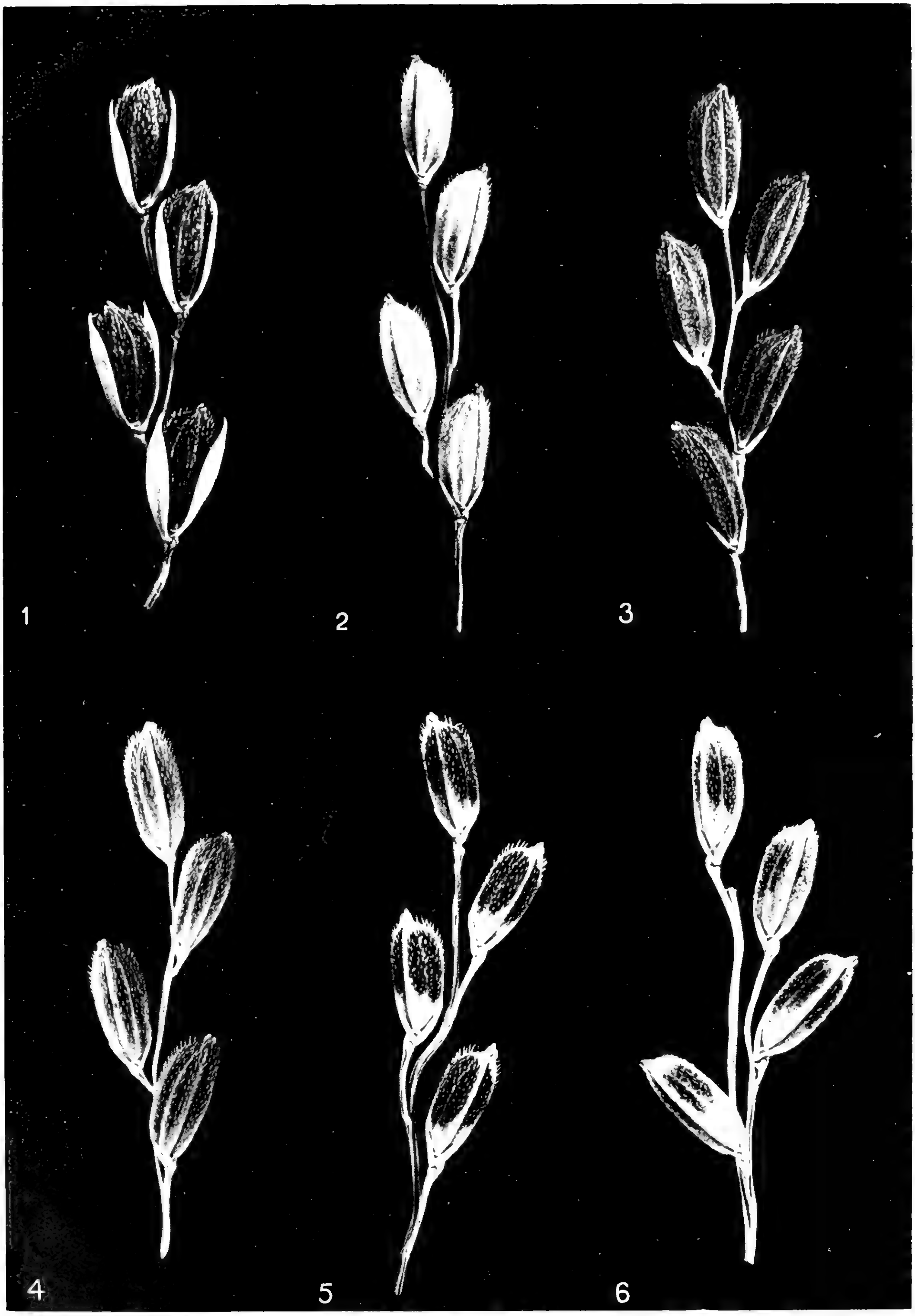
It appears that the amount of crossing varies considerably with the variety, as would be expected from the variation in time of dehiscence of the anthers.

The last two lines of the table show the amount of crossing taking place between two varieties growing on adjacent plots. No. (1) represents 50 heads of *Rascadam* taken from the line of contact, that is actually commingling, with another variety. No. (2) represents 50 heads taken at a distance of three feet from the line of contact. That the amount of crossing is practically the same for both is no doubt due to the fact that the prevalent wind, which is fairly constant at the time of flowering, was blowing towards the *Rascadam* from the other variety. Further experiments are necessary to determine the amount of crossing taking place over greater distances.

(b) METHOD OF SELFING.

The method of selfing adopted has been to cover the entire upper portion of the plant with a bag made of fine mull. The bag reaches from well above the fully developed heads down far enough to include the tops of young tillers in shot blade. The latter can thus grow up into the bag before the panicle emerges. In this way the whole of the flowers are selfed, with the exception of such already set flowers as have to be removed at the time of bagging.

The bag is supported inside by two bamboo stakes standing vertically, one on each side of the plant, to a height a little above that of the developed panicles. It is closed loosely at the bottom by means of a pin on each side between the bamboos and the plant.


1
2
3
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5
6

The setting inside such a bag is perfectly normal and the bag may be left on till harvest when it is tied tightly round the bottom, after removing the bamboos, and the whole plant is pulled up and dried.

This method of selfing has proved very satisfactory, requiring little labour and causing no loss of seed. Only in one or two cases, out of a very large number of plants, have wrong types appeared which may have been due to crossing. It is possible, though not certain, that these were due to accidents of another nature.

Waterproof paper bags, one over each head, were tried, but, in spite of liberal ventilating holes, the moist atmosphere developed inside very seriously interfered with setting.

In all cases where the progeny of an unselfed plant are included in a table this fact is indicated by the letter "N" after the reference number of the parent. Such plants have been used freely in tables for simple ratios where a small amount of crossing would only slightly affect the ratio.

III. CHARACTERS INVESTIGATED.

(*a*) SIZE OF OUTER GLUMES.

The spikelet of rice is single flowered and possesses two outer or sterile glumes, an inner fertile glume and a palea. In all references to the spikelet, the *outer glumes* will be referred to as such. The fertile glume and palea are hooked together at their edges to form one common structure, the husk; they are of similar texture and appearance and are affected by the same characters and will, therefore, be referred to together as *inner glumes*.

The outer glumes are usually small and inconspicuous, about $\frac{1}{4}$ to $\frac{1}{5}$ the length of the inner glumes (Plate I, figs. 2-6). In one of the varieties growing at Coimbatore, *Rakki Pakshi Bhatta*, the outer glumes are approximately equal in length to the inner glumes (Plate I, fig. 1). In India this character appears to be met with in only a few rare varieties in different parts.

In a plot of a short-glumed variety, which was showing considerable variation due to previous crossing, several long-glumed plants were found. Eight of these plants were selected and their progeny, though showing segregation for other characters, were all pure long-glumed. On the other hand, of the short-glumed plants from the same plot, selected for variations in other characters, several gave families showing segregation for this character. There were two very definite groups, *short-glumed* and *long-glumed*, in the ratio of about *3* : *1* respectively. The individuals of the dominant group were all typically short-glumed with no distinction between heterozygotes and homozygotes. The long-glumed recessives were rather variable, but in no case did they approach the other group.

A number of F_2 plants from two segregating families gave the following results in F_3:—

7 long-glumed F_2 plants gave pure long-glumed F_3.

20 short-glumed ,, ,, {7 pure short-glumed F_3. 13 segregating F_3.}

From the figures given in Table II it is evident that the normal *short-glumed* character is simply dominant to the *long-glumed.*

This is in accordance with the results of Van der Stok[1] who states that the normal type is dominant.

TABLE II.

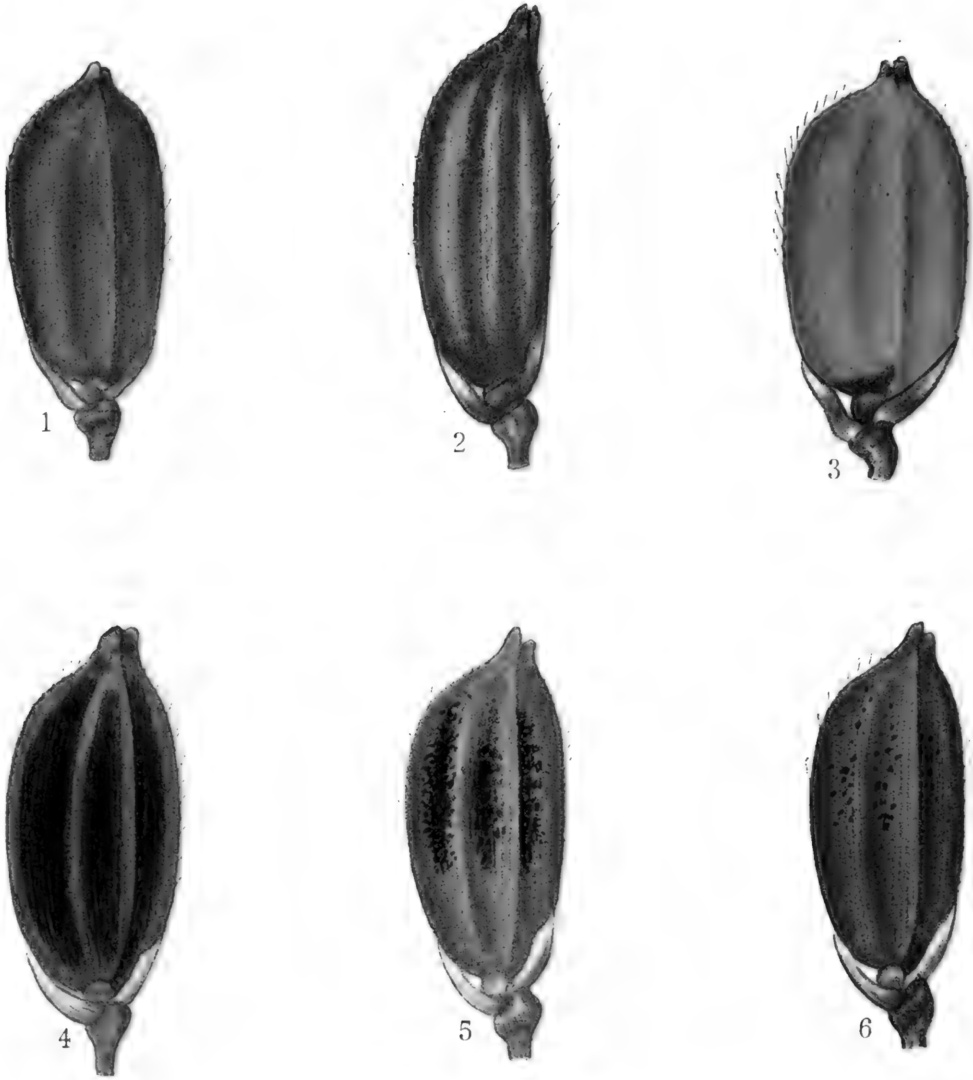
Length of outer glumes.

Origin of parent	Reference No.	Short-glumed	Long-glumed
Natural crosses	45	96	35
	131–N	74	26
	166	75	19
	169	19	6
	637	258	126
No. 45, F_2	four plants short-glumed	1,101	360
No. 637, F_2	eight plants short-glumed	7,034	2,324
Total ..	....	8,657	2,896
Calculated 3 : 1 ..		*8,664·75* :	*2,888·25*

(*b*) GOLDEN COLOUR OF INNER GLUMES AND INTERNODE.

The most usual colour of the inner glumes is a light green (Plate II, fig. 1) ripening to pale straw, but there are numberless varieties with other colours. Of these one of the commonest is some form of what may be described as *golden* colouring, though this varies in different varieties from orange-yellow to reddish-brown (Plate II, figs. 2 and 3) at the time of flowering, becoming rather darker and duller on ripening. Plate I shows photographs of ripe grains of green (fig. 2) and gold (figs. 1 and 3.)

[1] Van der Stok, *l. c.*, p. 47.



COLOURS OF INNER GLUMES.

1. Ordinary green, "Sadai Samba."
2. Light gold, "Sakalati Sanna Bhatta."
3. Dark gold, "Ottadan.
4. Dark furrows, "Pisini."
5. do. piebald, } "Manawari."
6. do. do. }

COLOURS OF INNER GLUMES.

7. Gold piebald, "Garudan Samba."

8. Green,
9. Gold,
10. 11. 12. Patchy gold (one panicle)

} from No. 432, F_2.

In plants with golden inner glumes the internode is golden, whereas a light green internode normally accompanies green glumes. In all the material so far examined, with the exception of one family to be described later, this connexion between the golden colour of inner glumes and internode has been constant. It will be seen later that purple colouring of inner glumes and internode depends on two separate factors which may be coupled so closely as to appear as one factor. Whether this is the case with golden colouring remains to be seen from future work.

The golden character, irrespective of the actual shade of colouring, behaves as a simple recessive to green. The total available figures are given in Table III which shows a simple *3 : 1* ratio of *green* to *gold.*

Thompstone[1] describes a *3 : 1* ratio of *white* : *deep rusty-red* which is presumably the same as the above *green* and *gold.*

TABLE III.

Golden colouring of inner glumes and internode.

Origin of parent	Reference No.	Green	Gold
Natural cross	10	219	80
No. 10, F_2	446–N	173	60
	455–N	377	119
Natural cross	178	447	161
No. 178, F_2	589–N	300	92
Green crosses from unbagged golden plants ..	540–N	944	378
	543–N	808	266
	544–N	362	118
	657–N	828	276
From F_2 not counted	563–N	157	49
	566–N	284	73
	574–N	229	62
Total of 17 other families ..	....	3,436	1,155
Total ..	....	8,564	2,889
Calculated 3 : 1 ..		*8,589·75* :	*2,863·25*

[1] Thompstone, E., *l. c.*, p. 45.

All the greens are the same with no difference between heterozygotes and homozygotes. In all the above families the type of golden colouring has been uniform in each family but varying in different families.

On the presence and absence hypothesis an inhibitory factor must be responsible for the failure to develop golden colouring in the above families. It is possible that the actual production of this colouring is dependent on the presence of a factor which may vary for the different types of colouring. In this case it must be assumed that all these families were pure for one or more such factors. No definite proof of the existence of such factors has so far been obtained but there is some indication of this in certain complicated families in which different types of golden colouring occur together.

In one such family, which was not giving the ordinary *3 : 1* ratio, two distinct types of gold were present. The F_1 parent, which possessed light golden inner glumes and internode, gave very few plants in F_2. Of these the inner glumes varied from green to dark gold with various intermediates; a rough analysis showed *green* 9, *light gold* 9, *dark gold* 5. All internodes were golden and this character has been pure in the further generations. Four of these F_2 plants gave glume characters in F_3 as shown in Table IV.

TABLE IV.

Reference No.	Character of parent	Green	Patchy-gold	Gold	Ripening gold
429-N	Green	2,545	..	..	..
431-N	do.	1,208	..	..	357
432-N	Light gold	597	1,292	592	..
430-N	Dark gold	..	..	1,118	..

In all plants described as green the glumes were distinctly yellowish as compared with typical greens but they ripened to the ordinary straw colour.

In No. 431-N the ripening gold group could be distinguished only with difficulty at flowering, but, as the grain developed, the colour became more pronounced till at maturity it was a definite dull gold of a rather light shade. All unset grains remained green whereas in ordinary gold types unset grains are definitely gold though they fail to darken with age. Table V gives the results of a further generation from this family.

TABLE V.

Origin of parent	Reference No.	Character of parent	Green	Ripening gold
No. 3, F_2	431–N	Green	1,208	357
No. 431–N, F_3^*	742–N	Ripening gold	..	all
	743–N	do.	..	all
	744–N	Green	all	..
	745–N	do.	1,421	525
	746–N	do.	all	..
	747–N	do.	993	273
Total segregating ..	..	..	3,622	1,155
Calculated 3 : 1 ..	..	..	*3,582·75* :	*1,194·25*

The figures show an obvious *3 : 1* ratio, similar to that of Table III, and it appears that a somewhat similar inhibitory factor may be concerned. If so, this factor differs from that already described in that it has no effect on the internode and the inhibition in the glumes is not complete since, as already noticed, they possess a distinctly yellowish tinge. It may be noted that in some of the families concerned one or two plants occurred in which both glumes and internode were entirely green. These must have been natural crosses from outside as they also varied from the group in certain other characters. There is little doubt that they possess the ordinary inhibitory factor, crossed on from another group, and their progeny will be of interest in their connexion.

To return to Table IV, in No. 432-N, three groups appeared, *viz.*, *green*, *patchy-gold* and *gold*, in the approximate ratio of *1 : 2 : 1*. These groups, which are shown in Plate II, figs. 8-12, were distinct and easily separable. The greens were of the same yellowish type as has already been described and the golds were of an ordinary medium shade but with small green areas at the apex and base of the grain. In the patchy-golds the colouring varied considerably, both in shade and extent (Plate II, figs. 10-12) even on the same plant. It was always irregularly patchy and quite distinct from the piebald type (Plate II, fig. 1) which will be described later.

The results of a further generation are shown in Table VI.

TABLE VI.

Origin of parent	Reference No.	Character of parent	Green	Patchy-gold	Gold
No. 3, F_2	432-N	Light gold	597	1,292	592
No. 432-N, F_3	749-N	Green	all	..	..
	750-N	do.	all	..	..
	751-N	Gold	..	..	all
	752-N	do.	..	..	all
	753-N	Patchy-gold	287	675	282
	754-N	do.	286	604	288
	755-N	do.	74	231	78
	756-N	do.	76	172	82
Total segregating ..	..	..	1,320	2,974	1,322
Calculated 1 : 2 : 1 ..	..	..	*1,404* :	*2,808* :	*1,404*

It is evident that the figures represent a *1 : 2 : 1* ratio and the patchy-golds apparently form a heterozygous group intermediate between homozygous greens and golds. It may be that this is due to an inhibitory factor incompletely dominant for this type of gold, or possibly no inhibitory factor is concerned but only an incompletely dominant gold-producing factor.

Since the families of Tables V and VI were derived originally from the same parent it is probable that the same inhibitory factor is concerned in both lots and that the difference in effect is due to the different gold-producing factors present. This supposition is supported by the fact that in one of the pure green families of Table V there occurred one typical patchy-gold plant which no doubt was a natural cross by a gold plant in No. 432 of Table VI which was growing in the vicinity. Moreover in the pure green families of Table VI there occurred one or two obvious crosses with entirely green glumes and internode, due undoubtedly to the introduction of the ordinary inhibitory factor from outside as has been already described for similar crosses in families of Table V.

(c) DARK FURROWS OF INNER GLUMES.

In this character a dark blackish-brown colour develops in the inner glumes, more especially in the furrows (Plate I, fig. 4 and Plate II, fig. 4).

It begins to appear at about flowering time, increases in intensity as the grain develops, and then fades to a dull brown during the later stages of ripening.

It was at first thought that an inhibitory factor, similar to that described for golden colouring, existed for this character also. Numerous figures were obtained showing a *3 : 1* ratio of *green* to *dark furrows*. It now appears likely that the greens were not in reality entirely green but that the colour was limited by the *piebald* factor described below.

Since the action of this factor was noted all families apparently segregating into greens and dark furrows have been examined carefully and in every case the *greens* have proved to be in reality *piebald dark furrows*. It is recorded for some of the earlier lots that the greens were not entirely devoid of colouring and these no doubt were really piebalds. It is not certain, however, that this was true in all cases.

Many varieties exist in which the glumes are entirely free from this colouring, but whether this is due to the absence of the determining factor or to the presence of an inhibitory factor remains to be seen from future work.

(*d*) Piebald pattern of golden colouring and dark furrows of inner glumes.

There is a definite localization factor which affects the distribution of both ordinary golden colouring and dark furrows of the inner glumes. This was first noted in golden types where the colour is inhibited at the base of the glumes, typically to about one-third of the length, and also in a small area at the apex. There is often considerable variation, even in grains on the same head, but the character on the whole gives the very definite *piebald* appearance of the grain which is common in many varieties (Plate I, fig. 5 and Plate II, fig. 7).

Reference has already been made to this factor in connexion with dark furrows. Here the effect is extremely irregular in segregating families and even in varieties pure for this character considerable variation exists. The minimum of inhibition corresponds roughly with typical gold piebald (Plate I, figs. 5 and 6 and Plate II, figs. 5 and 7). This amount of colouring is generally seen in occasional plants only and, even there, is often confined to a few of the upper grains in the panicle. From this all stages may be found down to those in which a careful search reveals, on a whole plant, only a few grains in which a few specks of colour are present. An ordinary typical *piebald dark furrows* plant exhibits about the amount of colouring shown in Plate II, fig. 6, on a number of grains in each panicle.

The *piebald* character is dominant to *self-colour*, giving the ordinary *3 : 1* ratio in F_2 (*see* Table VII). It has not yet been ascertained whether the variation noted as existing in the piebalds is to any extent dependent on the heterozygosis or otherwise of the localization factor.

TABLE VII.

Piebald localization factor.

Origin of parent	Reference No.	Dark Furrows		Golden	
		Piebald	Self-colour	Piebald	Self-colour
Natural cross	47	25	8	12	7
No. 47, F_2	504	..	..	177	55
	505	..	..	121	44
	506	39	16	..	..
	507	111	39	39	21
	508	..	..	40	12
Natural crosses	166	55	19	15	5
	626	340	147	101	42
	217	..	..	180	63
No. 639, F_2, not counted ..	1,003–N	1,250	390	..	..
	1,004–N	1,304	433	..	..
	1,007–N	766	233	..	..
	1,009–N	1,082	330	..	..
Total ..	..	4,972	1,615		
Calculated 3 : 1 ..	..	*4,940·25 :*	*1,646·75*		
	Total ..		..	685	249
	Calculated 3 : 1		..	*700·5 :*	*233·5*

There can be no doubt that the same factor is concerned in both types of colouring though the numbers illustrating this are not very good approximations to a *9 : 3 : 3 : 1* ratio.

(*e*) PURPLE PIGMENTATION.

The occurrence of anthocyan pigmentation in some part of the plant is extremely common and different localizations of this colouring form some of the most striking varietal characters.

The pigment, which occurs in solution in the cell-sap, will be referred to throughout as purple. The actual appearance, however, varies considerably according to the concentration of the pigment and the colour of the tissue in which it is present. Thus in the epidermis of a dark green sheath it appears bluish, whereas in an otherwise colourless stigma it appears reddish when in low concentration and almost black when highly concentrated. In no case has the pigment itself appeared to show variation when examined under a lens.

The inheritance of several localization factors will be considered later; the factor at present under consideration is the power to produce purple pigment.

One of the commonest types of segregation in F_2 families from naturally occurring heterozygotes has been the production of pigmented and unpigmented plants. The former group has varied in the different families according to the localization factors present in each case.

Table VIII shows a few F_2 and F_3 families in which the ratio *pigmented : unpigmented* is *3 : 1*.

TABLE VIII.

Purple pigmentation, 3 : 1 *ratio.*

Origin of parent	Reference No.	Pigmented	Unpigmented
Natural cross	10	222	77
	437–N	1,276	361
No. 10, F_2	440–N	362	119
	441–N	1,093	360
Natural cross	640	211	66
	671–N	701	231
No. 640, F_2	673–N	1,064	356
	687–N	680	241
Total ..	..	5,609	1,811
Calculated 3 : 1 ..	..	*5,565* :	*1,855*

This ratio has been obtained in a large number of families, the totals for which are as follows:—

		Pigmented		*Unpigmented*
85 families F_2-F_4	..	41,164		13,664
Calculated 3 : 1	..	*41,121*	:	*13,707*

In two F_2 families, however, a *9 : 7* ratio was obtained, and in each case both ratios, *9 : 7* and *3 : 1*, appeared in further generations as shown in

Table IX. In all cases several localization factors were present, some pure, others segregating, so that all plants capable of producing pigment must have possessed a localization factor.

TABLE IX.

Purple pigmentation, 9 : 7 ratio.

Origin of parent	Reference No.	Pigmented	Unpigmented	Ratio
Natural cross	178	345	263	9 : 6·9
No. 178, F_2	602–N	445	327	9 : 6·6
	589–N	*296*	*96*	*9 : 2·9*
	599–N	166	120	9 : 6·5
	605–N	*305*	*130*	*9 : 3·8*
Natural cross	190	40	30	9 : 6·75
No. 190, F_2	611–N	*762*	*204*	*9 : 2·4*
	614–N	817	602	9 : 6·6
No. 614–N, F_3	Ten families	*7,884*	*2,519*	*9 : 2·9*
	Six families	3,001	2,333	9 : 7·0
Total 3 : 1 ratios, distinguished by *italics* ..		9,247	2,949	
Calculated		*9,147* :	*3,049*	
Total 9 : 7 ratios ..		4,814	3,675	
Calculated ..		*4,775* :	*3,714*	

The figures for these families are sufficiently definite to leave no doubt that the formation of pigment is dependent on the simultaneous presence of two factors. It must be assumed that all the above families, giving a *3 : 1* ratio, were pure for one of these factors.*

Confirmatory evidence of the existence of two pigmentation factors has been obtained by the production of a pigmented plant by crossing two unpigmented types.

* *Note:*—Since this was written a paper has been published by Hector, "Observations on the Inheritance of Anthocyan Pigment in Paddy Varieties," *Mem. Dept. of Agr. in India, Bot. Series*, vol. VIII, no. 2.

He has obtained both *3 : 1* and *9 : 7* ratios of *pigmented : unpigmented*, the latter being more common. His interpretation of results differs from that adopted in the present paper in that no distinction is made between *pigmentation* and *localization* factors. Such a distinction would simplify the explanation of many of the results given ; thus all the families of Table III, p. 94, might be considered to be segregating for two pigmentation factors and the stigma localization factor, but pure for the leaf-sheath and apiculus localization factors. [F. R. P.]

PLATE III.

1. Ripening black } from No. 568, F 2.
2. do. straw }

3. Pulvinus and auricle dark purple } from No. 456, F 2.
4. do. do. green }

Six unpigmented F_3 plants, from No. 614-N of Table IX, were crossed with pollen from a pure unpigmented strain of *Garudan Samba*. One cross gave two plants one of which was pigmented whereas the other was not. In the other five lots, comprising 13 plants, all were unpigmented.

(*f*) Dark purple colouring of pulvinus and auricle.

In this character a very dark purple colouring of the epidermis is present in the pulvinus and also in the auricle and pulvinus-like region from which it springs at the junction of leaf-sheath and lamina (Plate III, fig. 3). The term *pulvinus* is applied to the swollen growth zone at the base of the leaf-sheath immediately above the node. The pigment is so concentrated as to appear black unless closely examined.

In all cases so far noted the two localizations have gone strictly together, forming a single character which is dominant to the unpigmented type. It is probable that a single factor is concerned though it might be a case of complete coupling of two separate factors.

The figures given in Table X show, approximately, a simple *3 : 1* ratio. There is some variation in the pigmented group which is possibly due to the heterozygotes being less evenly coloured. This is a matter more of distribution of pigmented cells than of concentration of pigment in the cell.

Table X.

Dark purple colouring of pulvinus and auricle.

Origin of parent	Reference No.	Pigmented	Unpigmented
Natural cross	10	175	48
No. 10, F_2	437	971	305
	439-N	476	140
	442-N	695	182
	453-N	226	74
Natural crosses	11	61	22
	86	190	58
Total	..	2,794	829
Calculated 3 : 1 ..	..	*2,717·25* :	*905·75*

(*g*) Full-purple self-colour of leaf-sheath.

In this character the epidermis of the leaf-sheath is coloured very distinctly purple, especially in the sides and edges. The colouring, although frequently most intense in the lower half of the sheath, always extends up to the junction with the lamina and often into the ligule. The lower sheaths, especially such as are poorly developed, show the maximum amount of colouring.

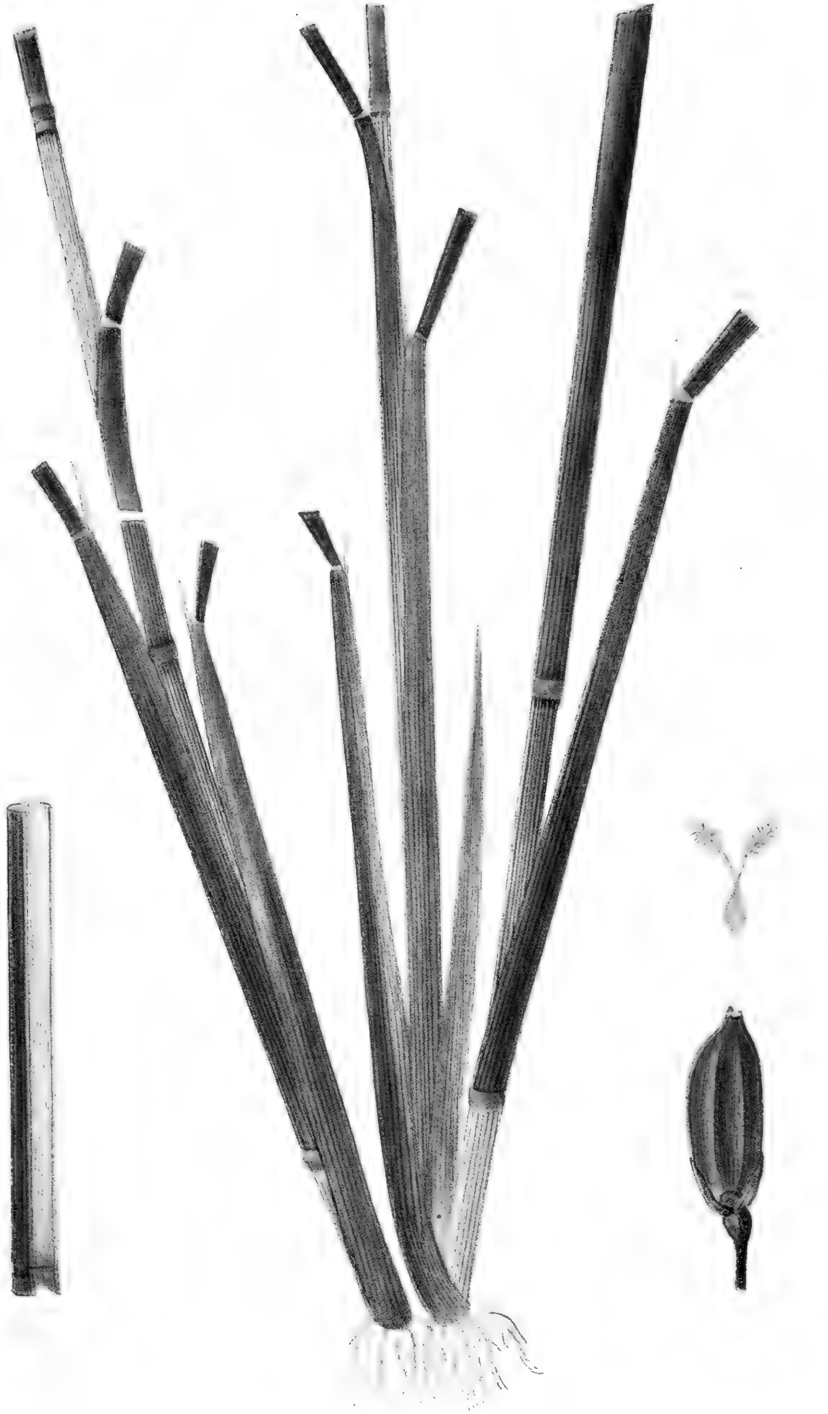
Plate IV shows two types which were crossed, B, 1 possessing this character and B, 23 in which, although some purple colouring appeared in the sheath, this definite character was absent. The purple lining of the sheath and internode of B, 1 is due to a separate factor, to be considered later, which is in no way connected with that under consideration.

Six F_1 plants were obtained from this cross, all with full-purple sheaths. In F_2 a simple *3 : 1* ratio was obtained for presence and absence respectively of full-purple. In the latter group some individuals were practically devoid of self-colour, whereas others reproduced the small amount shown by B, 23. It was found that this colouring in B, 23 was almost entirely due to a separate character, to be described later as *purple axil,* mainly affecting the colour of the inside surface of the sheath. This was absent in B, 1 ; hence the F_2 was segregating for this character as noted. Certain families in F_3 again gave the *3 : 1* ratio for full-purple. Table XI gives the figures obtained with regard to this character only, leaving out of account other characters which do not affect it in any way.

TABLE XI.

Full-purple self-colour of leaf-sheath.

Origin of parent	Reference No.	Full-purple	Slight purple or green
F_1—B, 1 × B, 23	642	310	87
	643	304	111
	644	388	108
	645	138	47
	646	149	52
	647	344	91
No. 645, F_2	694–N	459	152
	696–N	420	145
	700–N	125	45
	703–N	615	236
	707–N	249	91
Total ..	..	3,501	1,165
Calculated 3 : 1 ..	..	*3,499·5* :	*1,166·5*



Type B, 1.—Full-purple self-colour leaf-sheath; purple lined sheath and internode; purple glumes; white stigma and axil.

Type B, 23.—Leaf-sheath full-purple absent; purple lining absent; green glumes; purple stigma and axil.

The full-purple character is obviously due to the presence of a simple factor, irrespective of any other colouring that may be present in the sheath. A good deal of variation in intensity of colouring exists in the dominant group and this proved to be partly due to the heterozygotes showing, on the whole, rather less colour than the pure dominants. The former could not be separated as a definite group, however, owing to the fact that varying exposure to light also affects the intensification of the colouring.

(*h*) PURPLE LINING OF INTERNODE, PURPLE GLUMES, PURPLE STIGMA, PURPLE AXIL.

The above characters will be considered together, since, in certain crosses in which they were all concerned, several types of gametic reduplication occurred.

Purple lining of the internode is due to pigment in the sheaths of the vascular bundles. It is normally associated with a certain amount of lining in the leaf-sheath and it is possible that one factor determines both. It is a common character, found in very many varieties, and shows great variation. In some types the lining is faint and scarcely noticeable, developing only when the internode is exposed to strong light. Many intermediate forms exist between such types and those showing the fullest development where the whole internode is deeply coloured in shades varying from almost red to almost black.

Such deeply coloured types are included under purple lining as examination shows that the pigment is present mainly in the bundle sheaths, although it spreads into the surrounding cortex sufficiently to give the appearance of self-colouring.

There are undoubtedly several factors concerned in the various types of lining, but there appears to be considerable complication and they have not yet been worked out. So far as concerns the present considerations the actual type of lining is immaterial since all have behaved in the same manner.

The *purple glumes* character is somewhat variable. In all types noted the small outer glumes are almost entirely purple. The inner glumes vary, in the distribution of the colouring, from the type shown in Plate IV, B, 1, to one in which they are uniformly purple. The actual colouring also varies from ordinary purple to almost black.

The factors concerned in these variations have not been worked out, but, as in the case of purple lining, all types behave in the same manner in their relations considered below.

The type of *purple stigma* under consideration is shown in Plate IV, B, 23. Other types exist but are not included in this account.

The term *purple axil* is applied, for the sake of convenience, to a deep purple colouring of the epidermis on the inside of the sheath. It is most intense in the axil and gradually diminishes as it extends upwards till it disappears about half way up the sheath (Plate IV, B, 23).

As will be seen below, the above four characters behave as simple dominants to their respective unpigmented types, each character being due to the presence of a simple factor. In the following description the presence of these factors will be denoted by the capital letters L, G, S, A, respectively, and their absence by the corresponding small letters.

The principal material to be considered was derived from the cross between types B, 1 and B, 23 of Plate IV. Reference has already been made to this cross in connexion with purple self-colouring of the leaf-sheath ; this is entirely independent of the above characters and may be disregarded here.

These two types were plants from pure strains of the variety *Basangi*, separated by Mr. Hilson on the Government Farm at Samalkota. Their composition, together with that of F_1, may be represented as follows :—

B, 1	L L G G s s a a
B, 23	l l g g S S A A
F_1	L l G g S s A a

In F_2 it was found that each character, considered separately, behaved as a simple dominant, giving a *presence* : *absence* ratio of *3 : 1*. When all four characters were considered together it was found that :—

purple lining was associated with *purple glumes ;*
purple stigma ,, ,, *purple axil ;*
green internode and *glumes* were associated with *purple stigma* and *axil.*

Thus only three types occurred, which may be represented as L G s a : L G S A and l g S A. The ratio approximated to *1 : 2 : 1* respectively, as shown by the figures in Table XII. It follows that—

L	is coupled with	G
S	,, ,,	A
L G	repels	S A

Thus the F_1 — L l G g S s A a — can form only two types of gamete, *viz.*, L G s a and l g S A, which result in the following ratio in F_2 :—

1, L L G G s s a a : *2*, L l G g S s A a : *1*, l l g g S S A A—*i.e.*, two pure types similar to the parents and a heterozygous type similar to F_1. This was confirmed in F_3 as will be seen from Table XII.

TABLE XII.

Type B, 1×B, 23.

Parents		L G s a	L G S A	l g S A	
F_1	6 plants	566	1,097	466	
F_2	23 plants, N, L G S A ..	6,969	14,070	7,242	also *L g S A, 8*; *l G S A, 11*
	Total	7,535	15,167	7,708	
	Calculated 1 : 2 : 1 ..	*7,602·5* :	*15,205* :	*7,602·5*	
F_3	8 plants, N, L G s a ..	2,750	..	..	
	8 plants, N, l g S A ..	..	..	5,622	

In the six F_2 families, totalling 2,129 plants, no case occurred in which L and G were not coupled. In the twenty-three splitting F_3 families, totalling 28,281 plants, nineteen showed failure of this coupling, as shown in italics in Table XII.

Unfortunately the F_2 parents of these families were not selfed and, therefore, it is not absolutely certain that these aberrant types were not crosses from outside the group. Crossing inside the group could only slightly affect the *1 : 2 : 1* ratio but could not produce the aberrant types.

A few undoubted cases of crossing from outside were found, but these were easily recognizable since the type of internode and glume colouring was quite distinct from that of the group, which was peculiar to itself.

The nineteen aberrant plants were absolutely typical of the group in all respects and there appears to be little doubt that they represent examples of incomplete coupling of L and G. It will be seen from tables that follow that occasional aberrant plants of these types are constantly occurring in families segregating for L and G and this fact supports the idea of incomplete coupling. To make quite certain of this point, and in order accurately to estimate the amount of coupling, fifty plants of the L G S A type have now been selfed. In view of this no further reference to this point will be made beyond giving the numbers of such aberrant types as occur in the families described.

No departure from complete coupling occurred with regard to purple stigma and axil.

The same set of characters appeared in No. 640, another cross with B, 23 but by an unknown male parent. F_1 was in appearance the same as the cross already described and its constitution proved to be the same, except that it was heterozygous for one of the pigmentation factors. Thus in F_2 *pigmented* and *unpigmented* plants appeared in the ratio of *3 : 1*. This did not affect the composition of the pigmented group, which was made up of the three groups already described — L G s a, L G S A and l g S A — in the *1 : 2 : 1* ratio. Here, again, in F_3 the same result was obtained. Six plants of the L G S A group all reproduced the *1 : 2 : 1* ratio, whereas six from each of the other groups all bred true (*see* Table XIII). No aberrant types were produced in this group.

TABLE XIII.

Parents	Reference No.	L G s a	L G S A	l g S A
F_1, B, 23 × ?	640	47	96	68
No. 640, F_2	6 plants, N, L G S A	731	1,702	879
Total	..	778	1,798	947
Calculated 1 : 2 : 1 ..	..	*880·75* :	*1761·5* :	*880·75*
F_3	6 plants L G s a	2,824	..	..
	6 plants l g S A	..	..	4,014

N.B.—Unpigmented groups, occurring in certain of the above families, have been disregarded.

The above results are quite definite in showing repulsion between *purple lining and glumes coupled* on the one hand and *purple stigma and axil coupled* on the other. The exact nature of the repulsion, however, is not evident; thus either L, or G, or the L G combination, may repel either S, or A, or the S A combination. Some light is thrown on this point by another group of families arising from a naturally occurring heterozygote. This plant, No. 153, was a *rogue* with purple-lined internode and purple glumes in a variety, *Dalwa*, with green internode and glumes. F_2 was not counted but it was noted that segregation was taking place for purple lining and glumes, which were coupled, and that purple axil was pure. The stigma was not examined but from the results given by F_3 it must have been segregating. Pigmented and unpigmented plants occurred in the ratio *3 : 1* in F_2; in F_3 and F_4 some families were pure and others impure for pigmentation. All unpigmented plants are disregarded in the following description.

The original rogue, referred to as F_1, must have been of the constitution L l G g S s A A—*i.e.*, the same as those described above with the exception of the pure purple axil. The results from F_3 and F_4, given in Table XIV below, show the same behaviour of the segregating factors. L and G are coupled in all but a few rare individuals, and repulsion takes place between LG and S.

As noted the stigma was not examined in F_2 but its nature in the F_2 parents selected can be deduced with certainty from their behaviour in F_3. The general behaviour of the whole group, neglecting unpigmented plants, was as follows :—

6 F_2	plants	LGsA	type	bred	true in 2,486	individuals.
7 F_3	,,	,,	,,	,,	6,945	,,
6 F_2	,,	lgSA	,,	,,	2,916	,,
8 F_3	,,	,,	,,	,,	5,988	,,
6 F_2	,,	LGSA	,,	gave *1 : 2 : 1* ratio *		*see* Table XIV.
11 F_3	,,	,,	,,	,,		

TABLE XIV.

Origin of parent	Reference No.	L G s A	L G S A	l g S A	
No. 153, N, F_2 ..	553–N	104	227	97	*also* *L g S A*, 1
	557–N	98	214	108	
	560–N	135	268	156	
	568–N	49	96	48	,, *L g S A*, 1
	570–N	132	250	125	
	571–N	102	173	116	
F_3	11 plants, N, L G S A	2,016	4,301	2,279	.. *L g S A*, 3; *l G S A*, 4
Total	..	2,636	5,529	2,929	
Calculated 1 : 2 : 1	..	*2,773·5*	: *5,547*	: *2,773·5*	
No. 190, F_2 ..	614–N	197	399	221	*also* *l G S A*, 1
No. 614, N, F_2 ..	8 plants, N, L G S A	1,471	2,960	1,504	,, *l G S A*, 5; *L g S A*, 2
Total	..	1,668	3,359	1,725	
Calculated 1 : 2 : 1	..	*1,688*	: *3,376*	: *1,688*	

* With very occasional aberrant types in addition.

The second half of Table XIV shows exactly similar results obtained in a totally unrelated group. The composition of No. 190, F_2, was not ascertained except that it was giving a *9 : 7* ratio of *pigmented* : *unpigmented* plants, in which connexion it has already been considered.

To return to the *Dalwa* cross, two F_2 plants of the L G S A type proved to be of the constitution L L G g S s A A. These may have been crosses, as the F_1 parent was not selfed, or they may have been due to failure of coupling of L and G. Their exact origin is immaterial to the present consideration. *viz.,* repulsion between G and S where both L and A are pure.

The results given in F_3 and F_4 are shown in Table XV.

TABLE XV.

Origin of parent	Reference No.	L G s A	L G S A	L g S A
? crosses in No. 153-N, F_2 ..	566-N	73	195	89
	577-N	77	230	144
No. 566-N, F_3	5 plants, N, L G S A	827	1,557	747
No. 577-N, F_3	6 plants, N, L G S A	1,018	2,249	1,242
Total	..	1,995	4,231	2,222
Calculated 1 : 2 : 1 ..	..	*2,087* :	*4,174* :	*2,087*

No explanation can be offered for the wide divergence of No. 577-N from the ordinary ratio, but it has been disregarded in view of the fact that the F_4 families show only a slight tendency to such divergence. The figures, on the whole, undoubtedly represent the ordinary *1 : 2 : 1* ratio, showing simple repulsion between G and S, with no complication due to coupling.

A similar example of simple repulsion, but this time between L and S, was furnished by an aberrant plant of the L g S A type arising from No. 568-N of Table XIV. The constitution of this plant appears to have been L l g g S s A A and simple repulsion between L and S resulted in the usual *1 : 2 : 1* ratio (Table XVI).

TABLE XVI.

Origin of parent	Reference No.	L g s A	L g S A	l g S A
No. 568-N, F_3	829-N	47	87	48
Calculated 1 : 2 : 1 ..	..	*45·5* :	*91* :	*45·5*

The results so far obtained show the following types of repulsion :—

L G	repels	S A
L G	,,	S
G	,,	S
L	,,	S

Altogether over 60,000 plants have been examined with respect to the above types of repulsion and no example of incomplete repulsion has been recorded. It follows that the repulsion is at the least of an extremely high degree.

With regard to the coupling of purple stigma and purple axil the families showing segregation for both factors include about 34,000 plants but no failure of this coupling has been noted. This indicates that it is either complete or of a very high degree.

In this connexion it may be noted that purple stigma and axil are very commonly found associated with a purple tip to the inner glumes. This is a very well marked character (Plate IV, B, 23) quite distinct from the purple glumes already described. The above three characters are characteristic of a large number of varieties and there is evidence that they are also present in certain unpigmented varieties where the lack of a pigmentation factor prevents their appearance.

It is highly probable that the purple tip is coupled with the other two but no undoubted case has been noted. In the presence of purple glumes the tip cannot be determined ; thus the cross B, 1×B, 23 may have been either pure or impure for this factor. In the resulting families all plants with green internode and glumes possessed purple tips, showing that, if it was impure in the cross, this factor also was concerned in the reduplication already described.

It was at first thought that purple tip and stigma might be due to a single factor, since they invariably occurred together, but a few rare cases have now been found of purple tip associated with white stigma and *vice versâ.*

(*i*) Ripening black character of inner glumes.

In this character a black pigment appears in the inner glumes at the time when the fully developed grain begins to ripen. In one or two days the glumes become almost entirely black, with a slight brownish tinge, and the colour then fades considerably so that the grain, when dead ripe, has a dull smoky appearance. The change takes place so rapidly that it is common to find faded smoky grains at the tips of the panicle before the lowest grains have developed the colour.

Plate III, figs. 1 and 2, show grains ripening *black* compared with others, from the same segregating family, ripening to the ordinary *straw* colour.

The results obtained show considerable complication and are not yet fully worked out. There is no doubt that two factors are concerned in the production of the black pigment and that segregating families may show *black : straw* ratios of *3 : 1* or *9 : 7* according as the parent is heterozygous for one or both of these factors.

Table XVII shows both ratios appearing in a group of F_4 families derived from an F_3 giving a *9 : 7* ratio.

TABLE XVII.

Origin of parent	Reference No.	Black	Straw	Ratio
No. 153–N, F_2, not counted ..	564–N	331	300	*9 : 8·1*
No. 564–N, F_3	813–N	359	86	*9 : 2·2*
	817–N	525	158	*9 : 2·7*
	815–N	246	197	*9 : 7·2*
	816–N	220	167	*9 : 6·8*
	818–N	309	280	*9 : 8·1*

There is little doubt that Nos. 813-N and 817-N represent *3 : 1* ratios, though the former is not a very near approximation, and that the other families represent *9 : 7* ratios.

The above families were pure for the absence of purple-lined internodes. They were segregating for a purple pigmentation factor which, however, did not affect the segregation for ripening black. In certain families, on the other hand, which were also segregating for purple lining in the internode, there was clear indication of gametic reduplication. It was not until much material had been destroyed, after making simple counts of *black* and *straw,* that this reduplication was noted, hence the internode character was not determined in many cases.

Table XVIII gives the figures for certain families segregating for purple lining in addition to *one* of the ripening black factors.

TABLE XVIII.

Reference No.	PL. Internode		G. Internode		Total	
	Black	Straw	Black	Straw	Black	Straw
825–N	189	83	88	3	277	86
851–N	673	339	348	10	1,021	349
849–N		695		6	524	177
Total ..		2,415		19	1,822	612
Partial repulsion, 3 : 1 type ..		*2,396*	:	*38*		
Partial repulsion, 7 : 1 type ..		*2,424·5*	:	*9·5*		
		Calculated 3 : 1		..	*1,825·5* :	*608·5*

The right side of the table shows that, in each family, the simple ratio of *black : straw* is *3 : 1*, due to segregation for a single factor. The figures on the left clearly indicate partial repulsion between this factor and the purple lining factor. Unfortunately in No. 849-N the full figures are not available since only the *straw* plants were examined with regard to internode. It is obvious, however, that in all three families the repulsion was approximately of the same degree.

The degree of repulsion is of interest since, as seen by the calculated figures, it is definitely intermediate between the two recognized reduplication ratios — *3 : 1* and *7 : 1*.*

When both ripening black factors are segregating it appears that both are subject to partial repulsion by the lining factor. The few families for which figures are available show considerable irregularity in their ratios, suggesting varying degrees of repulsion, but further results are necessary before a definite statement to this effect can be made.

It is of interest to notice that where both ripening black factors are subject to this partial repulsion they come together oftener than would otherwise be the case and the ordinary *9 : 7* ratio is upset. This explains certain irregular results that had been very puzzling before the cause was known. Thus from a family giving a *black : straw* ratio of *9 : 3·8* further generations gave a mixture of definite *3 : 1* ratios together with others varying from

* Three families of a later crop have given about the same degree of repulsion.

9 : 5·3 to *9 : 6·4*. Both factors must have been segregating in the original *9 : 3·8* family and the very wide deviation from a *9 : 7* ratio was no doubt due to the repulsion of both factors as already described.

Eleven families, comprising 7,617 plants, have given such abnormal ratios, ranging from *9 : 3·8* to *9 : 6·4*. These may be compared with the following ratios calculated on the assumption that both factors are repelled to the same degree :—

				Black		*Straw*
3	:	*1*	*partial repulsion gives*	*9*	:	*6·06*
7	:	*1*	,, ,,	*9*	:	*4·79*
15	:	*1*	,, ,,	*9*	:	*3·95*

This partial repulsion of ripening black factors may be compared with the total repulsion, already described, of purple stigma and axil by the same internode lining factor. It is of interest, in connexion with theories regarding gametic reduplication in general, that, in certain cases, total repulsion between purple lining and purple stigma was recorded in the same families as were giving the partial repulsion described above.

(*j*) Red rice.

In the process of husking the inner glumes are removed from the *paddy* leaving the *rice* grain free. The colour of this unpolished rice varies in different varieties from clear white, through various subdued shades of cream, yellow, reddish-brown, etc., to the deep red of ordinary *red rice* (Plate V, fig. 1). A still deeper shade, dark blackish-purple, also exists, but has been noted in only one or two varieties of which crosses have not yet been examined.

The colour is contained entirely in the pericarp which is largely removed in the process of polishing to which the rice is submitted before being cooked. Red rice is generally disliked as the polished rice still possesses streaks of red colour in the furrows unless it is very thoroughly polished, in which case the loss of weight and labour entailed are considerable.

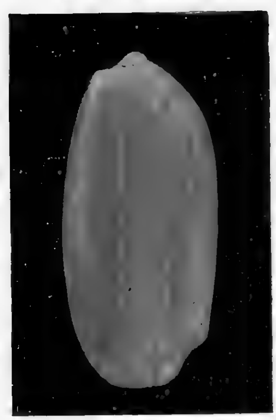
Many families segregating for the ordinary *full-red* colour have been examined and, with the exception of a few cases to be considered later, this character has proved to be a simple dominant, due to the presence of a single factor, irrespective of any lighter colouring that may be present.

The figures given in Table XIX indicate a very definite *3 : 1* ratio of *full-red* to *light colour*.

1

2

3



4

COLOURS OF RICE.

1. Full-red } from No 153, F_2.
2. Grey-brown } from No 153, F_2.
3. White } from No 153, F_2.
4. Light reddish-brown, No. 162.

TABLE XIX.

Red rice, 3 : 1 *ratio.*

Origin of parent	Reference No.	Full-red	Light colour	
Sadai Samba × *Boru Muruthagna Bhatta* } F_1 ..	639	285	111	*white*
No. 639, F_2	1,003-N	1,203	413	*do.*
	1,004-N	1,263	398	*do.*
	1,008-N	946	338	*do.*
	1,010-N	798	244	*do.*
	1,012-N	1,044	392	*do.*
Natural crosses, F_1 & F_2 ..	Twenty-two lots	6,180	2,023	*varying*
Total ..	..	11,719	3,919	
Calculated 3 : 1 ..	..	*11,728·5 :*	*3,909·5*	

In the individual families shown in the above table the *light colour* groups were all *white* since the parents, *Sadai Samba* and *Boru Muruthagna Bhatta* were white and red respectively. In the twenty-two families shown together the *light colour* groups varied. In some cases the group was uniform, either white or some definitely light shade of red or brown, whereas in other cases two or more types were present in the same group. In all cases they were very definitely distinct from the *full-red* group.

A similar simple *3 : 1* ratio of *red : white* rice has been recorded by Hector[1], McKerral[2], Thompstone[3], and Van der Stok[4].

In certain exceptional cases a definite departure from this simple ratio was obtained.

Two natural crosses possessing red rice gave three definite groups in F_2, *viz., full-red, grey-brown,* and *white.* The *grey-brown* type of colouring was a distinct type which did not occur in any of the families of Table XIX. The ground-colour was a dull light grey and over this a distinct brown appeared in small scattered spots giving the grain a dingy granular appearance as of white rice rubbed with soil (Plate V, fig. 2). A definite brown line occurred fairly constantly on the ventral edge of the grain.

[1] Hector, G. P., *l.c.,* p. 8.
[2] McKerral, A., *l.c.,* p. 326.
[3] Thompstone, E., *l.c.,* p. 45.
[4] Van der Stok, J. E., *l.c.,* p. 47.

Table XX gives the results obtained in these families with further generations from red-riced parents only as no grey-browns were carried forward.

TABLE XX.

Rice colour.

Origin of parent	Reference No.	Full-red	Grey-brown	White
Natural crosses	822-N	574	206	243
	153-N	72	16	21
No. 153-N, F_2	553-N	315	109	67
	556-N	464	184	150
	562-N	272	81	72
	577-N	340	107	82
No. 577-N, F_3	854-N	650	210	329
	865-N	736	224	189
Total ..	..	3,423	1,137	1,153
			2,290 (Grey-brown + White)	
Calculated 9 : 3 : 4 ..	..	*3,213* :	*1,071* :	*1,428* *
,, *9 : 7* ..	..	*3,213* :	*2,499* (Grey-brown + White)	
No. 153-N, F_2	569-N	674	234	..
No. 577-N, F_3	855-N	908	337	..
	858-N	1,018	331	..
	859-N	1,313	266	..
	860-N	813	348	..
	861-N	905	335	..
	862-N	843	289	..
Total ..	..	6,474	2,140	
Calculated 3 : 1 ..	..	*6,460·5* :	*2,153·5*	

* *To nearest whole figure.*

In the upper half of the table, where all three groups are present, all the families, in spite of some irregularity, show a definite tendency to a *9 : 7* ratio of *full-red : grey-brown + white,* and the totals approximate fairly nearly to this ratio. In the lower half, where white is absent, the ratio *full-red : grey-brown* is undoubtedly *3 : 1.*

It would seem from this that in these families the production of full-red is due to the simultaneous presence of two factors, one of which, by itself, produces the grey-brown type. In this case the three groups should show a *9 : 3 : 4* ratio but the actual figures obtained are not very near to this. The ratio of *grey-brown* to *white* varies considerably in the different families and for this reason it is hardly legitimate to total them together.*

A red-riced plant, No. 617-N, from an F_2 family that was segregating but not counted, gave in F_3 *full-red* 949 : *white* 753, a very definite *9 : 7* ratio. Twenty-four segregating F_4 families showed an extraordinary range of ratios, mostly varying from *9 : 3·3—9 : 5·9* but with a few approximating to *9 : 7*. These ratios recall strongly the set of similarly varying ratios obtained in connexion with the ripening black character, where there was evidence that it was due to partial repulsion of the two determining factors by another factor. It appears highly probable that the present case is due to a similar phenomenon.

Two plants in No. 617-N possessed slight reddish rice, quite distinct from the full-reds, and proved to be natural crosses since their progeny contained golden-glumed plants though this character was absent from the original family. When the rice of these two families was examined it was found to vary from definite slight reddish to pure white. This variation was so gradual, as is usual in families segregating for this type of colouring, that definite groups could not be separated, but in both cases all plants with golden glumes possessed pure white rice. An exactly similar result was seen in a totally unrelated family arising from a similar cross in another group. There can be no doubt that in these three families some form of gametic reduplication was taking place in which the factor or factors determining light reddish rice were concerned. This fact supports the supposition that the varying ratios of the families derived from No. 617 were due to gametic reduplication.

The whole question will be carefully followed up, using selfed seed only and noting all segregating characters in connexion with rice-colour. Attempts will also be made to produce red-riced plants by crossing *white* and *grey-brown*, in the case of the 153 group, and different *white* plants in the 617 group. Should both the above types of *9 : 7* ratio be confirmed it would follow that red rice may be due to the simultaneous presence of two factors of which at least one may vary.

With regard to the various light shades of red, brown, etc., it has proved very difficult to obtain definite results. Many families undoubtedly showing

* In the light of later evidence, *see* Postscript, this view is probably incorrect. [F. R. P.]

segregation have been examined, but, with only one exception, it has been impossible to separate them into distinct groups without all stages of intermediates.

The exceptional family resulted from a naturally occurring heterozygous plant, No. 162, with light reddish-brown rice (Plate V, fig. 4). In F_2 the same type appeared together with pure white. The groups, which were absolutely distinct, showed the ratio *light reddish-brown* 109 : *white* 42, presumably representing a *3 : 1* ratio indicating the simple dominance of this character.

COIMBATORE,
February 14, 1917.

POSTSCRIPT.

Since this paper was written a careful examination has been made of a later crop comprising a number of F_4 families from No. 553, F_3 of Table XX. When the character of the rice was noted in conjunction with other segregating characters it was seen that all *red-riced* plants were *purple-pigmented* whereas all plants with *grey-brown* rice were *unpigmented*.

Table XXI gives the numbers for five families showing segregation for both pigmentation and rice colour. It will be seen that a very definite *9 : 3 : 3 : 1* ratio results from a *3 : 1* ratio of *pigmented : unpigmented*, together with a *3 : 1* ratio of *red : white* in the former group and of *grey-brown : white* in the latter group.

TABLE XXI.

Origin of parent	Reference No.	PURPLE-PIGMENTED		UNPIGMENTED	
		Red rice	White rice	Grey-brown rice	White rice
No. 553-N, F_3 ..	775-N	612	220	226	53
	776-N	400	131	130	46
	777-N	391	147	116	43
	781-N	682	220	235	68
	782-N	450	135	146	50
Total ..	..	2,535	853	853	260
Calculated 9 : 3 : 3 : 1	..	*2,532* :	*844* :	*844* :	*281*

Other families from the same parent gave a simple *3 : 1* ratio of *pigmented, red rice : unpigmented, grey-brown rice* and further analysis of some of the families given in the second half of Table XX shows that the same occurred there.

The most simple and probable explanation of this is that a single red rice factor is concerned, and that this is only able to produce the full-red colour in the presence of the particular purple pigmentation factor that is segregating in this group ; in the absence of this pigmentation factor the red rice factor gives grey-brown.

The existence of unpigmented varieties with red rice would be explained on the assumption that they lack the other of the two pigmentation factors which have already been shown to exist. If this theory is correct crosses between unpigmented red-riced varieties and the above grey-brown type should give a pigmented red-riced F_1, and F_2 should show segregation for both pigmentation factors. This will be tested in due course.

It was found that, owing to the rice-colour not developing properly till the grain is dead ripe, it was better to note this character in the field, leaving each plant till it was absolutely definite, rather than to take one head from each plant when the crop was ripe. The latter method no doubt accounts for much of the irregularity of the numbers in Table XX.

F. R. P.

June, 1917.

PLATE I.

Photographs of Ripe Grains.

1 Long Outer Glumes, "Rakki Pakshi Bhatta."
2-6 Short ditto.

Colours of Inner Glumes.

2 Green, ripening straw, "Poombalai."
3 Dark Gold, "Ponkambi Samba."
4 Dark Furrows, "Shiyali Kar."
5 Piebald Gold, "Garudan Samba."
6 Piebald Dark Furrows, "Manawari."

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OROBANCHE AS A PARASITE IN BIHAR

BY

F. J. F. SHAW, D.Sc. (Lond.), A.R.C.S., F.L.S

Second Imperial Mycologist

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OROBANCHE AS A PARASITE IN BIHAR.

BY

F. J. F. SHAW, D. Sc. (Lond.), A.R.C.S., F.L.S.,

Second Imperial Mycologist.

(Received for publication on 21st March, 1917.)

I. SYSTEMATIC.

In view of the fact that "tokras" are so widespread in Bihar, and occur on so many different hosts, the present research was commenced to investigate the biology of these parasites and in the hope of discovering whether any method could be devised to lessen the damage which they cause.

As is well known the parasitic species of *Orobanche,* known locally as "tokras," are small yellow plants from 3-12 inches high with bluish flowers. The stems are thick and succulent and the leaves are reduced to small scales, as is usual in plants of this habit. A very brief experience of this parasite in the field is sufficient to convince one that there are at least two species, which are common in Bihar. Hooker[1] describes eleven species in India, of which the greater number occur in the Himalaya and only three appear to be common in the plains; these are *O. indica* Ham., *O. cernua* Lœffl., and *O. Nicotianæ* Wight, the last named is stated to be a common and destructive pest of tobacco in the Deccan, while *O. indica* is said to be especially common in mustard throughout the plains of India. Prain[2] mentions two species, *O. indica* Ham. and *O. cernua* Lœffl., as being present in Bihar; he states that *O. cernua* is rare, and occurs on *Brassicas,* and that *O. indica* is the common pest of mustard, tobacco, *Brassicas,* etc. The presence of two bracteoles to each flower, and the fact that in *O. indica* the flowers are larger and not so closely crowded together as in *O. cernua,* are the distinguishing characters between the two species (Plate I, figs. 1 and 2; Plate II, fig. 3.).

The results of the observations recorded in the present paper differ somewhat from the facts given by Prain, and coincide more nearly with

[1] Hooker, *Flora of British India,* Vol. IV, 1885.

[2] Prain, *Bengal Plants,* 1903.

the statements of Hooker. The two species of *Orobanche* in Bihar are as follows :—

(1) *O. indica* Ham. Flowers with two bracteoles, calyx four—rarely five-toothed, divided to the base posteriorly, entire anteriorly, spikes loose flowered, corolla large, blue, stem often branched. This form belongs to the section of the genus named *Trionychon* Wallr. and is probably identical with *O. ægyptiaca* Pers. (*vide* Beck von Mannagetta[1]), and very closely related to, if not identical with, *O. ramosa* L.[2] ; this latter name is given by Massee[3] as that of a species which is parasitic upon tomato in England. In Bihar *O. indica* is the form which is the common and destructive parasite of mustard, cabbages, turnips, etc. It occurs on tobacco and tomato but does not appear to be, as a general rule, as serious a parasite of solanaceous crops as is *O. cernua.*

(2) *O. cernua* Lœffl. Bracteoles not present, calyx divided to the base posteriorly and anteriorly, lobes of the calyx bifid, spikes dense, corolla smaller and paler in colour than in *O. indica*, stem usually unbranched and thicker than in *O. indica,* frequently showing fasciation. This species belongs to the section *Osproleon* Wallr. of the genus *Orobanche,* and is stated by Beck von Mannagetta to be identical with *O. Nicotianæ* Wight. Hooker, however, distinguishes between these two species and states that *O. Nicotianæ* differs from *O. cernua* in the fact that the bract in the former is as long as the corolla tube and the lobes of the calyx are entire, and not divided. Prain makes no mention of the species *O. Nicotianæ,* which, according to Hooker, is restricted to the Deccan, and we have not seen any undoubted specimens although some specimens of *O. cernua* have closely approached to it when the lobes of the calyx were only slightly divided and the bract was rather larger than usual.

The species *O. cernua* is the common parasite of solanaceous crops in Bihar but does not appear to attack *Cruciferæ* (*cf.* Prain), only in four specimens were plants of *O. cernua* found on mustard. The parasitism of this species is therefore more restricted than is that of *O. indica,* which, while being a serious parasite on *Cruciferæ,* does occur to a certain extent on *Solanaceæ.* The life-histories of the two species appear to be identical, the " tokras " appearing a few weeks after the host crop is well established and rising to flower and fruit along with it. On mustard *O. indica* is sometimes a good deal earlier than on other crops, flowering from the beginning of December to the beginning of February, while *O. cernua* on tobacco is distinctly later, but there is a good

[1] Beck von Mannagetta, G. R., " Monographie der gattung Orobanche," *Biblioth. Botan.* Heft. 19. Cassel, 1890.

[2] Hooker, p. 326 *loc. cit.*, page 107.

[3] Massee, G., *Diseases of Cultivated Plants and Trees,* 1910.

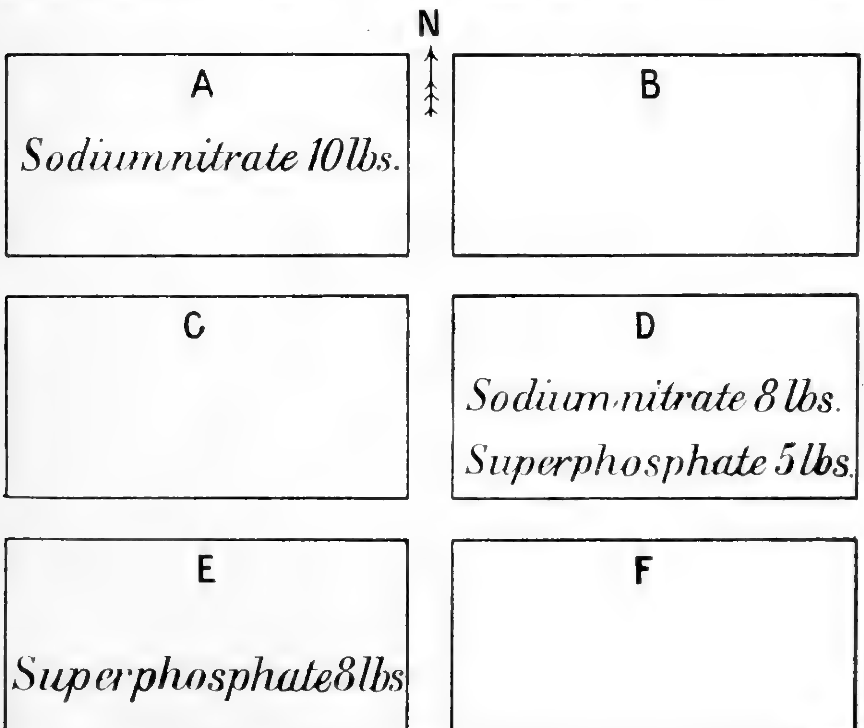
deal of variation in this matter from one season to another. Both species rely on the production of countless millions of minute seeds for their dissemination and perennation. These seeds are present all over the cultivated lands of Bihar, their number and minute size being extremely favourable to their dispersal in the strong winds which often prevail in February and March when the fruits of *Orobanche* are ripe.

The universal distribution of this parasite and the severity of the damage caused to a valuable crop, such as tobacco, make any practical remedial measures an important factor in Bihar agriculture. The field experiments described in this paper were devised with a view to testing whether the claim, which had recently been advanced, that Chili saltpetre (sodium nitrate) was a specific against "tokras" was founded upon fact.

II. FIELD EXPERIMENTS.

(1) Pusa—Season 1914-15.

A piece of land in the kitchen garden which had been under vegetables (cabbage, cauliflower, potatoes) for some years, and was known to be badly



Text-figure 1.

infected with "tokras," was selected for experimental work. This area was divided up into six equal plots (A, B, C, D, E, F), each about $\frac{1}{20}$th acre, and chemical manures were applied as indicated on the plan (Text-figure 1).

On the 6th October, 1914, the manure was spread evenly on the surface of the soil and mixed with the soil with a khurpi, a light beam harrow was then run over the surface. Tobacco (*Nicotiana tabacum*) was planted out in all the plots during the following fortnight.

In spite of the fact that the land was known to be badly infected with "tokra," a fair crop of tobacco was obtained and there were very few "tokras." Both *O. indica* and *O. cernua* occurred, but their incidence did not appear to be in any way affected by the application of the manures. The total number of "tokras" in the tobacco was about twenty, although in the previous year when the land was under cabbages they were to be counted by the thousand. The "tokras" which occurred on the cabbages were, of course, *O. indica*, the common "tokra" of *Brassicas*, and the explanation of the relative immunity of the tobacco, during this first season, seemed to be that this species was not a serious parasite of tobacco. This coincided with observations in the fields round Pusa where, although *O. cernua* usually prevailed on the tobacco, a certain amount of *O. indica* could nearly always be found.

(2) Pusa—Season 1915-16.

The same land was placed under tobacco, mustard and cabbage as indicated in the Text-figure 2. (See p. 111.)

(*a*) *Tobacco.* The two northern plots (A and B) were planted with tobacco (*N. tabacum*); each plot contained 18 rows with 16 plants in each row. Of the two plots under tobacco the one on the western side (A) was manured with sodium nitrate. Instead, however, of mixing the nitrate with the soil before planting out, the manure was dissolved in water and given to each plant in solution. Each tobacco plant received 1 oz. of sodium nitrate, given in three doses at intervals of 7 days, during the later portion of November; in all about 18 lb. of sodium nitrate was distributed among 288 tobacco plants in an area of $\frac{1}{20}$th acre. This works out at a rate of about 3 cwt. per acre. The first "tokra" appeared in the unmanured plot in December, but by the middle of January plants were appearing in both plots. The tobacco was cut on March 13th and the amount of "tokra" counted with the following results:—

		Number of tobacco plants	Number of *O. indica*	Number of *O. cernua*
Manured (A)	..	288	70	185
Unmanured (B)	..	288	2	1,156

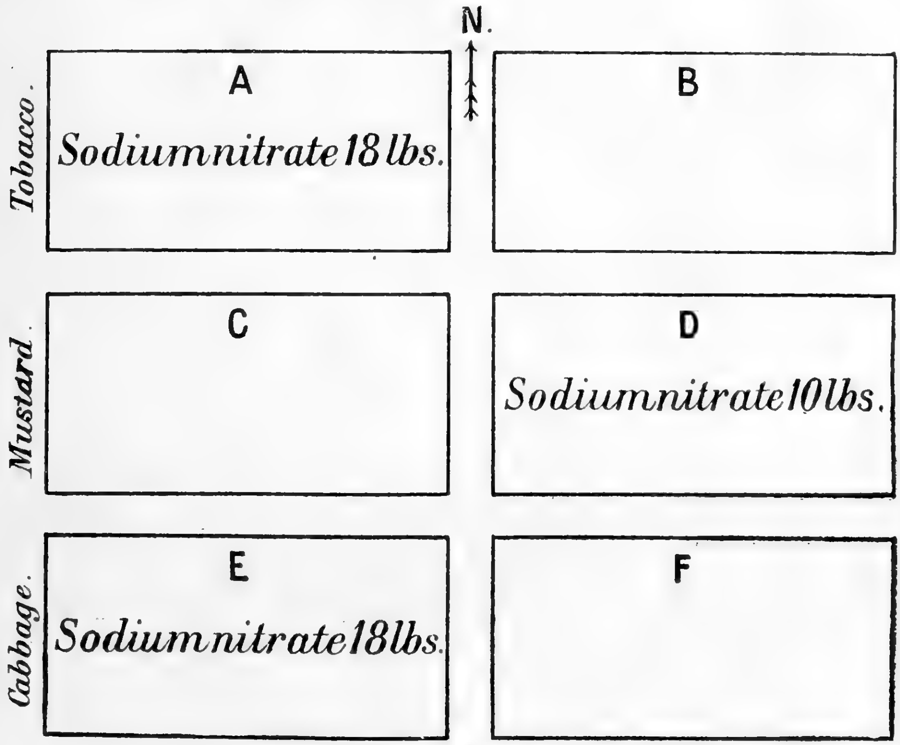
These figures bring out several facts :—

(1) The total amount of "tokra" in the second year was very much greater than in the first, the increase being particularly marked in *O. cernua,* which constituted 94 per cent. of the total number of "tokras" present.

(2) The bulk of the *O. indica* was concentrated in the manured plot and the bulk of the *O. cernua* in the unmanured plot ; in the latter case the bulk of the *O. cernua* was on the eastern edge.

(3) The total amount of *O. indica* was very much less than was known to be in the soil but showed a substantial increase on the amount present in the previous years.

(4) The amount of "tokra" in the manured plot was only about one-fifth of that in the unmanured plot.



Text-figure 2.

With regard to the increase in the total amount of "tokra," this increase is really larger than appears from the figures since the area under tobacco in the second year was only one-third of that under tobacco in the first year, the remaining plots being used for mustard and cabbage. This increase consisting as it does principally of *O. cernua* is to be attributed to the seeds from last year's "tokras," which fell into the soil as the fruits ripened and germinated next season with the second crop.

Although it was evident, from an inspection of the numbers of "tokras" in the neighbouring plots of mustard and cabbage, that large quantities of the seed of *O. indica* were in the soil yet in proportion very few plants of *O. indica* occurred in the tobacco. This bears out the conclusion of the previous season that this species is not normally a heavy parasite of tobacco. Yet a field of tobacco was found near Pusa in which the crop had been very severely damaged by *O. indica*—there being hardly any *O. cernua* present. These facts must be considered later when describing the results of the pot cultures.

The fact that the bulk of the *O. cernua* was in one corner of the unmanured plot, and the bulk of the *O. indica* was scattered over the manured plot, cannot but suggest that the degree of local infection in a particular field is a very potent factor in the number and distribution of the "tokras" which appear and that the differences between the two plots in this experiment might be due to some factor other than the application of nitrate.

(*b*) *Mustard* (*Brassica campestris* var. *glauca*). Of the two plots under mustard that on the east (Plot D), received 10 lb. of sodium nitrate scattered on the surface and mixed with the soil immediately before sowing. The germination was good and the crop came into flower on 24th November, the first "tokra" showing above the surface about the same time in both the manured and the unmanured plot. From the end of November onwards there was a steady appearance of "tokra," all of which was *O. indica*. On February 12th the mustard was cut and the number of mustard plants and "tokras" in each plot was counted, the results were as follows :—

	Number of mustard plants	Number of *O. indica*
Manured (D) ..	1,949	2,012
Unmanured (C) ..	1,634	3,070

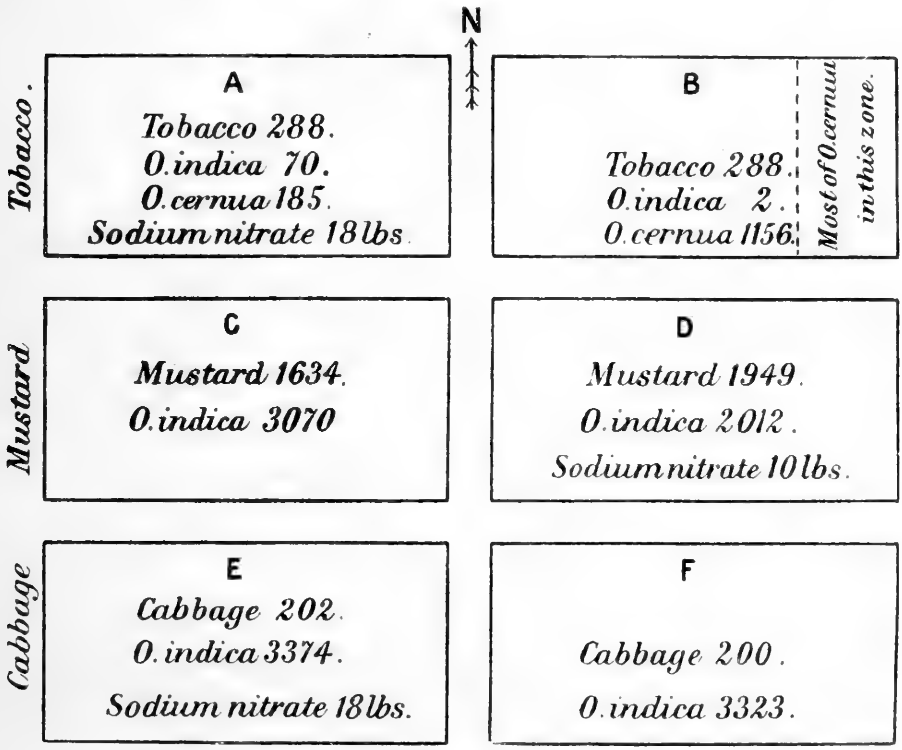
The weight of the mustard cut from each plot amounted to about 8½ maunds. From the above figures it cannot be contended that the sodium nitrate had any very marked effect on the appearance of the "tokras," while the number of "tokras" which came up showed that their non-appearance in the previous season, when the plots were under tobacco, was not due to lack of infection in the soil but rather to lack of a suitable host.

(*c*) *Cabbage* (*Brassica oleracea*). Cabbage seedlings were planted out in two of the plots towards the end of November. There were 200 seedlings in each plot and one plot (E) received $18\frac{1}{2}$ lb. of sodium nitrate. The nitrate was given to the plants in solution, each plant receiving about 1·4 oz., in three doses at intervals of six days. The cabbages grew well and there was a steady appearance of "tokra." In March the crop was counted and the figures were—

	Number of cabbages	Number of *O. indica*
Manured (E) ..	202	3,374
Unmanured (F) ..	200	3,323

Sodium nitrate did not have any effect on the "tokra."

The following Text-figure 3 is a diagrammatic summary of the second year's experiments :—

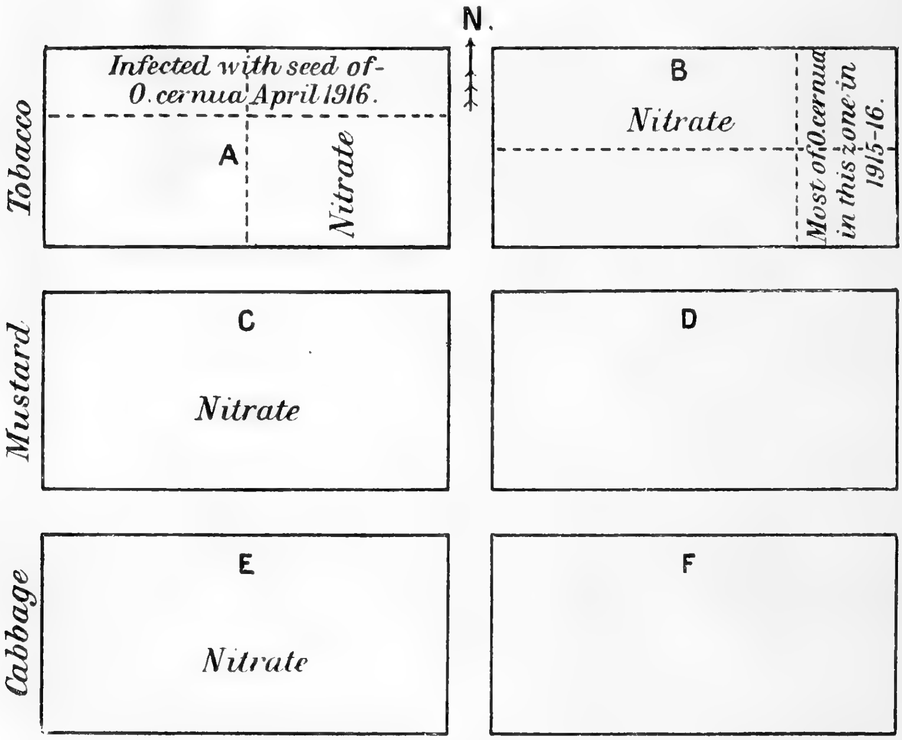


Text-figure 3.

(3) Pusa—Season 1916-17.

The same plots were placed under tobacco, mustard and cabbage as in the previous season.

(*a*) *Tobacco.* Of the two tobacco plots, that which had not received any nitrate in the previous season, 1915-16 (Plot B), had contained the larger quantity of *O. cernua* and the bulk of this had been concentrated in a strip along the eastern edge of the plot. In April, 1916, about 4 oz. of seed of *O. cernua* was collected from this plot and scattered along the northern side of the other plot, for about one-third of the breadth of the plot, a light beam was then run over the plot. In September, 1916, both plots were planted out with tobacco ; there were 18 rows with 16 plants in each row, making a total of 288 plants in each plot. Instead of manuring the whole of one plot, the eastern half of the western plot (A) and the northern half of the eastern plot (B) received sodium nitrate. The nitrate was given in solution in three doses, as in the previous year, and each plant manured received a total of 1 oz. of nitrate. Thus in each manured area 9 lb. of sodium nitrate was distributed among 144 tobacco plants. The scheme of the experiment in 1916-17 is shown in Text-figure 4.



Text-figure 4.

The effect of the nitrate upon the tobacco was especially marked in the case of eastern plot (B). This plot in the experiments of the two previous seasons had not received any nitrate and the tobacco in the manured half of this plot was distinctly greener and larger than in the remaining portion. This difference was not observed in the western tobacco plot (A), which had been manured in the two previous seasons.

The tobacco was cut and the "tokras" counted on 2nd March with the following results :—

Eastern plot (B).

	Number of tobacco plants	Number of *O. indica*	Number of *O. cernua*
Manured	144	5	2,192
Unmanured	144	0	4,615

Western plot (A).

Manured	144	1	1,715
Unmanured	144	4	2,994

It was interesting to observe that in the eastern plot (B), in both manured and unmanured areas, the "tokra" was most plentiful in the eastern half, in which it had been the more abundant in the previous season. In the western plot it was most abundant in the northern portion of the plot which had been infected with seed of *O. cernua* in the previous April. The amount of *O. indica* in both plots was considerably less than in the previous season—a fact which will be found to apply to all the experiments in 1916-17. The amount of *O. cernua*, however, in each plot was very greatly increased. Thus last year plot (A) had only 185 *O. cernua* but this year it had 4,709. The significance of these results in relation to the application of the nitrate will be considered, in conjunction with the results of other experiments, later.

(*b*) *Mustard.* The two plots (C and D) were sown with mustard on October 14th and 20 lb. of sodium nitrate was scattered on the western plot (C) on October 30th, when the young plants were up. The crop grew well but in both plots the "tokra" seemed to be later and less than in the previous season. The crop was cut on February 3rd and the figures were :—

	Weight of mustard	Number of mustard plants	Number of *O. indica*
Manured (C) ..	10½ mds.	3,753	1,402
Unmanured (D) ..	7¼ „	4,109	732

These figures show that the amount of *O. indica* in both plots was very much less in 1916-17 than in the previous season. No reason can be given for this. Comparing the two plots with one another in each season it is seen that the western plot (C) always had the most "tokra" irrespective of whether it had received sodium nitrate or not. *O. cernua* was not present.

(*c*) *Cabbage.* The same two plots (E and F), as in the season 1915-16, were planted out with cabbages. Each plot contained 196 cabbage seedlings and each seedling in the western plot (E) received 1 oz. of sodium nitrate applied in solution in three doses. The "tokras" were counted on 28th February and the figures were :—

		Number of cabbages	Number of *O. indica*
Manured (E)	..	196	592
Unmanured (F)	..	196	642

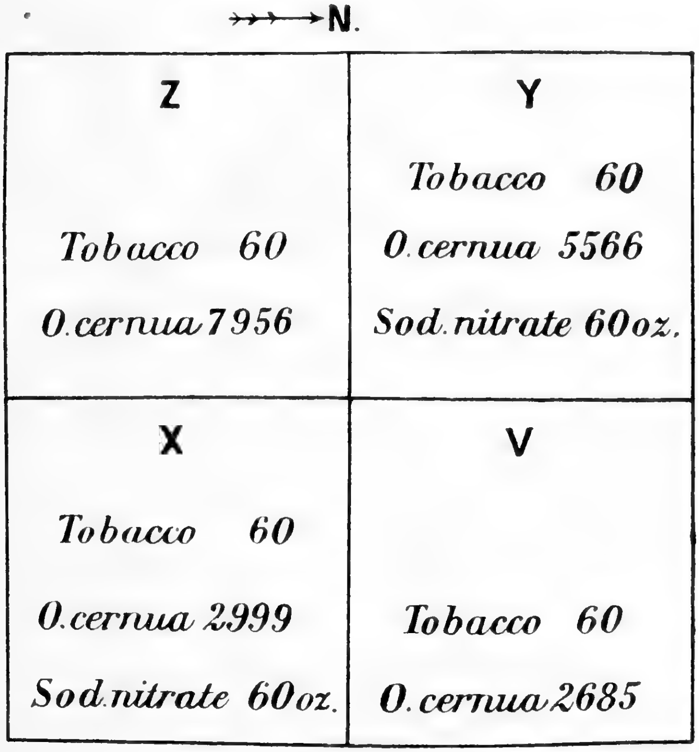
O. cernua was not present at all. These results agree with those of the previous season in the fact that the quantity of "tokra" in the manured plot (E) was substantially the same as in the unmanured plot (F)—although the same plot had received the nitrates in two successive years. The most striking difference is in the actual amount of *O. indica* present in the second season relative to what was present in the first, a comparison showing a reduction from about 3,000 to 600 in both plots. This peculiarity has already been mentioned in the case of the tobacco and mustard at Pusa and appears also in that crop at Birowlie. It is important to notice that the decrease affects equally manured and unmanured plots and is entirely independent of the application of sodium nitrate.

Tobacco New Plot. During the season 1915-16, a plot (about one-twentieth acre) of tomatoes in the kitchen garden was noticed to be suffering severely from both *O. cernua* and *O. indica.* This plot was ploughed and harrowed in May 1916 and after cultivation was planted out with tobacco in October. The tobacco was planted in 8 rows or 30 plants in each row, the lines selected being those in which the tomatoes had stood during the previous season, the correct position having been marked before taking up the tomatoes. The plot was then divided into four equal areas (X, Y, Z, V), and sodium nitrate at the rate of 1 oz. per plant was applied in solution to the south-eastern (X) and north-western quarters (Y) of the plot (Text-figure 5, p. 117).

"Tokra" appeared early in December and came up in large numbers until the crop was cut on 1st March. The amounts of "tokra" present were as follows :—

		Number of tobacco plants	Number of *O. cernua*
Manured areas ..	..	60—60	2,999 (X)—5,566 (Y)
Unmanured areas	..	60—60	7,956 (Z)—2,685 (V)

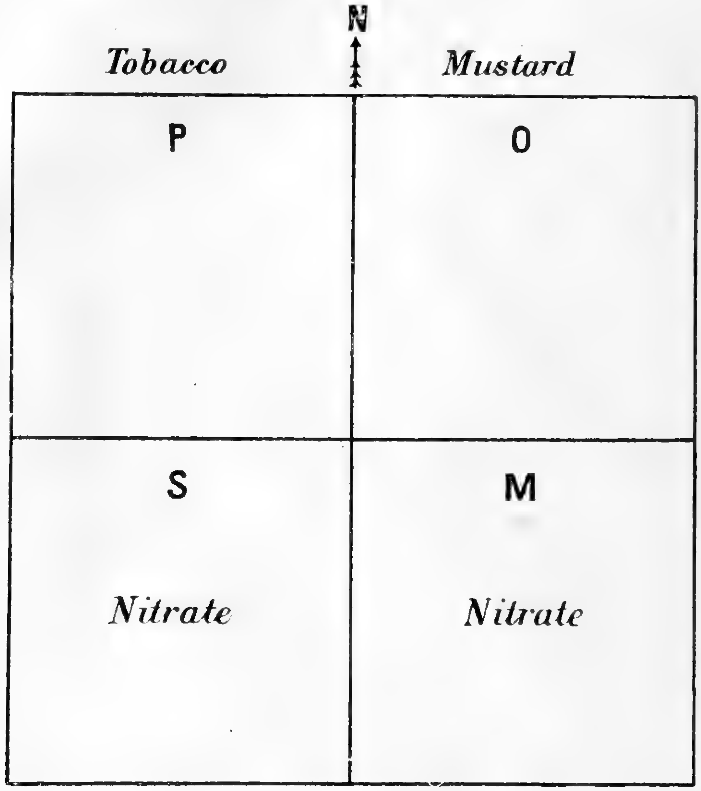
The distribution of these numbers of "tokras" is shown on the plan (Text-figure 5), and it is at once clear that the western half of the field contained the larger number of "tokras" irrespective of any application of the nitrate. It is most interesting to observe that *O. indica* did not come up on the tobacco although in the previous season it had been present on the tomatoes in this field in relatively large numbers.



Text-figure 5.

(4) Birowlie—Season 1915-16.

During March 1915 a field of tobacco at Birowlie Indigo Factory was very badly infected with "tokra" of which the vast majority were *O. cernua* and a few *O. indica*. A portion of this field was, therefore, selected for experimental work during the cold weather of 1915-16. The experimental area was about one-fifth acre and was divided up into four plots (S, M, O, P); two plots were sown with mustard and two were planted with tobacco at the rate of 288 tobacco plants to each plot. One plot each of tobacco (S) and mustard (M) received 20 lb. of sodium nitrate spread and mixed with the soil about two weeks before sowing (Text-figure 6).



Text-figure 6.

Mustard. The crop grew well and "tokra" appeared in both plots early in December; it was entirely *O. indica.* There was no appreciable difference in the amount of "tokra" relative to the mustard between the manured and the unmanured plot. As *O. cernua* had been very common in this land in the past season, when it was under tobacco, the predominance of *O. indica* when mustard was grown furnished a good illustration of the differences in their parasitism. In four plants, however, *O. cernua* was found attached to the roots of mustard indicating further possibilities in the parasitism of this species. The actual figures were:—

	Number of plants	Number of *O. indica*	Number of *O. cernua*
Manured (M) ..	1,453	2,201	4
Unmanured (O) ..	2,553	3,797	0

The depredations of some stray cattle were responsible for the paucity of mustard in the manured plot.

Tobacco. The tobacco crop grew well at first but "tokra" appeared early in December and continued to come up in ever increasing numbers causing large cracks to appear all round the tobacco plants. Whether from the loss of moisture through these cracks or from the actual parasitic effect of the "tokra," the tobacco had a wilted appearance, this condition was most noticeable in the afternoon. In February the whole field was full of "tokra," a certain amount of *O. indica* being mingled with *O. cernua* (Plate II, fig. 4; Plate III, figs. 5 and 6). On the 20th February the crop had a very poor appearance and was cut. The following figures give the actual amounts of the two species of *Orobanche* in comparison with the tobacco :—

		Number of tobacco plants	Number of *O. cernua*	Number of *O. indica*
Manured (S)	..	287	16,574	1,999
Unmanured (P)	..	288	9,976	1,700

These figures are most emphatically against the claim that sodium nitrate may be used as a preventive against "tokra." In comparison with the figures for the mustard plots, those for the tobacco show the extent to which the species which is the chief parasite of one crop can infect the other crop.

(5) Birowlie—Season 1916-17.

The same field was placed under mustard and tobacco as in the previous season (Text-figure 6).

Mustard. Sodium nitrate (20 lb.) was scattered upon the southern mustard plot (M) about two weeks after sowing. The crop grew badly and, as at Pusa, "tokra" was later in appearing and less in amount than in the previous season. The crop was cut on February 18th.

		Weight of mustard		Number of plants of mustard	Number of *O. indica*
		Mds.	Srs.		
Manured (M)	..	3	6	3,445	687
Unmanured (O)	..	2	28	2,846	1,404

There was no *O. cernua* in the mustard. These figures show that in 1916-17 the total amount of *O. indica* in both plots was very much less than in the previous season; this fact has already been noticed in the case of the Pusa experiment. No explanation can be given as to why the season 1916-17 appears to have been less favourable to *O. indica*.

The distribution of the "tokra" in the manured and unmanured plots was the same as in last year; the southern (manured) plot (M) had the smaller amount of "tokra."

Tobacco. Tobacco was planted out in the two plots next to the mustard as in the previous season, the number of plants in each plot being increased in 1916-17 from 288 to 342. The nitrate was applied to the same plot as in the season 1915-16 but was given in solution at the rate of 1 oz. to each plant. The total quantity of nitrate used thus came to about 22 lb.

"Tokra" appeared at the end of November and continued to come up until the crop was cut on 26th February, by which date the tobacco was in a very bad condition. The actual amounts of "tokra" present were as follows :—

	Number of tobacco plants	Number of *O. cernua*	Number of *O. indica*
Manured (S) ..	342	17,291	442
Unmanured (P) ..	342	14,822	981

In comparison with the previous season the total amount of *O. cernua* shows an increase in both plots, the larger quantity being, as in the previous season, in the manured plot; the increase, however, is proportionately greater in the unmanured plot. The amount of *O. indica* present shows the decrease which has already been mentioned as occurring in all the experiments in the season 1916-17.

III. POT CULTURE, 1916-17.

The fact that the tobacco grown at Pusa in a field which was known to be infected with seed of *O. indica* suffered from "tokra" only very slightly in the first year, and in the second year contained far less *O. indica* than the adjoining plots of mustard and cabbage, in conjunction with the fact that one field of tobacco outside Pusa was found to be practically destroyed by this species, suggested that the morphological species *O. indica* possibly contained two races differing in their parasitic properties.

With a view to testing the parasitism of *O. cernua* and *O. indica* on different hosts, with greater accuracy than was possible within the limits of a field experiment, a series of pot cultures was made at Pusa during the cold weather of 1916-17. Soil for the pots was obtained from land which had been lying fallow for a large number of years, and which was not known to have ever been under a crop liable to the attack of *Orobanche.* There was therefore a strong probability that such soil would not contain any seed of *Orobanche* and moreover a number of the pots, filled with a mixture of leaf-mould and this soil, were sterilized in the steam sterilizer in order to kill any chance seeds which might be present. As, however, the conditions necessary for the germination of the seed of parasites such as *Orobanche* are known to be delicate, it was not considered advisable to sterilize all the pots. In all 92 pots were used of which 36 were planted with tobacco, 24 with mustard, 16 with turnip (*Brassica campestris* var. *rapa*) and 16 with cabbage. These pots were then infected with seed of *O. cernua* and *O. indica* which had been collected in the season 1915-16. In the case of *O. cernua* the seed used had been collected from three distinct sources—from plants which were parasitic on tobacco, from plants which were parasitic upon tomato and from plants which were parasitic upon brinjal (*Solanum Melongena* Linn.) In the case of *O. indica* the seed used was obtained from four sources, namely, from plants parasitic respectively upon cabbage, mustard, turnip, and tobacco. For convenience in this account the particular kind of seed of *Orobanche* is indicated by the addition of the name of the host plant, from which it was collected, after the specific name; thus seed *O. indica cabbage* means seed of *O. indica* collected from plants parasitic upon cabbage. In this way it was hoped to observe whether the influence of the previous host had any effect upon the parasitism of the seed of either *O. cernua* or *O. indica*. The number of pots sterilized was 16, and 46 pots received each 1 oz. of sodium nitrate when the host plants were well established. These details are apparent in the list of the pots (page 123) and in the plan of the experiment. (Text-figure 7.)

Seed *O. cernua tobacco* was infected upon four pots each of tobacco, mustard, cabbage, and turnip. This was done by scattering a quantity of the seed on the surface of the soil and mixing lightly with a small stick. In the case of tobacco and cabbage the host plant had been planted in the pot some days previously; in the mustard and turnip pots the seed of the parasite was sown mingled with that of the host. Half of the pots had received 1 oz. each of sodium nitrate. After about six weeks (from November 8th to 15th) plants of *O. cernua* appeared in three of the tobacco pots and considerably later (2nd January) also in the fourth pot of tobacco. Those pots which had received nitrate were indistinguishable, except in regard to the development of the host, from the others. No plants of *O. cernua* appeared in the pots of mustard, cabbage, or turnip. Late in January, when the pots had been standing in the open for four months, a few plants of *O. indica* appeared in one pot of cabbage and three pots of turnip. The time at which they appeared, coupled with the fact that they were not of the species of *Orobanche* used in the infection, indicates that their origin is to be attributed to chance infection by air-borne seed after the experiment was started.

Seed *O. cernua brinjal* was infected upon eight pots of tobacco, four of which received 1 oz. each of sodium nitrate. In the first six weeks "tokra" came up in all the non-nitrate pots and in two of the nitrate pots. In the two remaining nitrate pots it did not appear until after the lapse of three months. Seed *O. cernua tomato* infected upon tobacco behaved in much the same manner, but in one pot, which had received sodium nitrate, "tokra" did not appear.

Seed *O. indica cabbage* was infected upon four pots each of tobacco, mustard, cabbage, and turnip; half of the pots had received 1 oz. each of sodium nitrate. No "tokra" at all appeared upon the tobacco; "tokra" (*O. indica*) came up in all the pots of mustard and turnip and in two of the pots of cabbage. It did not appear in the two cabbage pots which had received nitrate, and in the mustard and turnip nitrate pots it was distinctly later in appearing than in the non-nitrate pots. Seed *O. indica mustard* behaved in exactly the same way as the seed *O. indica cabbage* when infected upon tobacco, mustard, cabbage, and turnip. Here, again, "tokra" was much later in appearing in the nitrate pots and in one nitrate pot of cabbage did not come up at all. Seed *O. indica turnip* gave the same result, coming up on mustard, cabbage and turnip but not appearing in the tobacco pots. "Tokra" was again late in the nitrate pots and did not appear at all in the cabbage pots which had nitrate.

It has been mentioned previously in this account that *O. indica* is sometimes found parasitic upon tobacco. Seed of *O. indica* from this source was accordingly used to infect eight pots of mustard and four pots of tobacco. In the eight pots of mustard "tokra" only appeared in two pots and in each of these pots there was only one "tokra" and that a very small and weak specimen of *O. indica*. In all the tobacco pots "tokra" appeared very abundantly; it was appreciably later in those pots which had received nitrate but still each of the four pots had about 50 "tokras." In every case this "tokra" was *O. indica* and was morphologically indistinguishable from the "tokra" which had appeared in the mustard, cabbage, and turnip pots when these were infected with seed of *O. indica* from cabbage, mustard, and turnip hosts. Yet these latter varieties of *O. indica* seed failed to give any "tokras" when infected upon tobacco. It appears therefore that seed of *O. indica* collected from mustard, cabbage, and turnip hosts will infect these hosts and will not infect tobacco, while seed of *O. indica* collected from tobacco host will infect tobacco and will hardly infect mustard at all.

The facts established by these pot cultures therefore appear to be as follows :—

(1) Seed *O. cernua tobacco* is strongly parasitic upon tobacco, does not infect mustard, cabbage, and turnip, and its incidence upon tobacco is not influenced by applications of sodium nitrate.

(2) Seed *O. cernua brinjal* and *O. cernua tomato* is strongly parasitic upon tobacco and is slightly influenced by nitrate.

(3) Seed *O. indica mustard*, *O. indica cabbage*, and *O. indica turnip* do not infect tobacco but come up equally on the other three hosts ; applications of nitrate delay the appearance of the " tokra."

(4) Seed *O. indica tobacco* comes up strongly upon tobacco but very slightly upon mustard ; nitrate has the same effect as upon the other varieties of seed of *O. indica*.

The most interesting point brought out by these results is that the morphological species *O. indica* appears to consist of two races. One race is strongly parasitic upon *Cruciferæ* and does not attack tobacco (*N. tabacum*) and the other race attacks tobacco and does not attack *Cruciferæ*. In the field experiments in 1916-17 it has already been mentioned that a crop of tobacco, grown in a field which in the previous season had been under tomato and which then contained plenty of *O. cernua* and *O. indica*, did not contain a single plant of *O. indica*, although *O. cernua* was abundant. This suggests the possibility of further specialisation in the parasitism of *O. indica*. The details of the pot culture experiment are shown in the following list and in the plan (Text-figure 7).

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of " tokra "	Species of " tokra "	Total number of " tokras " which came up	REMARKS
1	Tobacco 27th Sept.	*O. cernua tobacco* 3rd Oct.	S	8th Nov.	*O. cernua*	17	S=pot sterilized.
2	do.	do.	..	2nd Jan.	do.	13	
3	do.	do.	N	16th Nov.	do.	21	N=1 oz. nitrate given.
4	do.	do.	N	do.	do.	29	
5	do.	*O. indica cabbage* 3rd Oct.	S	none	none	none	
6	do.	do.	..	do.	do.	do.	
7	do.	do.	N	do.	do.	do.	
8	do.	do.	N	do.	do.	do.	

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of "tokra"	Species of "tokra"	Total number of "tokras" which came up	REMARKS
9	Tobacco 27th Sept.	*O. indica mustard* 3rd Oct.	S	none	none	none	S=pot sterilized.
10	do.	do.	..	do.	do.	do.	
11	do.	do.	N	do.	do.	do.	N=1 oz. nitrate given.
12	do.	do.	N	do.	do.	do.	
13	do.	*O. indica turnip* 3rd Oct.	S	do.	do.	do.	
14	do.	do.	..	do.	do.	do.	
15	do.	do.	N	do.	do.	do	
16	do.	do.	N	do.	do.	do.	
17	Mustard 14th Oct.	*O. cernua tobacco* 14th Oct.	S	do.	do.	do.	
18	do.	do.	..	do.	do.	do.	
19	do.	do.	N	do.	do.	do.	
20	do.	do.	N	do.	do.	do.	
21	do.	*O. indica cabbage* 14th Oct.	S	30th Nov.	*O. indica*	20	
22	do.	do.	..	12th Dec.	do.	13	
23	do.	do.	N	6th Jan.	do.	24	
24	do.	do.	N	20th Dec.	do.	43	
25	do.	*O. indica mustard* 14th Oct.	S	26th Nov.	do.	9	
26	do.	do.	..	2nd Dec.	do.	51	
27	do.	do.	N	6th Jan.	do.	11	
28	do.	do.	N	19th Dec.	do.	21	
29	do.	*O. indica turnip* 14th Oct.	S	2nd Dec.	do.	10	
30	do.	do.	..	6th Dec.	do	85	
31	do.	do.	N	2nd Jan.	do.	112	
32	do.	do.	N	do.	do.	47	
33	Cabbage 23rd Oct.	*O. cernua tobacco* 23rd Oct.	S	none	none	none	
34	do.	do.	..	do.	do.	do.	One plant of *O. indica*, result of chance infection, appeared on 12th January.
35	do.	do.	N	do.	do.	do.	
36	do.	do.	N	do.	do.	do.	
37	do.	*O. indica cabbage* 23rd Oct.	S	6th Dec.	*O. indica*	29	
38	do.	do.	..	9th Dec.	do.	68	
39	do.	do.	N	none	none	none	
40	do.	do.	N	do.	do.	do.	
41	do.	*O. indica mustard* 23rd Oct.	S	6th Dec.	*O. indica*	16	

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of "tokra"	Species of "tokra"	Total number of "tokras" which came up	REMARKS
42	Cabbage 23rd Oct.	*O. indica mustard* 23rd Oct.	..	6th Dec.	*O. indica*	28	
43	do.	do.	N	17th Jan.	do.	19	N=1 oz. nitrate given.
44	do.	do.	N	none	none	none	
45	do.	*O. indica turnip* 23rd Oct.	S	13th Dec.	*O. indica*	49	S=pot sterilized.
46	do.	do.	..	9th Dec.	do.	48	
47	do.	do.	N	none	none	none	
48	do.	do.	N	do.	do.	do.	
49	Turnip 23rd Oct.	*O. cernua tobacco* 23rd Oct.	S	do.	do.	do.	A few plants of *O. indica* appeared in these pots towards end of January—the result of chance infection by air-borne seed.
50	do.	do.	..	do.	do.	do.	
51	do.	do.	N	do.	do.	do.	
52	do.	do.	N	do.	do.	do.	
53	do.	*O. indica cabbage* 23rd Oct.	S	6th Dec.	*O. indica*	13	
54	do.	do.	..	19th Dec.	do.	39	
55	do.	do.	N	2nd Jan.	do.	13	
56	do.	do.	N	14th Dec.	do.	56	
57	do.	*O. indica mustard* 23rd Oct.	S	6th Dec.	do.	28	
58	do.	do.	..	6th Dec.	do.	26	
59	do.	do.	N	19th Jan.	do.	24	
60	do.	do.	N	do.	do.	19	
61	do.	*O. indica turnip* 23rd Oct.	S	14th Dec.	do.	29	
62	do.	do.	..	6th Dec.	do.	16	
63	do.	do.	N	30th Jan.	do.	20	
64	do.	do.	N	10th Jan.	do.	65	
65	Tobacco 27th Sept.	*O. cernua brinjal* 3rd Oct.	S	20th Nov.	*O. cernua*	34	
66	do.	do.	..	15th Nov.	do.	72	
67	do.	do.	..	do.	do.	78	
68	do.	do.	..	20th Nov.	do.	42	
69	do.	do.	N	8th Nov.	do.	29	
70	do.	do.	N	do.	do.	61	
71	do.	do.	N	10th Jan.	do.	41	
72	do.	do.	N	do.	do.	42	
73	do.	*O. cernua tomato* 3rd Oct.	S	1st Dec.	do.	87	
74	do.	do.	..	20th Nov.	do.	53	
75	do.	do.	..	do.	do.	32	

Number of pot	Host and date of planting	Parasite and date of sowing	Sterilization and nitrate	Date of first appearance of "tokra"	Species of "tokra"	Total number of "tokras" which came up	REMARKS
76	Tobacco 27th Sept.	*O. cernua tomato* 3rd Oct.	..	6th Dec.	*O. cernua*	46	
77	do.	do	N	none	none	none	N=1 oz. nitrate given.
78	do.	do.	N	19th Jan.	*O. cernua*	58	
79	do.	do.	N	20th Dec.	do.	36	
80	do.	do.	N	do.	do.	46	
81	Mustard 14th Oct.	*O. indica tobacco* 14th Oct.	S	none	none	none	S=pot sterilized.
82	do.	do.	..	do.	do.	do.	
83	do.	do.	..	do.	do.	do.	
84	do.	do.	..	11th Dec.	*O. indica*	1	Probably result of chance infection by air-borne seed.
85	do.	do.	N	none	none	none	
86	do.	do.	N	do.	do.	do.	
87	do.	do.	N	do.	do.	do.	
88	do.	do.	N	12th Jan.	*O. indica*	1	Ditto
89	Tobacco 3rd Oct.	*O. indica tobacco* 3rd Oct.	S	12th Dec.	do.	·60	(*see* Plate I, fig. 2.)
90	do.	do.	..	do.	do.	46	One plant of *O. cernua*—the result of air-borne infection —the remainder all *O. indica*.
91	do.	do.	N	2nd Jan.	do.	52	
92	do.	do.	N	10th Jan.	do.	50	

IV. CONCLUSIONS.

Considering the question whether applications of sodium nitrate can be advocated as a preventive for "tokras" the results of the experiments described in this paper cannot be said to support that view.

In the case of cabbage the field experiments at Pusa did not show any diminution in the amount of *O. indica* in the plot which had the nitrate, relative to that which had not received any nitrate. With mustard, both at Pusa and at Birowlie, it was found that the plot which had the larger number of "tokras" (*O. indica*) in one season was that which had the larger number in the previous season and that the application of sodium nitrate did not alter these proportions. It is of course not contended that the application of sodium nitrate is without benefit to the mustard but simply that it is not a specific against the "tokra" which is parasitic upon mustard and cabbage

HOST.	O. CERNUA OF TOMATO.							O. INDICA OF TOBACCO.							
TO	74 C 53	75 C 32	76 C46	77 N	78 N C58	79 N C36	80 N C45	89 I60	90 I46	91 N I52	92 N I50				
MU n.								81	82	83	84 I1	85 N	86 N	87 N	88 N I1
CA															
TU															

is the number of the pot
umeral gives the total
which came up in that pot.

Host \ Parasite	O. CERNUA OF TOBACCO.				O. INDICA OF CABBAGE.				O. INDICA OF MUSTARD.				O. INDICA OF TURNIP.			
TOBACCO	1 S C_{17}	2 C_{13}	3 N C_{21}	4 N C_{29}	5 S	6	7 N	8 N	9 S	10	11 N	12 N	13 S	14	15 N	16 N
MUSTARD	17 S	18	19 N	20 N	21 S I_{20}	22 I_{13}	23 N I_{24}	24 N I_{43}	25 S I_{9}	26 I_{51}	27 N I_{11}	28 N I_{21}	29 S I_{10}	30 I_{85}	31 N I_{112}	32 N I_{47}
CABBAGE	33 S	34	35 N	36 N	37 S I_{29}	38 I_{68}	39 N	40 N	41 S I_{16}	42 I_{28}	43 N I_{19}	44 N	45 S I_{49}	46 I_{48}	47 N	48 N
TURNIP	49 S	50	51 N	52 N	53 S I_{13}	54 I_{39}	55 N I_{13}	56 N I_{56}	57 S I_{28}	58 I_{26}	59 N I_{24}	60 N I_{19}	61 S I_{29}	62 I_{16}	63 N I_{20}	64 N I_{65}

Host \ Parasite	O. CERNUA OF BRINJAL.								O. CERNUA OF TOMATO.								O. INDICA OF TOBACCO.							
TOBACCO	65 C_{34}	66 C_{72}	67 C_{78}	68 C_{42}	69 N C_{29}	70 N C_{61}	71 N C_{41}	72 N C_{42}	73 C_{87}	74 C_{53}	75 C_{32}	76 C_{46}	77 N	78 N C_{58}	79 N C_{36}	80 N C_{45}	89 I_{60}	90 I_{46}	91 N I_{52}	92 N I_{50}				
MUSTARD																	81	82	83	84 I_{1}	85 N	86 N	87 N	88 N I_{1}

S = sterilised.
N = 1oz nitrate given.
C = O. cernua.
I = O. indica
The large numeral is the number of the pot and the small numeral gives the total number of tokras which came up in that pot.

Text-figure 7.

In the case of the tobacco the results of the field experiments were not so obvious. At Birowlie in two successive seasons the larger quantity of *O. cernua* appeared in one particular plot, although this plot received a heavy application of sodium nitrate in each season. This suggested that the incidence of "tokra" in a field was dependent upon factors, other than the application of nitrate, such as the amount of "tokra" seed present and the resulting degree of infection of the soil. The results of the experiments in the "new plot" at Pusa in 1916-17 confirm this view. A reference to Text-figure 5 will show that in this plot the *O. cernua* occurred chiefly in the western half of the field and was not materially influenced by the nitrate. The two original tobacco plots, A and B, gave results which superficially did not agree with this. In these plots the amount of *O. cernua* was less in the areas which had received the nitrate. This was most marked in the case of the plot B which had not had any manure in the two previous seasons, and received an application of nitrate upon half its area for the first time in the season 1916-17. In this plot the unmanured area contained about 30 plants of *O. cernua* to every tobacco plant and the manured area contained about 15 plants of *O. cernua* to each tobacco plant. But a proportion of 15 "tokras" to each tobacco plant in the manured area appears, in the writer's opinion, too large to justify the claim of any curative properties against "tokra" for nitrate of soda. Moreover it must be pointed out that in the two plots A and B in the season 1916-17, the amounts of "tokra" in the two unmanured areas differed from one another nearly as much as when the comparison was made between one of the areas which had received nitrate and one which had not received any (*see* page 115). If applications of sodium nitrate were likely to prove a preventive against "tokra" a result would surely have appeared in the pot cultures, where the application of 1 oz. to each pot was at the rate of several tons to the acre. In this case, however, *O. cernua* on tobacco was almost quite uninfluenced by the nitrate and the most favourable result obtained with other crops was a delay in the appearance of the "tokra."

Chili saltpetre therefore can hardly be advocated as a cure for "tokra." In a valuable crop, such as tobacco, and in a district where labour is as cheap as it is in Bihar, much may be done to keep these pests down by hand-weeding, the "tokras" being uprooted before they have formed mature seed which could infect the soil for the succeeding crop. With a crop such as mustard it might be possible to cultivate early varieties, which ripen before the "tokra" has matured its seed, and by ploughing immediately after harvesting to bury the

" tokra " before its seed has ripened. In this connection it may be mentioned that the practice of taking a second cut from the tobacco is a bad one ; the longer the tobacco is kept in the soil the more " tokras " come up and the more seed is matured to infect the soil for the next crop.[1]

It is evident that the parasitism of *O. indica* is much more complicated than that of *O. cernua*. *O. cernua* is practically restricted to solanaceous crops ; in all the thousands of " tokra " counted only four specimens of *O. cernua* were found upon mustard. *O. indica* has, however, a much wider range of hosts as is evident from a glance at the list (page 130). Field observations suggested, and pot culture experiments have shown, that in *O. indica* there are at least two races, one of which is parasitic upon tobacco and does not attack mustard, while the other is parasitic upon mustard, turnip, and cabbage and does not attack tobacco. It has been proved by other investigators[2] that the seed of some phanerogamic parasites (e.g. *Orobanche, Tozzia*) will not germinate except in the presence of the appropriate host. If the conditions for the germination of the seed of such parasites are so delicately adjusted to their environment it is not surprising to find that in a morphological species such as *O. indica*, differences in parasitic quality may exist without accompanying morphological distinctions.

In this connection the scarcity of *O. indica* in the second season indicates that the slight climatic differences between two successive cold seasons may have a powerful influence in determining the amount of this parasite, and Beck von Mannagetta considers that some species, notably *O. cernua*, have shown marked morphological variations in their spread to regions of different climates.

Plants such as *Orobanche* have always attracted a good deal of attention from botanists. One of the earliest works on this genus appears to be that of Vaucher[3], who gives a list of parasitic species and their hosts and made some observations on the germination of *O. ramosa* upon *Cannabis sativa*. This was probably one of the first attempts to grow *Orobanche* in cultures. The biology and anatomy of the genus was very extensively studied by Koch[4], the later monograph of Beck von Mannagetta[5] being rather from a systematic

[1] Howard, A. and G. L. C., " Tobacco cultivation in Bihar." *Agri. Res. Institute, Pusa, Bull.*, No. 50, 1915.

[2] Heinricher, E., *Die Aufzucht und kultur der Parasitischen Samenpflanzen.* Jena, 1910.

[3] Vaucher, J. P., *Monographie des Orobanches*, Paris, 1827.

[4] Koch, L., *Die Entwicklungsgeschichte der Orobanchen*, Heidelberg, 1887.

[5] Mannagetta, Beck von., *loc cit.*, page 108.

standpoint, and received a good deal of attention from Chatin.[1] The work of Fraysse[2] deals with the biology of some phanerogamic parasites, but species of *Orobanche* were not among the number investigated.

Throughout this paper the names of *O. indica* Ham. and *O. cernua* Lœffl. have been used in the sense in which they are used by Hooker. Beck von Mannagetta states that *O. indica* Ham. is synonymous with *O. ægyptiaca* Pers. and gives this species and the nearly related *O. Muteli* Schltz. as being parasitic upon species of *Brassica*, and *O. Muteli* Schltz. and *O. ramosa* L., another related species of the section *Trionychon*, together with *O. cernua* Lœffl. are said to be parasitic upon *Nicotiana tabacum*. It appears therefore that Beck von Mannagetta's observations of the parasitism of *Orobanche* on *Brassica* and *Nicotiana* agree with the facts recorded by Hooker and described in this paper. In a more recent communication[3] the species of *Orobanche* which are parasitic upon tobacco are given as follows :—

O. ramosa L.
O. Muteli Schltz.
O. cernua Lœffl. and *O. cumana* Wallr., a sub-species *of O. cernua.*
O. ludoviciana Nutt.

The first two species occur also on hemp, tomato, and *Brassica* and the last species is restricted to North America.

Koch states that heavy applications of manure lessen the incidence of *O. ramosa* upon tobacco for a time but that ultimately the crop becomes diseased and succeeding crops show on the whole a more severe infection. More recently Peters and Schwartz[4] conducted experiments with a variety of chemical substances (copper sulphate, sodium chloride, etc.) without obtaining results which enabled them to recommend applications of these substances against *Orobanche* in tobacco.

[1] Chatin, A., *Anatomie comparee des vegetaux plantes parasites,* Paris, 1892.

[2] Fraysse, A. *Contribution a la biologie des plantes Phanerogames parasites,* Montpellier, 1906.

[3] Peters, L. and Schwartz, M., "Krankheiten und Beschädigungen des Tabaks." *Mitt. Kais. Biol. Anstalt f. Land u. Forstwirtschaft* Heft 13, Berlin, 1912.

[4] Peters and Schwartz, *loc cit.*

List of Host Plants of Genus Orobanche *in Pusa.*

Serial No.	Name of crop	Date of first appearance of "tokra"	Species of "tokra"	REMARKS
1	*Brassica campestris* var. *rapa* ..	30th November ..	*Orobanche indica* Ham. ..	The crop was full of this.
2	*Brassica campestris* var. *glauca* ..	30th November ..	*Orobanche indica* Ham. ..	The crop was full of this.
	Brassica campestris var. *glauca* ..	25th January ..	*Orobanche cernua* Lœffl. ..	Only four specimens of this were found in Birowlie mustard plot; previously this plot was full of *O. cernua* on roots of tobacco.
3	*Brassica campestris* var. *cauliflora* ..	3rd January ..	*Orobanche indica* Ham. ..	Very little.
4	*Brassica oleracea*	3rd January ..	*Orobanche indica* Ham. ..	Crop has been found full of this.
5	*Iberis* sp. (Candy tuft)	18th February ..	*Orobanche indica* Ham. ..	
6	*Solanum Melongena*	11th December ..	*Orobanche cernua* Lœffl. ..	Only this species has been observed in this host.
7	*Nicotiana tabacum*	7th January ..	*Orobanche cernua* Lœffl. ..	Does great damage to this crop.
	Nicotiana tabacum	7th January ..	*Orobanche indica* Ham. ..	
8	*Lycopersicum esculentum* ..	3rd January ..	*Orobanche cernua* Lœffl. ..	Good deal of this has been observed.
	Lycopersicum esculentum ..	3rd January ..	*Orobanche indica* Ham. ..	Amount of *O. cernua* is more than *O. indica* on this crop.
9	*Petunia*	7th March ..	*Orobanche cernua* Lœffl. ..	
	Petunia	15th March ..	*Orobanche indica* Ham. ..	Very little *O. indica* is found on this host.
10	*Launea pinnatifida*	18th February ..	*Orobanche indica* Ham. ..	Only two small specimens.
11	*Bellis* sp. (Daisy)	15th March ..	*Orobanche indica* Ham. ..	
12	*Nasturtium*	7th March ..	*Orobanche indica* Ham. ..	
13	*Verbena*	7th March ..	*Orobanche indica* Ham. ..	
14	*Coleus*	7th March ..	*Orobanche indica* Ham. ..	
15	*Cynodon dactylon*	20th February ..	*Orobanche indica* Ham. ..	Scarce.

LIST OF ILLUSTRATIONS.

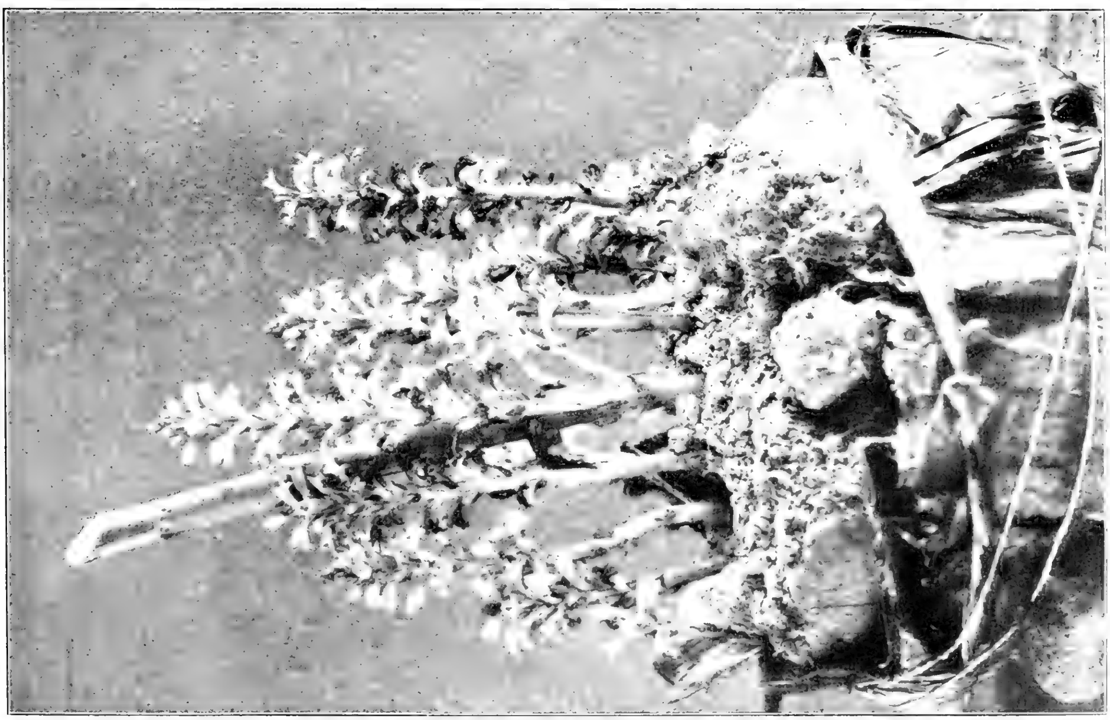


Fig. 1. *Orobanche indica* on mustard.

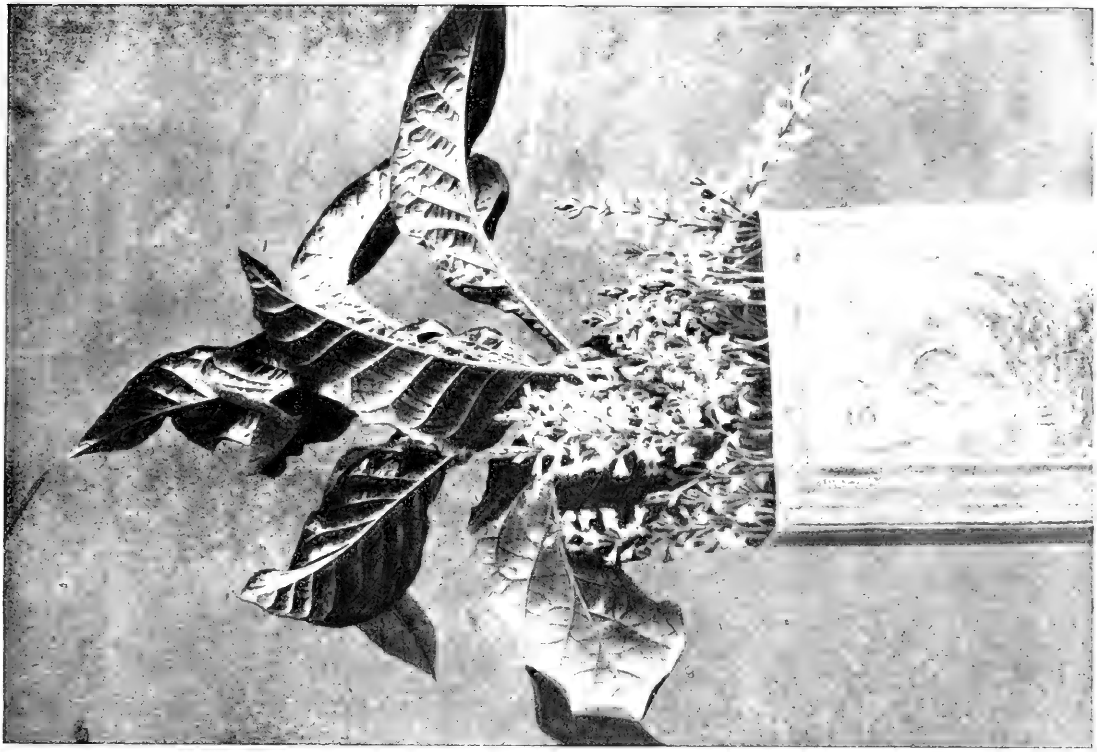


Fig. 2. *Orobanche indica* on tobacco.

Fig 3. *Orobanche cernua* on tobacco.

Fig. 4. Tobacco field at Birowlie: *Orobanche cernua* and *Orobanche indica*.

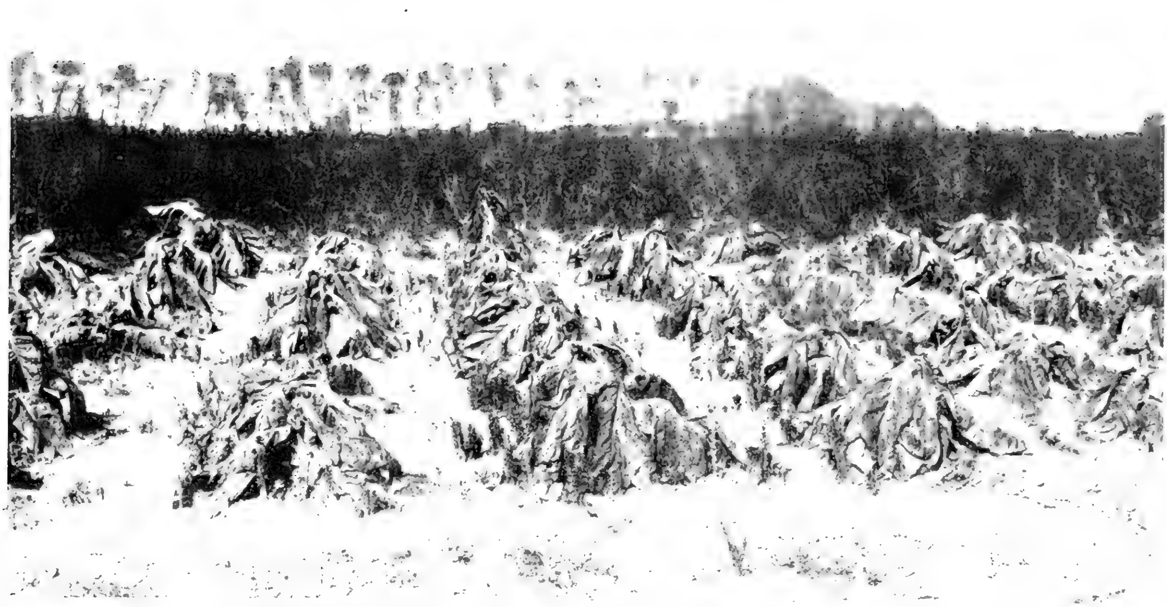


Fig. 5. Tobacco field at Birowlie; *Orobanche cernua* and *Orobanche indica* in plot which had received sodium nitrate—Season 1915-16.

Fig. 6. "Tokra" at Birowlie in tobacco plot which had not received any nitrate—Season 1915-16.

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THE CLASSIFICATION OF INDIAN CANES WITH SPECIAL REFERENCE TO THE SARETHA AND SUNNABILE GROUPS

BY

C. A. BARBER, Sc.D. (Cantab.)

Government Sugarcane Expert, Madras

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useful in replacing their parents. It was known that many of them did not flower in North India and that, in those that did, the anthers were closed and the pollen inside was ill-formed and immature. It was hoped that the change to South Indian conditions might induce some of them to flower, and that the sexual organs might recover tone so as to become better formed and thus more fertile.

A very sharp distinction soon obtruded itself between two classes of cane varieties thus collected. There was a large series of thick, juicy canes, generally excellent in appearance. These were commonly grown on a crop scale in the more tropical parts of India but, in the northern parts, they were usually grown in small plots under high cultivation, near large towns, in which they were used for eating as a fruit. In contrast with this first class there was another, of thin, hardy canes, grown under field conditions all over India, but

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Government Sugarcane Expert, Madras.

[Received for publication on the 25th June, 1917.]

I. INTRODUCTION.

One of the first pieces of work undertaken on founding the Cane-breeding Station at Coimbatore was to make as large a collection as possible of the cane varieties growing in different parts of India. This was done, primarily, with the object of obtaining material for the study of these canes when grown together, at the same time and under similar conditions. It was also desired to gain some idea as to the kinds of cane grown in different tracts, so as the more readily to obtain improved varieties suited to them. It was, lastly, hoped that seedlings might be obtained from these canes, of which some might prove useful in replacing their parents. It was known that many of them did not flower in North India and that, in those that did, the anthers were closed and the pollen inside was ill-formed and immature. It was hoped that the change to South Indian conditions might induce some of them to flower, and that the sexual organs might recover tone so as to become better formed and thus more fertile.

A very sharp distinction soon obtruded itself between two classes of cane varieties thus collected. There was a large series of thick, juicy canes, generally excellent in appearance. These were commonly grown on a crop scale in the more tropical parts of India but, in the northern parts, they were usually grown in small plots under high cultivation, near large towns, in which they were used for eating as a fruit. In contrast with this first class there was another, of thin, hardy canes, grown under field conditions all over India, but especially in the north, which showed themselves capable of growing in the open with comparatively little attention. These were unfitted for chewing and were universally crushed in mills and made into *jaggery* or *gur*.

The number of thick canes accumulated at Coimbatore soon became very large, and there was no evidence of our having exhausted the varieties grown in different tracts. It was noted that they were often only known by the name of the place from which they had been received, with the addition of some such word as "*Paunda*," and a number of them were obviously the same cane hailing from different places. The names frequently suggested that they were introduced or foreign canes and not indigenous in the country. It was found to be difficult to grow them on the untreated land of the Cane-breeding Station and many of those which survived were abnormal in their growth. It was thus seen that any attempts at their classification, which was at first projected, would be extraordinarily difficult, and that it would be idle to commence this, until further details were obtainable as to their migrations and original sources. When a good stock was obtained for seedling work, their further collection was therefore discontinued, or at any rate took a secondary place.

The other class, of thin, *gur*-making varieties, proved, however, to be much more interesting. There was no trace of their having been introduced into India, and there was no country with which I was acquainted from which they could have come. The only exotic varieties of this class, which had been received from abroad, were the *Yuba* cane from Natal, which readily falls into line in the great Pansahi group, and two Java varieties which I have as yet been unable to place in any special Indian class, but which have been imperfectly examined. These thin canes were therefore considered to be indigenous in India, as contrasted with the introduced varieties, and soon showed among themselves several well-defined classes which were easily separable. Each year, in planting out the increasing series of thin canes, care was taken to put together all those which showed systematic relationship, so that the plots themselves might indicate the classification. Many of them were, indeed, so similar to one another that the conclusion forced itself on one's mind that, here too, the same canes had been collected under different names from different localities, and that such slight differences as were observable might in all probability be ascribed to the varying conditions of culture and climate under which they had long been grown. The following groups were readily formed, Mungo, Nargori, Pansahi, and Katha, while there were indications of others, such as the transitional Bodi group and the small Khelia section.

But a number of forms were not so easily arranged, and the "unclassified list" steadily increased, without any light being obtained as to their relationships to the groups already collected and isolated. It almost seemed as if there were a large number of isolated forms growing in all parts of the country without any visible genetic connection. Some, such as *Barahi* from the Central Provinces, were as small as the thin and meagre varieties of the Punjab, while others, such as *Naanal* in Madras and *Mojorah* in Assam, were with some difficulty separated from the more juicy canes such as *Puri* of Bihar and *Bonta* of Madras, which appeared to have been introduced at some time, but, after long growth in the country, had apparently decreased in size and vigour. In fact, the rigid separation of exotic from indigenous canes has sometimes been far from easy, and many changes in the unclassified list have been made in consequence. Until a more detailed examination can be made, a certain number of forms will be under doubt, as it does not at first sight seem possible to decide whether such varieties as *Magh* in Assam and *Vendamukhi* in Bengal are in reality introduced or country canes. But the characters of the thick and thin canes, such as their mode of growth and tillering, their size and the relative hardness of their rind, the amount of fibre and juice and their resistance to disease, make the separation of the two classes in general easy enough, and this is emphasized by the character of such seedlings as have been raised from them, in that the parental differences are often exaggerated in the seedlings.

Two varieties placed among the unclassified indigenous Indian canes, still being grown occasionally in the midst of the thick canes of South India, received special attention, because they were more familiar, and we had raised seedlings from them. They were seen to differ markedly in two respects. *Ganda Cheni* from Mysore had bending or nodding leaf ends and well developed circlets of hairs at the nodes, while *Naanal* from Tanjore had more or less erect-tipped leaves and was practically devoid of the circlets of hairs at the nodes. In another place, habit, as here exemplified by the character of the leaf ends, has been regarded as important in classification, whereas it has been suggested that the presence of the circlet of hairs is a primitive character of fundamental importance. These differences, therefore, seemed to indicate that these two canes, like one another in many respects, might belong to entirely different groups. But there was no time available for classification studies until the seedling work had been placed on a firm foundation. The two varieties were obviously to be regarded as indigenous canes, when compared with the thick ones of South India, but their systematic position remained a mystery.

It was first possible during the harvesting season of 1916 to devote some attention to this side of the subject, and a series of more or less hurried comparisons were made between these two canes and the other indigenous varieties collected. Furthermore, it was only then that, by their growth and vigour, the North Indian canes showed that they were thoroughly acclimatized to their new surroundings. The two characters mentioned above, leaf tips and circlets of hairs, inevitably suggested a comparison with the two aboriginal types, *Katha* and *Dhaulu of Gurdaspur* in the Punjab, for these two varieties had been shown to differ in just these two respects.[1] A further study revealed the fact that it was possible to collect many of the unclassified varieties under two heads corresponding with *Ganda Cheni* and *Naanal*, in these and other respects. A preliminary note was sent to the *Agricultural Journal of India*,[2] and a detailed study of the members of the two series was commenced, as far as time was available, during March-April 1916. It was found that varieties of these two groups had been collected from Madras, Mysore, Bombay, the Central Provinces, Bihar, Assam, Bengal, and the United Provinces, besides those already described from the Punjab, with the not surprising tendency constantly to become thicker and more like tropical canes as we proceed eastwards to Assam and southwards towards Madras.

As *Katha* and *Dhaulu* represent the thinnest and most meagre members of these two series, and are only known in the Punjab, new names have been sought for the two classes. And, in selecting these, I have been chiefly guided by the extent to which the varieties are generally known in the Provinces. *Saretha* and *Sunnabile* have, at one time or another, been distributed and tested in almost every Province in India. *Saretha* is a characteristic and valuable cane in the Meerut District and *Sunnabile* is a Bombay cane. They are canes of medium thickness and display the characters of their respective groups sufficiently well. The fact that the name "Sunnabile" appears to be of comparatively rare occurrence in Bombay districts has not been allowed to stand in the way of its selection, because the cane is well known as an introduction on the Government Farms of Madras, the Central Provinces, the United Provinces and the Punjab, and doubtless elsewhere.

[1] Barber, C. A., Studies in Indian Sugarcanes, No. 1, Punjab Canes. *Mem. Dep. Agr. Ind., Bot. Ser.*, Vol. VII, No. 1, May 1915. This Memoir will in future be referred to as Mem. 1. A second paper by the same author, Studies in Indian Sugarcanes, No. 2, Sugarcane Seedlings, etc., *Mem. Dep. Agr. Ind., Bot. Ser.*, Vol. VIII, No. 3, July 1916, will be referred to as Mem. 2.

[2] Barber, C. A., The Classification of Indigenous Indian Canes. *The Agricultural Journal of India*, Vol. XI, Part IV, p. 371.

The following are the varieties thus far grown at Coimbatore and, after examination, placed in these two groups. For more exact details as to locality and synonymy, Section V may be referred to (pp. 34 and 35).

Saretha Group: Punjab, *Katha, Lalri, Kansar, Mesangan;* United Provinces, *Raksi, Ramui, Chin, Chunnee, Baraukha, Burra Chunnee, Saretha* (brown), *Saretha* (green); Bihar, *Chynia, Jaganathia;* Bengal, *Khari;* Bombay, *Kalkya;* Mysore, *Ganda Cheni;* Madras, *Hullu Kabbu.*

Sunnabile Group: Punjab, *Dhaulu, Teru, Ekar;* United Provinces, *Rakhra, Kaghze;* Assam, *Putli Khajee, Mojorah;* Central Provinces, *Dhor;* Bombay, *Bansi, Sunnabile, Khadya;* Mysore, *Hotte Cheni;* Madras, *Naanal.*

In the description of the prototypes of these two groups, *Katha* and *Dhaulu*, it was noted that some of the differences were equally remarkable for their minute character and their apparent constancy. The same has held in the present study. We have not received much help from characters usually employed in botanical systematic work, such as differences in the floral organs and size of organs and plants, but have been dependent on a series of minute local differences, a well known occurrence in the separation of closely allied cultivated varieties. Thus, in all of the Saretha group, there is a minute black incrustation on the rind, as if it had been attacked by a small mite, whereas this is entirely absent in the Sunnabile group. The density of bloom is greater in the Saretha group but the blackening of this bloom by fungus is much sharper and more circumscribed in the Sunnabile group. Minute characters of this kind thus become of prime importance in classification, just as the greater liability of certain classes of canes to different fungus attacks. Thickness of stem and size and vigour of plant seem to be of no value, in that, in each series, we pass from the smallest and thinnest canes in India to great growths with difficulty distinguished from luxuriant tropical canes. And the very insistence of these insignificant characters, in canes so widely differing in external appearance and extending through such wide stretches of country under such different climatic and cultural conditions, does but add to their importance. Other characters than those mentioned above, which have helped to distinguish the two groups are:—The presence or absence of the groove, the brown coloration on the stem, the arrangement and frequency of the corky lines (ivory markings) on the stem, the presence of the scar band and scar line, the bursting of buds, whether apical or dorsal, the character of hairs on the bud, the colour of the edges of the young leaf-sheath, the presence or absence of spiny hairs on the back of the leaf-sheath, the venation of the leaf-sheath, the extent to which the leaf-sheath clasps the stem at its base, the character of the ligular hairs, the width and shape of the leaves, the relations between their length and width (leaf module), the erectness of the leaf tips, the length and thickness of the joints and the cane module, the number of joints in the cane, the obliqueness of the first formed shoots, the nature of the underground branching, freedom of flowering and seed formation, the roughness of the surface of the leaves and the nature of the serrature on their edges, and so forth. Some sixty to seventy such characters are dealt with below, many of them of prime importance, while in others the groups hang together generally but exceptions occur.

The two new classes of indigenous canes thus differ markedly from those already recognized. Thus far, we have depended in our grouping on obvious resemblances by which, at a glance, varieties could be placed together, as if the same cane had been grown for long periods in different tracts. The members of the new classes often show no such obvious likeness, and it has required a great deal of detailed study of many minute characters according to a prepared scheme, before we could decide on definitely placing each member in its proper class. Certain varieties, such as the great, grass-green *Putli Khajee*, are noted for the number of minor deviations, and there are other canes, such as *Shakarchynia* and *Barahi*, showing obvious connections, but with sufficiently important differences to prevent at present their inclusion in either class. Such cases may prove of special interest later, as showing transitions between the classes now dealt with and others as yet undetected, or they may be simply blind variations with no further relationship.

We have thus before us an interesting mass of information as to the systematic value of the numerous characters which have formed the basis of our cane descriptions, one of the desiderata set before us at the commencement of our study.[1] In the classification of the two groups, we see that it is more to the concurrence of a number of apparently unimportant resemblances that we must look for the proper grouping of our cane varieties, than to characters of real morphological significance, so commonly and successfully employed in the classification of plants. There is little doubt, moreover, that, to the characters detailed in this paper, may be added fundamental differences in the quality of the juice, fibre content, milling properties, requirements of soil and water, and general hardiness and liability to disease, and there are indications that such is the case. The members of the Saretha class are apparently hardier and less dependent on water than the Sunnabile varieties, and also have less juice but with more saccharine content. But a lack of first-hand

[1] Barber, C. A., Some Difficulties in the Improvement of Indian Sugarcanes. *Annals of Applied Biology*, vol 1, nos. 3 and 4, Jan. 1915, p. 219, "Problem 6."

knowledge of the canes in their natural conditions and the opinions of local cultivators regarding them, prevents us from analysing these characters at present. Enough has been said to show that, to the already well recognized groups of Indian canes typified by *Mungo*, *Pansahi*, *Nargori*, two more classes, less obviously marked to the casual observer but none the less genuine, must be added. In these groups the usual separation of the canes into *Ukh* and *Ganna* breaks down, and, indeed, there are some indications of a further gradation between the latter and the *Paunda* class. If this turn out to be the case, we shall perhaps be able ultimately to throw light on the hitherto insuperable gulf between the indigenous Indian and exotic tropical canes, a gulf which has led to the idea that we have in them two groups of cultivated plants closely related and yielding the same commercial substance, but arising from different wild parents. I know, at present, of no single, fundamental difference between these two groups, and regard it as quite possible that, in India itself, we may find the transition from one to the other. Historically, at any rate, the cultivated canes of the tropics have been traced to Northern India, and we may at present rest at that.

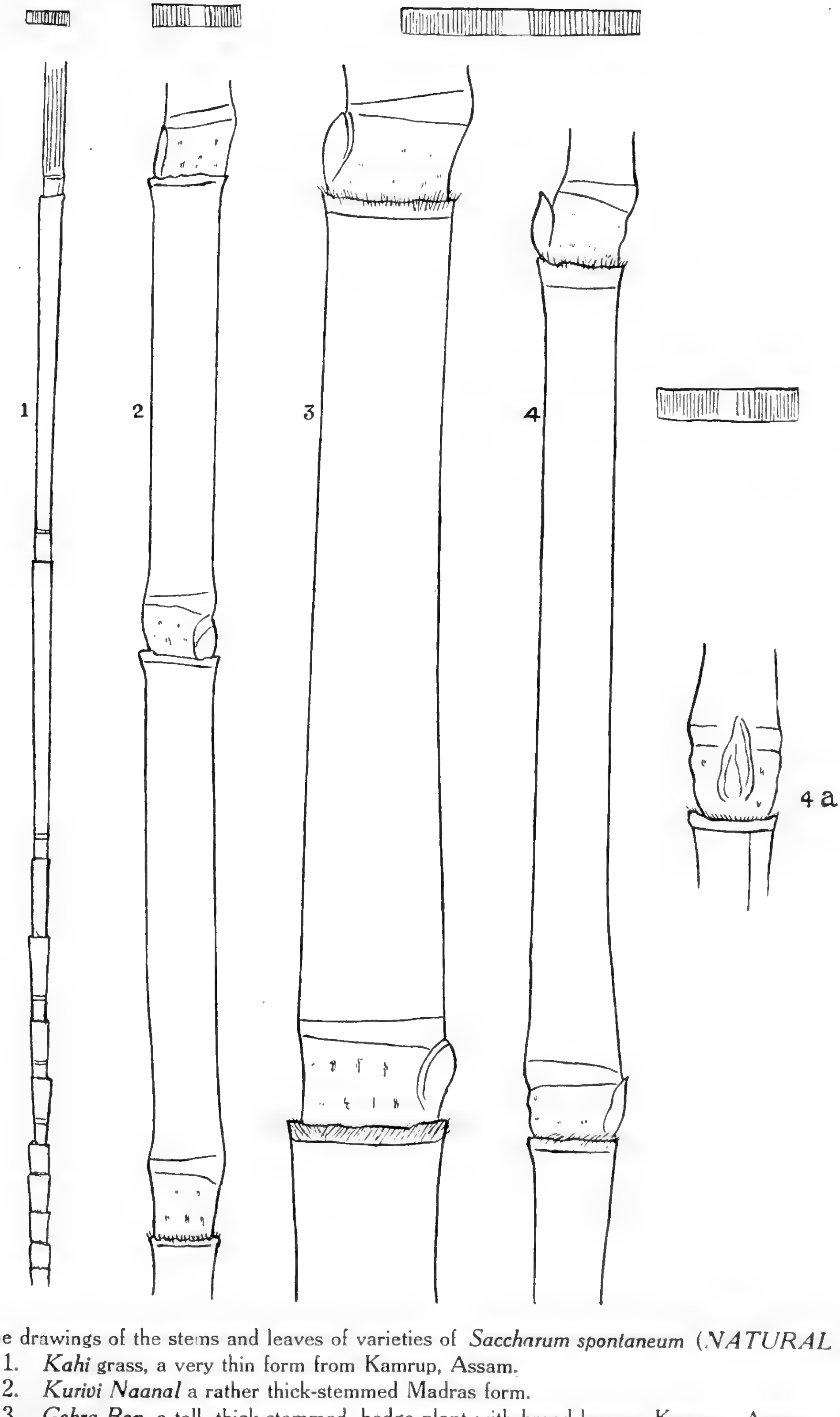
But there is another aspect of this study to which attention may be drawn. Our classification is not merely an empirical statement of unconnected differences, a sort of analytical key for the separation of varieties, but presents the data for a reasoned statement regarding the lines of evolution among a section of cultivated canes. We also claim to have made distinct advances along the difficult path of tracing the origin of cultivated canes from their wild ancestor.

There are, as already stated, in each class, a series of cane varieties, passing more or less imperceptibly from what are confessedly the thinnest and most primitive canes in the world to thick, well-developed forms showing distinct resemblances to tropical sugarcanes. By the careful study of the variation between these extremes, we are placed in a better position for tracing the evolution of the latter from primitive ancestors. And, what is more significant, we have established a series of connecting links between cultivated canes and wild Saccharums now growing in India.

Our study of *Saccharum spontaneum* is still incomplete, as the full method proposed is to examine and compare a large series of seedlings of this species, in order to establish the limits of variation in the vegetative organs. But a constant collection of specimens, while on tour in different parts of India, has demonstrated the fact that there are some very distinct varieties of this species, more or less confined to definite geographical regions. There is the common, wire-leafed weed, usually known as *kans* or *kahi* grass, met with all over India, but more abundant in the dry tracts. As we proceed to the more humid regions, Bengal, Assam, Burma, this form, although present, shows transitions to wider-leafed and thicker-stemmed forms, till we get canes with leaves nearly a couple of inches wide and stems as thick as *Ganna* canes. There is, moreover, a water form which is typically present in the ponds near Dacca, in the old alluvium of the Madhapur forest, with tender green nodding leaves and thickish stems rooting abundantly at the nodes, which in many respects is much more like a cultivated cane than the dry land form (Plates I and II). I learn from an Assistant Farm Manager at Dacca that this form is termed *kashi* in the Hooghly District, where it is common on the alluvial banks of streams. He says that it is given to children to chew and that his grandfather states that in former times it was crushed for making *gur*. Whether there be any truth in this or not, it is interesting to note that, among the seedlings obtained from it at the Cane-breeding Station, some had juice with over 8 per cent. of sucrose, which is higher than any yet obtained in our analysis of wild Saccharums. This form suggests a starting point for primitive cultivated canes. Throughout Burma we meet with a series of forms which appear to connect these two latter (the thick land form and the water form), sometimes in ponds, but more usually on the alluvial banks of the Irrawady, varying considerably in the thickness of the stem and width of the leaves. All of these have the typical inflorescence of *Saccharum spontaneum* and must therefore be included in that botanical species. They have been introduced into the Cane-breeding Station at Coimbatore and show themselves perfectly able to cross with the cultivated canes there, whether thick or thin. We have raised seedlings by selfing each of them, but at present there has been no opportunity of examining these in a detailed manner. We thus see in *Saccharum spontaneum* a development in the size of the vegetative organs, as we pass from the dry to the humid tracts in India, similar to that met with in the Saretha and Sunnabile series of sugarcanes. Attention has been drawn to the obvious resemblance between the *kahi* grass and *Katha* in the Punjab, where the local ryots are accustomed to point out *kahi* as the ancestor of *Katha*, their commonest cane.[1] In the detailed list of characters showing differences between the Sunnabile and Saretha groups, we shall find a number mentioned in which the latter group approaches *Saccharum spontaneum*. Such are the black incrustation on the stem, the venation and transverse bars on the leaf-sheath, the prominence of the midrib, the circlet of hairs on the nodes, the serrature of the leaf and the extent of roughness on the surface at the leaf tip, the red brown colour of many

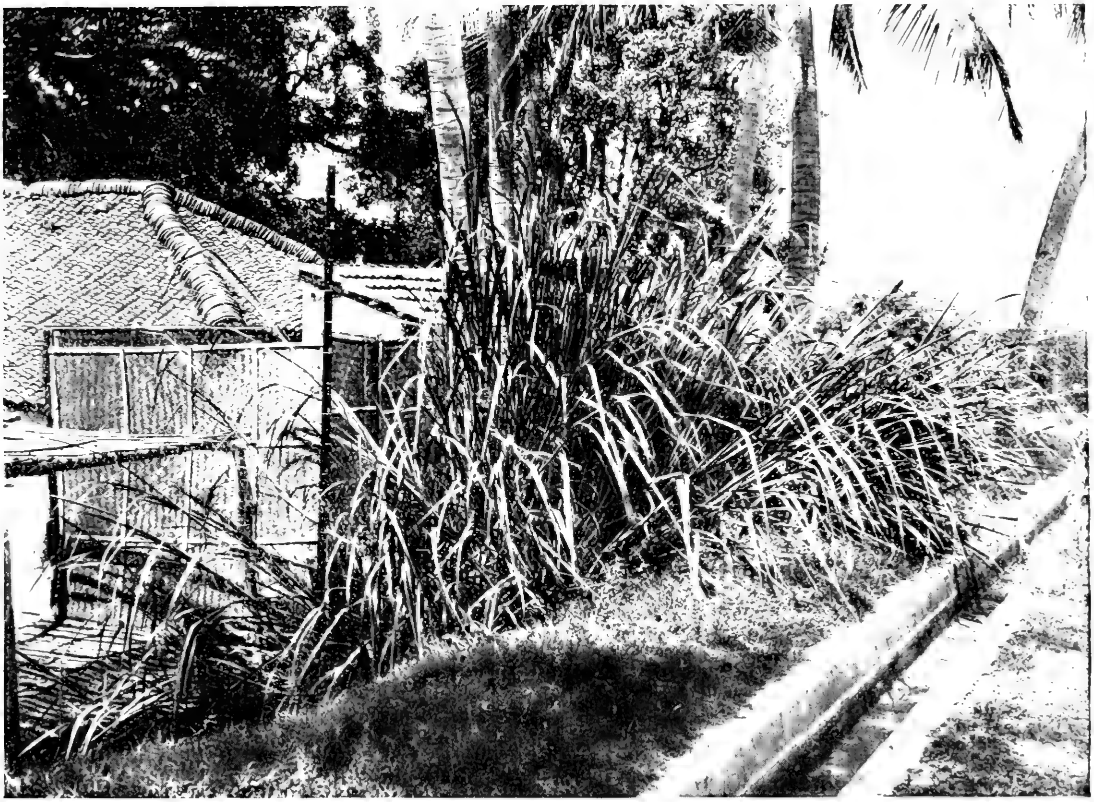
[1] Mem. 1, p. 2.

PLATE 1.



Outline drawings of the stems and leaves of varieties of *Saccharum spontaneum* (*NATURAL SIZE.*)

1. *Kahi* grass, a very thin form from Kamrup, Assam.
2. *Kurivi Naanal* a rather thick-stemmed Madras form.
3. *Gehra Bon,* a tall, thick-stemmed, hedge plant with broad leaves, Kamrup, Assam.
4. 4a. *Kashi,* a pond variety from Dacca. (The width of the leaf is indicated in each case.)



Saccharum spontaneum, a water form, collected in Dacca ponds and grown in a damp place in the Cane-breeding Station at Coimbatore.

Seedlings of *Saccharum spontaneum*. On the right, two rows of seedlings of the Dacca form; on the left, two rows derived from *Kurivi Naanal* of Madras.

seedlings, the mode of branching, etc., and we have utilized these resemblances to *Saccharum spontaneum* as strengthening our conviction that the Saretha series is the more primitive. But there is also some reason for supposing that the more highly developed Sunnabile varieties are also traceable to *Saccharum spontaneum*. Among the characters in which the Sunnabile and Saretha groups differ are the bending of the leaf tip, the erectness of the young (germinating) shoots, the colour of the stem, the ligule and its setæ, spines on the backs of the leaf-sheaths, scar band and scar line, and so on. Now a more or less imperfect study of the seedlings of *Saccharum spontaneum* raised at Coimbatore has also shown these very differences among themselves; there are white and brown stemmed forms, the ligules vary and the setæ are occasionally long, there are spiny and spineless forms, and there are variations in the scar band and scar line. When we consider the extremely primitive nature of *Dhaulu*, and its obvious resemblance to *Katha* in many particulars, there seems to be some justification for the expectation that a closer study will increase the number of these resemblances in some seedlings of *Saccharum spontaneum* to the Sunnabile series. There is thus some reason for tracing both of the primitive Punjab canes to a common ancestor, *Katha* from a red form and *Dhaulu* from a white, the differences in whose seedlings have been fixed and transmitted by the vegetative method of propagation.

The other groups of indigenous Indian canes have not as yet been subjected to the detailed comparative study accorded to the Saretha and Sunnabile classes. It is by no means impossible that, when this is done, similar resemblances may be detected. Judging from the single character, the mode of branching, it would seem that the Mungo and Pansahi groups are the more primitive, and that they fall into line with the Saretha class, while the Nargori group, as far as it has been studied, shows a formula more comparable with the Sunnabile series, a distinct advance towards the thick canes. *Khelia* and its allies are yet further developed, being intermediate in this respect between the Sunnabile and Nargori groups and the thick canes. We thus see that the study of merely one character *may* throw light on the various stages of development of Indian canes, and it is justifiable to assume that a comparative study of many characters will make the path plainer. The apparent absence of differences such as we have collected in this paper in the members of the Pansahi, Nargori, and Mungo groups may be due to their being more recent offshoots from the parent stem. Lastly, there are certain primitive canes growing in the Central Provinces which should be compared with *Saccharum spontaneum*, e.g., *Barahi* and *Katai*. The latter might lead to a connection with the Nargori group. So also *Shakarchynia* and *Kheri* in Bengal, which appear to be primitive forms, and doubtless many more in parts of the country where as yet the cane varieties have not been collected. These points are merely indicated here to support the idea suggested that the careful study of minute vegetative differences may be of use in tracing the course of development in closely allied varieties of cultivated plants. The line of work with seedlings of each variety is more complicated, in that the minute vegetative differences relied on are ruled out, as they do not appear to be always inherited, but a study of the range of variation in each group will also assuredly assist in fixing the probable wild ancestor. Such work is already possible, with the mass of details collected in the descriptions of different Indian varieties, but it is not likely that there will be time available in the immediate future for working these details out. One point may, however, be mentioned in passing. We have now a certain knowledge of the relative stability of vegetative characters in the groups forming the subject of this paper. But it is unlikely that this will apply to the same vegetative characters in other groups, even if they are derived from the same wild form, and this makes it all the more necessary that each group should be separately studied in all its varieties.

We have thus far ignored the fact, which has come to light gradually in our study, that in the Saretha group there is a distinct subdivision into two sections, primarily separable by the colour of the stem, which may be roughly termed the brown and green stemmed sections. Each section contains a primitive Punjab variety and they have been named after these. The Katha section is characterized by the regularity of brown marks or colorations on the canes and the Mesangan section is devoid of these. *Katha* and *Mesangan* are similar canes in many respects, but the Mesangan group, although including a thin cane, consists chiefly of the thicker forms found in other parts of India than in the Punjab and neighbouring parts of the United Provinces. *Saretha*, which is the thickest variety in the Katha section, has a form in the Mesangan section also, sometimes distinguished as *Dhaur Saretha*. In the detailed study of these two sections, which is interpolated in many of the character studies, we shall see that the Mesangan section is in many respects intermediate between the Saretha and Sunnabile groups, and it may therefore be regarded as, on the whole, a more developed series, further from the original wild form.

In some of the characters used in separating the varieties and groups, it has been found difficult to state the differences succinctly, especially in such as involve complicated series of measurements. For the sake of clearness, certain empirical expressions have been introduced, and the rows of figures have been plotted as curves on squared paper. But, for these to have any general value, it has been necessary to take a very large series of measurements, and this part of the work has been very laborious. For instance, on going through the varieties, it soon became evident that the organs in the Sunnabile forms were on the whole shorter and broader than in the Saretha varieties. As each series contained thick and thin, large and small varieties, it became necessary to include proportional measurements, and *modules* have been introduced, founded on the length of the organ divided by its breadth, and this has given satisfactory results. But one was also soon convinced that the shape of the leaf was different in the two groups, and the module fails to indicate this fully. For the demonstration of this difference in shape, it became necessary to take a series of width measurements at different places up the leaf till the widest point was reached. The points fixed were the base, 1″ from it, and also 6″ and 12″ and the widest place, wherever that was. By studying these in each variety and averaging them in the whole group, we have been able to express the shape of the leaf by means of the *gradient* of increase in width, and this gives an expression of the general shape of the leaf. The width of the midrib was measured at the same places, for it was noted that this part of the leaf was much more prominent in the Saretha series (as in *Saccharum spontaneum*) than in the Sunnabile group, and it was desired to state this accurately.

Many of these measurements were undertaken, not so much to give exact data, as to convince one's self that an observed difference was actually present as a group character—a matter of peculiar difficulty in varieties with such a wide range in general size—and, if present, what exceptions were observable. The results are interesting, as indicating the relative closeness of the different varieties in the groups, for, generally, where exceptions occur, such are also traceable in other characters, and we see that in each group there are fluctuations in various directions, suggestive of new points of departure in the evolution of the type.

The variation in the length of organs at different periods of growth has received special attention, and it is hoped will form the subject of another memoir. The length of joint, for instance, is very different at the base, in the middle and at the top, and the two groups under consideration show marked differences in this variation; there is greater variation in the Saretha series, and the longest joints are always nearer the base than in the Sunnabile series, which is more uniform all through. But to put this down in definite terms was very difficult. In each variety 20 canes were taken at haphazard, and each joint, leaf-sheath and lamina was measured in succession from base to apex. As the number of joints varies from cane to cane, it becomes an extremely difficult thing to obtain an average series of the figures, and the general result of investigation seems to demonstrate that it is impossible to obtain an *average* cane, and therefore, in its place, an *ideal* cane has been built up for each variety and group in these respects. The results have been reduced to curves which show the differences sufficiently well, but it may be mentioned that some of these curves are based on as many as 10,000 individual measurements, and it becomes a question if this amount of labour is justified by the result. The answer to this question can only be obtained by an inspection of the curves reproduced, but, in a classification built up on a morphological study of vegetative organs in closely allied cultivated plants, one object is to build up a typical form characteristic of the variety and group, and it is not obvious how this can be otherwise accomplished. It is worth while drawing attention to the fact that, in the end, characteristic curves of the lengths of organs in different parts have been obtained in each case, whereby the mode of growth in the two groups is seen to differ somewhat widely. But the matter is complicated, and a special note has been drawn up on it, wherein the difficulties are fully discussed and the method of overcoming them described.

A note has also been written on *early and late* canes in each clump. This matter has been referred to in the two preceding Memoirs on Indian Sugarcanes, and in the present paper new light has been thrown on the subject by the dissection of cane stools and the study of the method of branching. Some fifty stools have been dissected out recently, belonging to twenty-four varieties of canes, and some of the results are interesting. The main point is that there is overwhelming evidence that the late canes are the thickest, thus reversing earlier conclusions drawn from the behaviour of the Punjab canes, late in the season.

The examination of non-measurable characters has also involved a great deal of work. So much so, that it has been found necessary to curtail the list of observed differences for lack of time to conduct the observations on the necessary scale. After all, such a thing as a complete analysis of the differences between any two living organisms or groups of organisms is obviously unattainable. The omission of a character does not therefore indicate that there are not differences in it. As already said, there are probably a great many more than those detailed in this paper.

Before proceeding to the enumeration of the characters, it is advisable to state on what material the present examination has been based. As each new variety is added to the collection at the Cane-breeding Station, it is the custom to make as full an examination of it as is possible before planting. Further, fuller descriptions are then recorded year after year, when there is the time for it. There is thus a great mass of information available regarding the characters of varieties which have been growing for some years on the farm, and of course less for the newer importations. We are thus fairly well acquainted with many of the varieties dealt with in this paper, but, for the sake of comparison, we have mainly relied on studies in which all the varieties were grown on the same plot of land at the same time. Two such occasions have offered, namely, during the 1916 and 1917 cropping seasons. But the number of varieties in the classes under discussion grown in these two years differed a good deal in that a great many were added during the year, chiefly from the United Provinces and Bombay. The 1916 crop consisted of about eight varieties of the Saretha group and 10 of the Sunnabile. The canes were well grown, but the examination was taken up rather late, and many of them were obviously over-ripe, there were a large number of short joints at the ends of the canes and the leafy shoots were often injured, or flowering had taken place, with consequent shooting. For the better study of the leaf shoots, in which a great number of distinguishing characters were noted, it was decided to do the work over again in 1917, but at an earlier stage of growth. The varieties were therefore examined at about nine months. The numbers of varieties in the two groups had now considerably increased and there were 18 in the Saretha group and 15 in the Sunnabile. But the piece of land on which this crop was raised was not nearly so satisfactory, it was stiffer and more saline, and the general growth of the canes was poor. There were far fewer joints than could be accounted for by the youth of the plants, and the curves suffered accordingly. But the leafy shoots were healthy and the leaf characters were on the whole much more satisfactory. In most cases the results of the measurements in the two years are given separately, and it is interesting to note how well they agree, in spite of the great differences both in the varieties examined and the conditions under which the examination took place. This agreement is sufficiently striking in most cases to afford additional evidence of the justness of the classification.

The present Memoir is divided into the following parts :—

I. Introduction.

II. General list of characters dealt with, followed by a summary of the chief differences noted in the Sunnabile and Saretha groups, arranged in tabular form.

III. Note on the dissection of stools, as demonstrating the thickness of early and late canes and the relative systems of branching in the groups.

IV. Note on a method of building up an ideal cane for a variety or group by averaging measurements of the lengths of organs at successive joints.

V. Detailed list of characters in which differences have been noted, with tables of measurements for the individual varieties in the Saretha and Sunnabile groups.

For those desiring to obtain a general idea of the scope of the thesis and the conclusions arrived at, it will suffice to glance at sections I and II. The following sections contain an amplification of the same matter, with the details on which the conclusions are based. It was originally intended to add a section with detailed, illustrated descriptions of the individual varieties in the two groups, and I am indebted to several gentlemen for the kind way in which they have provided me with information regarding varieties grown in their Provinces. I would specially mention the Hon'ble Mr. Hailey and Rai Ganga Prasad Saheb of the United Provinces, and Mr. Evans in the Central Provinces. But the number of varieties has now increased so greatly, that it would take many months before this part of the paper could be prepared, and the notes received, together with my own descriptions, are filed in the office for working up whenever there is time to do this.

COIMBATORE,
19th May, 1917.

II. GENERAL LIST OF CHARACTERS DEALT WITH, FOLLOWED BY A SUMMARY OF THE CHIEF DIFFERENCES NOTED IN THE TWO GROUPS, ARRANGED IN TABULAR FORM. THE NUMBERS OPPOSITE THE CHARACTERS CORRESPOND WITH THOSE IN THE DETAILED LIST OF DIFFERENCES IN SECTION V.

List of Characters.

I. *General*—

Erectness of young shoots
Habit and mode of growth.
Tillering.
Dissection of stools.
Flowering.
Anthesis.
Seed production and seedlings obtained.
Number of dead leaves on the cane.
Length of cane bearing these.
Length of living leafy shoot.
Total length of plant.

II. *Cane*—

(1) Length of stripped cane.
Number of joints in the cane.
Average length of the mature joints.
Average thickness of the cane.
Cane module.
(2) Ovalness and thickness in different parts of the cane.
(3) Length of joints in different parts of the cane.

III. *Colour and markings of the cane*—

(1) General.
(2) Striping.
(3) Black incrustations.
(4) Bloom.
(5) Blackening.
(6) Corky markings.
(7) Colour of growth rings.
Colour of root zones.

IV. *Joint characters*—

(1) Groove.
(2) Circlet of hairs.
(3) Scar band and scar line.
(4) Growth rings.
(5) Root zones.

V. *Bud characters*—

(1) Bursting.
(2) Size.
(3) Form.
(4) Colour marks.
(5) Point of origin.
(6) Flanges.
(7) Bristles.
(8) Basal patches.
(9) Minute black hairs.

VI. *Leaf-sheath*—

(1) Colour.
(2) Bloom.
(3) Scarious border.
(4) Colour of young edges.
(5) Tuft of hairs.
(6) Spines on the back.
(7) Venation.
(8) Transverse bars.
(9) Ligular processes.
(10) Ligule.
(11) Clasping stem.
(12) Width at base.
(13) Width at apex.
(14) Length of mature leaf-sheath.
(15) Sheath module.
(16) Number of sheaths on the cane.
(17) Length of sheath in different parts of the cane.

VII. *Lamina*—

(1) Channelling.
(2) Callus.
(3) Scabrous feel at the tip.
(4) Serrature.
(5) Number of laminas on the cane.
(6) Length of lamina in different parts of the cane.
(7) Average length of mature lamina.
(8) Width of leaf.
(9) Leaf module.
(10) Pinching in above the base.
Position of widest part of the lamina.
Gradients of increase and decrease in width.
(11) Width of midrib in different parts.
Proportional width of lamina and midrib.

Summary of Differences in the Saretha and Sunnabile groups.

The summary of differences, noted in the characters of the Saretha and Sunnabile groups of indigenous Indian canes, has been drawn up in tabular form. By this means a great deal of repetition is avoided, the statement gains in clearness and the various measurements can be more readily compared. In all cases, a fuller study is made in the detailed list given further on, and reference to it is invited to clear up doubtful points. Mention has been made in the Introduction of the observations on which these comparisons have been based. Although many of the varieties have been studied for several years, the present details are afforded by examination of the 1916 and 1917 crops grown on the Cane-breeding Station. It must be repeated that these crops differed in several important respects. The 1916 crop was studied when about 13 months old, it was well grown but rather over-mature. The 1917 crop was examined chiefly for leaf characters. It was about 9 months old and therefore immature, and the number of joints and leaves developed were accordingly fewer : but this latter difference was unfortunately emphasized by the fact that the crop as a whole was poorly grown, although apparently perfectly healthy, and this has led to a diminution in certain differences. The Sunnabile group forms a remarkably homogeneous class of canes, in spite of the fact that, in its range, it passes from some of the most primitive of cane varieties to thick, almost tropical, forms. The range is somewhat narrower in the Saretha series, but the variations met with in the group are considerably greater, so much so that it has been found possible to subdivide it into two sections. These are termed the Katha and Mesangan sections, distinguishable, in the first instance, by the presence or absence of a red brown coloration of the cane as it matures. It is interesting to note that, in many characters, there is a tendency for the Mesangan section to occupy a position intermediate between the Katha section and the Sunnabile group. But, in spite of this, the Saretha series, as a whole, is sufficiently uniform to separate it from the Sunnabile in the characters enumerated below.

Character	Saretha Group	Sunnabile Group
	I. GENERAL.	
Erectness of young shoots. They are much more erect in the Sunnabile series.	Very oblique, averaging 13°—67° from the vertical at 4 months.	Averaging 5—30°. *Puth Khajee* and *Mojorah* are, exceptionally, oblique.
Habit and mode of growth. This differs considerably in the two groups.	Spreading or sprawling; leaf-tips often soon sharply bent at an angle.	Tending to straight, erect habit: leaf tips usually strict, erect, and, later, broadly curving.
Tillering generally greater in the Saretha series.	1917, 15 canes per stool.	1917, 12 canes per stool
Dissection of stools ..	Canes mature early and branching occurs to the fourth order.	Canes mature late and branching occurs to the third order.
Flowering much more abundant in the Saretha group.	Many varieties flower abundantly at Coimbatore.	Flowering is generally rare or absent.

Character	Saretha Group	Sunnabile Group
	I. General—*concld.*	
Anthesis. Open anthers and good pollen present only in the Saretha group.	In all the varieties flowering some of the arrows show 80—90% of open anthers.	In all flowers the anthers are completely closed.
Seed production and seedlings obtained only in the Saretha series.	Any number of seedlings can readily be obtained from many of the varieties, especially the more primitive ones.	No seedlings have been obtained, excepting a batch from *Naanal* in 1913, but there is some doubt as to these.
Number of dead leaves on the cane. There are fewer of these in the Saretha series.	Average numbers— 1916, 23 1917, 15	Average numbers— 1916, 32 1917, 16
Length of the part of the cane bearing these dead leaves. It is slightly greater in the Saretha series.	Average measurements— 1916, 7′ 7″ 1917, 4′ 8″	Average measurements— 1916, 7′ 5″ 1917, 4′ 2″
Length of living shoot. This is greater in the Saretha series.	1916, 6′ 5″ 1917, 6′ 7″	1916, 5′ 11″ 1917, 5′ 11″
Total length of plant is greater in the Saretha group.	1916, 13′ 4″ 1917, 14′ 0″	1916, 10′ 1″ 1917, 11′ 3″
	II. The Cane.	
Length of stripped cane. This is greater in the Saretha series.	Average measurements— 1916, 97·2″ 1917, 75·9″	Average measurements— 1916, 92·1″ 1917, 64·0″
Number of joints in the cane. This is greater in the Sunnabile series.	Average numbers— 1916, 33 1917, 26	Average numbers— 1916, 40 1917, 27
Average length of joint in mature part of cane. This is longer in Saretha series.	Average measurements— 1916, 3·9″ 1917, 3·8″	Average measurements— 1916, 2·9″ 1917, 3·0″
Average thickness of cane is greater in the Sunnabile series.	1916, 0·66″ 1917, 0·67″	1916, 0·73″ 1917, 0·77″
Cane module is much greater in the Saretha series.	Average numbers— 1916, 115 1917, 146	Average numbers— 1916, 87 1917, 119
Length of joints in different parts of the cane. This can be best seen in the curves on Chart II.	The Saretha joints are longer, but there are more of them in Sunnabile. The latter curves are therefore longer. The joints increase in length up the stem more rapidly in Saretha and reach an earlier maximum, and, after this is reached, they decrease more rapidly. The Sunnabile curve crosses that of Saretha towards the end because of the larger number of mature joints. There are, generally, greater fluctuations in the Saretha series, the length of joint being more uniform in the Sunnabile series.	

Character	Saretha Group	Sunnabile Group
III. Colour and Markings of the cane.		
General colour of the cane. There are considerable differences in this respect in the canes of the two groups, and in the Saretha group a subdivision is noticeable into brown and green sections.	Colour much obscured, in the lower parts, by weather and bloom and usually dirty here. Brown, bone yellow, green or grey, occasionally light purple (brown covered by bloom) below, passing upwards to yellow, glaucous green, green yellow or grey, and finally to greyish or glaucous or whitish green or even white at the top, owing to excessive bloom. In the Mesangan section the browns are absent or extremely rare and, consequently, the joints are rarely light purple. The brown occurs in patches or streaks or as a general tone, and increases with age. It is therefore more marked in the mature canes.	Brownish stone coloured or glaucous yellow, occasionally green below, passing upwards to clear light stone or greenish yellow, with distinct green patches at places where the cane is bent, finally to clear stone yellow, occasionally greenish yellow or dull green at the top. *Putli Khajee* is a vivid grass-green cane, and *Ketari* has a general greenish tinge when compared with the rest. Many of the varieties have what are termed "white" canes, and this is reflected in their local names.
Striping is present in many canes. This is especially so in the Sunnabile series, and appears to be absent in the Katha section.	Not noted in the Katha section, but seen in four of the seven Mesangan canes.	Met with in all the canes of this group excepting *Dhaulu* (14 out of 15), as occasional faint purple lines.
Black incrustations due to the out-growth and browning of epidermal cells, chiefly in the neighbourhood of the groove, only in the Saretha group.	Present in all, sometimes abundant and a striking feature in colouring.	Not met with in any variety.
Bloom is much more marked in the Saretha series.	Well developed, especially in the Katha section, where it is frequently very thick and copiously descending over the joint, especially in the upper part of the cane. It is less abundant in the Mesangan section. Bloom bands rather distinct, except where there is excess of bloom on the joint.	Not heavily developed and not descending much over the surface of the joint. Bloom bands not conspicuous on yellow joints. Quite sharp and distinct on the green joints of *Putli Khajee.*
Blackening caused by fungus attack on the bloom.	Moderately developed, rather faint and ill-defined, as if the surface had been smudged with soot	Well developed, in sharply isolated dense black patches.
Corky markings vary a good deal in different varieties, but there are general group distinctions.	In the main, short, fine, wavy lines, closely packed, but often not well developed.	More typically present. Usually as long, thick, parallel lines, rather widely separated and extending from the base of the bloom band about two-thirds of the way down the joint.

Character	Saretha Group	Sunnabile Group
III. Colour and Markings of the cane—*concld.*		
Colour of growth rings generally stronger brown in Saretha.	Strong brown in the Katha section ; less distinct in the Mesangan.	Fainter brown generally, and most clearly seen in the middle of the cane.
Colour of root zones, brown cream below to lighter cream above and often bloomed.	Not blushing green in the Katha section, but occasional traces of this in the Mesangan.	Usually blushing green when exposed, and then showing the eyes as bright yellow spots.
IV. Joint Characters.		
Groove, a character apparently of prime importance.	Present or indicated in all varieties.	Not traceable in any variety.
Circlet of hairs, characteristic of the Saretha series.	Usually well developed below and persistent at various parts of the stem.	Not usually present below or, if found there, soon disappearing upwards.
Scar band characterizes the Saretha series and scar line the Sunnabile.	Generally a scar band	Usually a scar line.
Growth ring wider in the Saretha series.	Measurements in width— Katha section 0·11″ Mesangan section 0·14″	Measurements in width— Sunnabile group 0·08″
Root zone wider in the Sunnabile series and with a different arrangement of the eyes.	Katha section 0·22″ Mesangan section 0·25″ Eyes usually in 2-3 rows, more or less equidistant.	Average width 0·34″ Eyes in unequal rows, the lower being much larger and rather widely separated from the rest.
V.—Bud Characters.		
Bursting differs in the two groups.	Generally more or less apical.	Usually dorsal.
Size. The buds are very small in both series, excepting in *Mojorah*. The amount of root zone covered by the bud gives a useful difference.	Average length— Katha section 0.23″ Mesangan section 0.27″ Root zone / bud { Katha section $\frac{22}{23}$; Mesangan section $\frac{25}{27}$ }	Average length— 0·27″ Root zone / bud $\frac{24}{27}$. In *Mojorah*, the thickest cane, the buds are rather large.
Form. There is little to choose here because of the smallness of the buds.	More pointed, ovate.	More rounded, oval or truncate.
Colour marks, consisting of brown blotches on greenish or yellowish bud.	Blotches of brown colour at the base and along the sides of the flanges.	Blotches of colour as two sharp brown lines at the top, like the head of an arrow.
Origin usually at the leaf scar in both, but a tendency to arise higher up in the Sunnabile series.	At leaf scar, especially in the Katha section, with a slight tendency to arise above it in the Mesangan section.	A marked tendency for the upper buds to arise higher up than the leaf scar.

Character	Saretha Group	Sunnabile Group
	V. Bud Characters—*concld.*	
Flanges present a point of difference of some importance.	Narrow, outline usually obscured by bristles.	Broad, outline well seen and usually free from hairs.
Bristles much better developed in the Saretha group.	Fairly well developed and often abundant.	Not well developed, irregular and often absent.
Basal patches better developed in the Saretha group.	Usually well developed and consisting of the typical, crisped, white, parallel hairs.	Usually poorly developed and often merely a roughness or pubescence. Well and typically developed in *Putli Khajee* and less so in *Bansi.*
Minute black hairs much better developed in the Sunnabile series.	Practically absent in the Katha section, but generally present in small numbers in the Mesangan section.	Usually abundant in all parts of the bud.
	VI. Leaf Sheath.	
Scarious border commences early only in the Sunnabile series.	Absent in the Katha section, and very occasionally commencing early in the Mesangan section.	Developing very early in the young leaf sheath.
Young edges colourless in the Saretha group, soon becoming red brown in the Sunnabile.	Light coloured or transparent in the young sheaths.	Quickly assuming a red brown colour, sharply contrasting with the green sheaths and often with a white border outside.
Tuft of hairs at the apex of the sheath usually meagre ; decurrent in the Sunnabile group.	Not usually decurrent along the edges of the sheath in the Katha section, occasionally slightly so in the Mesangan section.	Usually decurrent along the edge of the leaf sheath, sometimes very freely.
Spines on the back present only in the Sunnabile group.	Absent.	Present or indicated in all but one of the two *Khadya* specimens examined.
Venation finer and more distinct in the Saretha group.	Usually well marked, clear and rather fine parallel lines in the Katha section, and moderately distinct in the Mesangan section.	Irregular and often thickish and indistinct.
Transverse bars present only in the Saretha group.	Usually well developed in the Katha section, though sometimes obscured by bloom. Less distinct in the Mesangan section.	Usually absent, or their place only indicated by small patches of darker colour
Ligular processes only present in the Katha section.	Usually well developed in the Katha section, as long, sharp teeth ; seen, poorly developed, only in *Ganda Cheni* of the Mesangan section.	Absent.

Character	Saretha Group	Sunnabile Group
	VI. LEAF SHEATH—*concld.*	
Ligule. This is narrow in both groups although there appear to be differences. The setæ are very different.	The middle portion usually widens out so as to form a small, well defined lozenge. Setæ very minute, irregular, sparse and often absent.	The upper and lower margins are more or less parallel, and a lozenge is not present. Setæ strongly developed, usually longish and with isolated longer hairs in the middle.
Clasping stem. The sheath clasps the stem more widely in the Saretha group. Measurements taken in terms of the circumference.	1916, 1·45 1917, Katha section, 1·48; Mesangan section, 1·43; average 1·46	1916, 1·35 1917, 1·39
Width at base. The sheath is wider at the base in the Sunnabile group.	1916, 3·09″ 1917, Katha section, 2·79″; Mesangan section, 3·16″; average 2·93″	1916, 3·37″ 1917, 3·26″
Width at apex, also rather greater in the Sunnabile group, but widest in the Mesangan section.	1916, 1·23″ 1917, Katha section, 1·11″; Mesangan section, 1·40″; average 1·22″	1916, 1·34″ 1917, 1·30″
Length of mature leaf sheath. There is little difference in the groups in 1917, but in 1916 the sheaths are longer in the Saretha series.	1916, 12·4″ 1917, Katha section, 10·74″; Mesangan section, 13·84″; average 11·95″	1916, 11·7″ 1917, 12·0″
Sheath module (length divided by width) is greater in the Saretha group.	1916, 4·0 1917, Katha section, 3·8; Mesangan section, 4·4; average 4·1	1916, 3·5 1917, 3·7
Number of sheaths in the cane, greater in Sunnabile.	1916, 35 1917, 29	1916, 45 1917, 30
Length of leaf sheath in different parts. This is best studied in the curves on Chart III.	The curves resemble those of the length of joint. The average length and the extremes are greater in Saretha: there is a higher start, a more rapid rise and a steeper fall.	
	VII.—LAMINA	
Channelling. This is more marked in the Saretha series and the lamina takes part in it here.	Marked, especially in the midrib, but the lamina takes part at the base, especially in the Mesangan section.	Not very marked and confined to the midrib.
Callus, shaggier and more marked in the Sunnabile series.	Not well marked, usually covered by waxy granules and often thinly pubescent or puberulous.	Well marked, with dense, often shaggy pubescence, and sometimes long hairs at the sides.
Scabrous feel at the tip, more marked in the Sunnabile group.	Not marked, either ventrally or dorsally.	Strongly developed ventrally and less so dorsally.

Character	Saretha Group	Sunnabile Group
	VII. LAMINA—*concld.*	
Serrature harsher and more persistent in the Sunnabile group.	Soft, fine, soon deciduous	Thick, harsh and persistent.
Length of lamina in different parts of the cane. This is best studied in the curves on Chart IV.	The curves agree with those of joint and sheath, in that those of the Saretha series are higher and shorter, and steeper at the ends, than in the Sunnabile group. The lamina curves differ from the other two in themselves, in that, once the region of full grown leaves is reached, the curves remain more or less flat for a considerable time.	
Average length of mature lamina is greater in the Saretha series.	1916, 4′ 5″ 1917, Katha section, 3′ 10″; Mesangan section, 4′ 2″ } average 4′ 0″	1916, 3′ 9″ 1917, 3′ 8″
Extreme width of leaf. This is considerably greater in the Sunnabile group.	1916, 1·5″ 1917, Katha section, 1·2″; Mesangan section, 1·5″ } average 1·3″	1916, 1·8″ 1917, 1·7″
Leaf module is considerably higher in the Saretha series.	1916, 35 1917, Katha section, 38; Mesangan section, 33 } average 37	1916, 25 1917, 26
Pinching in above the base is marked only in the Saretha series.	$\frac{\text{Width at base}}{\text{Width 1″ higher up}}$ 1916, $\frac{95}{79}$ 1917, Katha section, $\frac{84}{69}$; Mesangan section, $\frac{110}{94}$ } average $\frac{94}{78}$	1916, $\frac{103}{111}$ 1917, $\frac{[illegible]}{101}$
Position of widest part of lamina, as percentage of length up the leaf: it is lower in the Sunnabile group.	1916, 0·47 of length of lamina 1917, Katha section, 0·46; Mesangan section, 0·50 } average 0·48	1916, 0·40 1917, 0·41
Gradients of increase and decrease in width, up to and beyond the widest part. The gradients are steeper in the Sunnabile group.	Increase, 1917, Katha section, 1 in 100; Mesangan section, 1 in 109 } average 1 in 102 Decrease, 1917, Katha section, 1 in 48; Mesangan section, 1 in 40 } average 1 in 44	Increase, 1917, 1 in 55 Decrease, 1917, 1 in 33

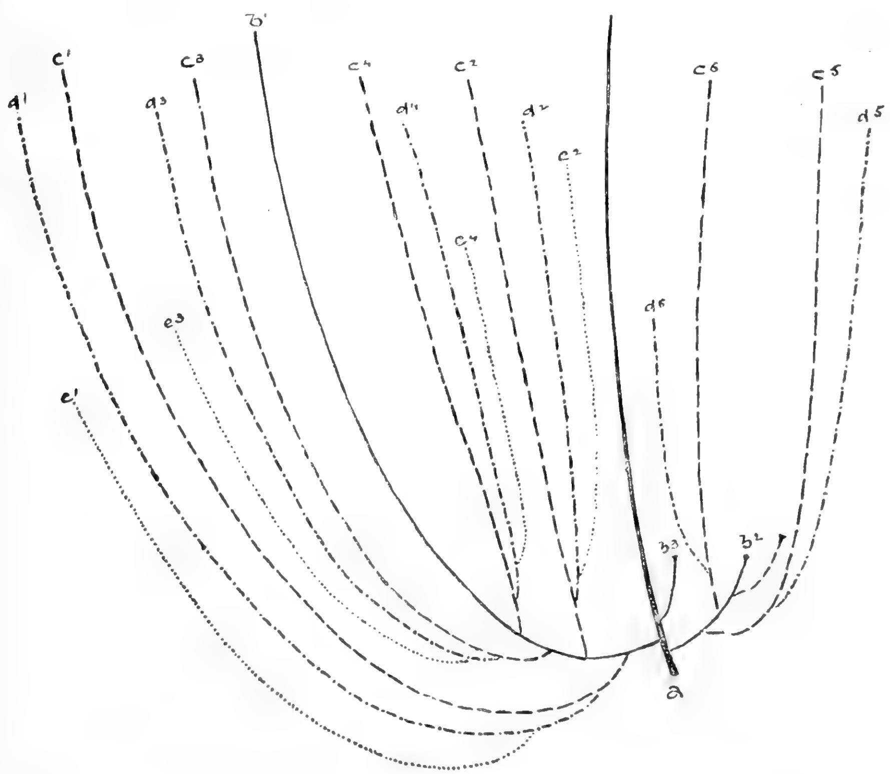
The midrib is more prominent in the Saretha series. It is not only wider in proportion to the rest of the lamina, but it is also intrinsically wider, although the leaves are narrower. For details refer to the table in the Detailed List of Characters.

III. NOTE ON THE DISSECTION OF STOOLS, AS DEMONSTRATING THE SYSTEMS OF BRANCHING AND THE THICKNESS OF EARLY AND LATE CANES.

The presence of early and late canes in the same clump has been referred to in the two previous Memoirs,* and a further note may here be added. In the first Memoir it was noted that, in the 20 canes in which measurements of joint length were made at the Gurdaspur Farm (in 1913-14), there were in certain varieties two classes of canes, differing sufficiently widely to throw the curves of length into some disorder. After more study it was found that these two classes were formed at different periods of growth in the clump. The morphological characters of these two kinds of canes were summarized as far as possible. The first formed canes were seen to have more joints, to commence with shorter ones and to be on the whole thicker than those formed towards harvest time. It was inferred that there might be important differences in the richness of the juice, but no analyses were available. In the second Memoir chemical analyses were given of early and late canes, and it was seen that the former have uniformly richer juice. At the same time it was shown that, while certain varieties habitually develop these two kinds of canes, it is not so in others, and the presence or absence of early and late canes in a clump becomes a varietal or even group character of some importance. These results have been confirmed by further observations, except in one respect. It was noted in Gurdaspur that the late formed canes were thinner than those formed earlier in the year, and it was contended that the former had therefore nothing to do with the thick watery, mostly immature, canes which are seen in many clumps at crop time. In the varieties grown at Coimbatore the dissection of stools has shown that, as regards thickness, the position is reversed. The first formed canes have, it is true, more joints and these are on the average shorter than in the later ones, but there is a regular series of increases in thickness from the first formed cane to those of its successive branchings. The main cane is the thinnest, branches of the first order are thicker, those of the second thicker still, and so on. The undoubted fact that this does not apply to the early and late canes measured at Gurdaspur is thus anomalous, but it seems possible that the latter, being developed late in the season, at a time when growing conditions were unfavourable, may reflect this fact in their relative thinness. Further observations are however not at present possible there.

*Mem. 1, p. 38 and Mem. 2, p. 158.

I take as an example of this increasing thickness in late-formed canes one of the Pansahi group, as it has been demonstrated that the presence of early and late canes is a character of the whole of the cane varieties included in it. It will be remembered that, in the Punjab measurements, *Kahu* was chosen as showing early and late canes most typically, and this is a local member of the Pansahi group. Recent stool dissections of *Pansahi* (9 months old) are so instructive that a study of one example is appended below. The development of the branches of succeeding orders are so regular as to be almost mathematically exact. In the diagram, *a* represents the main shoot arising from the bud on the set. There are two branches of the first order, b^1 and b^2, and the former, larger branch, is the one here analysed. c^{1-4}, d^{1-4}, e^{1-4} are branches of the second, third, and fourth orders respectively. All the canes in the clump were full grown, excepting three *e*s, which formed strong shoots, cane-forming at the base and about five feet long. There were no other shoots than those in the diagram, which shows that the branching system was completed for the season.



BRANCHING SYSTEM OF A PANSAHI SHOOT FROM A SINGLE BUD.

The thickness of the branches (canes), at 2 feet from the base, was measured in each case, excepting the three *e*s which were only strong shoots five feet long, and here it was taken at the base. The figures in these three are on the high side, as in these late shoots the thickness of the stem diminishes slightly upwards.

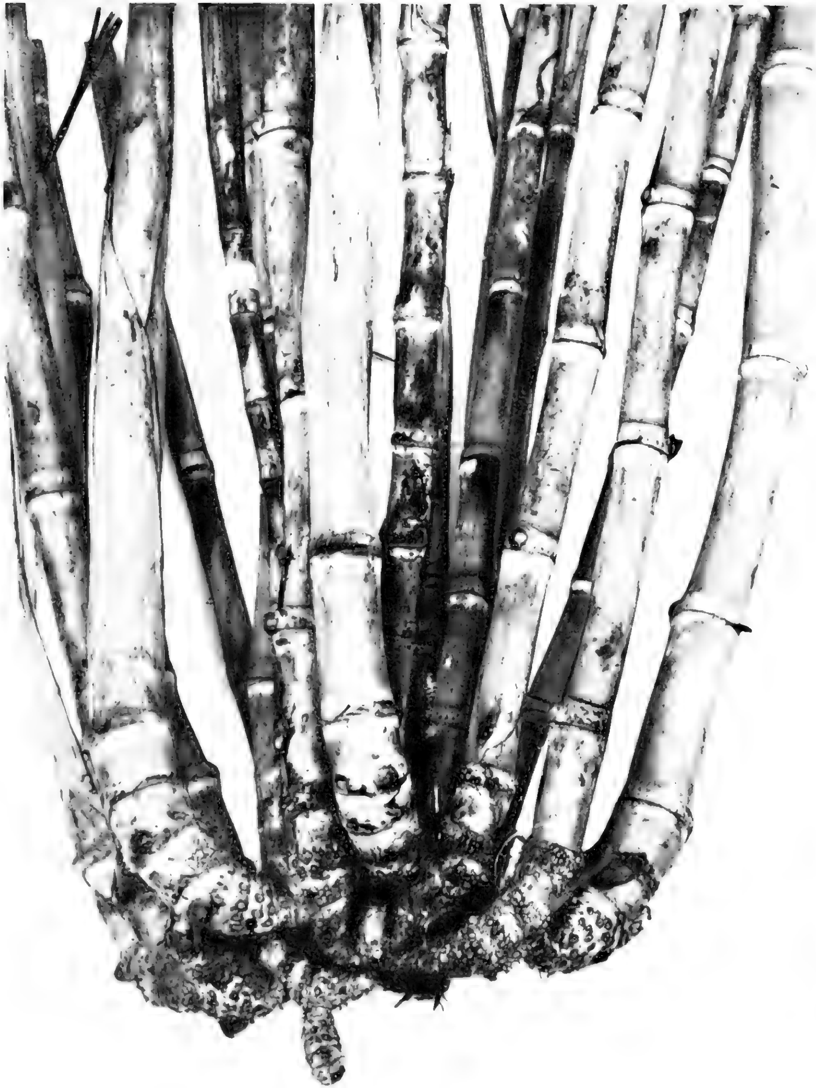
Thickness of branches of successive orders in a *Pansahi* clump of canes, in centimetres:

								Average
a	1·42							*a* 1·42
b	1·79							*b* 1·79
c^1	2·00	c^2	1·86	c^3	2·00	c^4	1·90	*c* 1·92
d^1	2·63	d^2	2·24	d^3	2·31	d^4	2·26	*d* 2·38
e^1	(3·52)	e^2	2·69	e^3	(3·35)	e^4	(3·40)	*e* 3·29

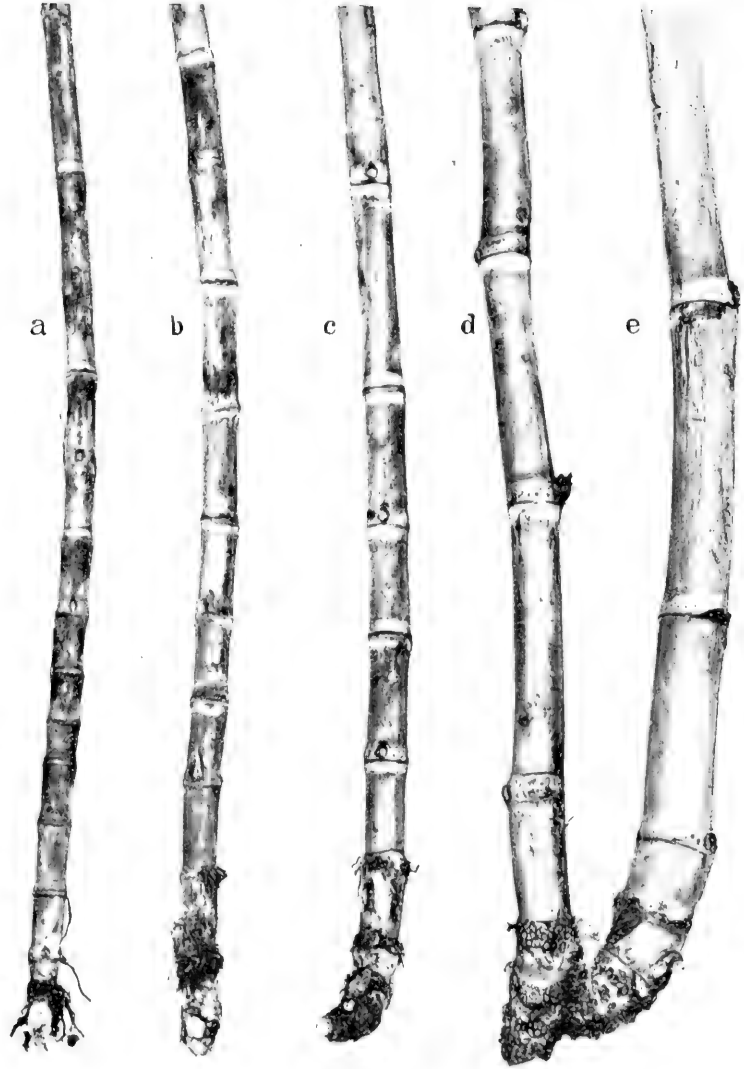
There is no doubt but that the *e*s are, in this case, to all intents and purposes, "water shoots." Two photographs of another dissection of a Pansahi clump are appended (Plate III) which show this increase in thickness in the later branches very clearly.

It will be seen from the above that the late-formed shoots are branches of a high order and that they are uniformly thicker than the earlier ones. It is also very evident in the dissections that the joints of the earlier canes are shorter than those formed later. In the special case under consideration the average length of the joints in the lowest two feet of the branches of different orders is as follows :—*a* 1″, *b* 2″, *c* 2″, *d* 2·8″, *e* 3″, and this difference is especially noticeable in the lowest part of each cane, namely, in the first formed or basal joints. The arrangement of the canes measured, in the tables of length of joint in different parts of the cane, where the cane with longest basal joint is placed first and those following are ones with successively shorter basal joints, is thus justified, in that, if there is any well marked division into early and late canes in the twenty measured in any variety, it will at once become evident (*cf.* page 30). From the study of a very large series of tables of measurements of all the joints in 20 canes of each variety, always arranged in this way, it may be stated, as a very general rule, that the canes with longer basal joints have, on the average, fewer joints, but it by no means follows that a definite division into two classes of canes, early and late, can be made at crop time. We have seen that such a division is definite in members of the Pansahi group. In other cases the transition from early to late cane is gradual. In the varieties dealt with in this paper, of the Sunnabile and Saretha classes, all the canes were spread out at crop time in 1917, and it was found

PLATE III.



Dissected stool of *Pansahi*, nine months old. The main stem has a piece of white paper round it.



Isolated canes of the same stool of different orders of branching : *a*, main stem, *b*, *c*, *d*, *e*, branches of the first, second, third and fourth order respectively

generally impossible to separate them into early and late, all the intervening stages being present. This would seem to indicate that, throughout the life of the plant, new canes are continuously being formed in these varieties.

In order to gain further information as to the cause of these differences in the canes of any one clump, a large number of stools of different varieties have been dissected out during the past season. One of these dissections has been detailed above and, among others, six varieties of each of the Sunnabile and Saretha groups have been dealt with. In the Saretha series, *Cheni, Chin, Hullu, Khari, Saretha*, and *Katha*, and, in the Sunnabile group, *Bansa, Bansi, Dhor, Kaghze, Sunnabile*, and *Naanal* were selected, and the dissections were analysed to see if there was any difference in their mode of branching. This work is to be regarded at present as preliminary, and it is intended to deal with the dissection of six varieties of each of the main classes of indigenous Indian canes on an extended scale during the coming season. The results thus far obtained appear to justify the idea that, by this study, light will be thrown upon the relative state of development of the different groups, as compared with the wild Saccharums on the one hand and thick, tropical canes on the other, these two forming the extremes of the series.

The adjoining table gives the results obtained for the Sunnabile and Saretha classes, in each case the most fully developed stools of those dissected being selected.

Dissection of clumps in six varieties each of the Saretha and Sunnabile groups (*a* being the main stem and *b, c, d, e,* branches of 1st, 2nd, 3rd, and 4th orders).

		Canes formed or forming					Shoots over 1′ long				Shoots under 1′ long				Bursting buds				Total canes	Total shoots and burst buds.
		a	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*		
4 months old.	Saretha group	1·0	3·0	2·3	0	0	0	3·0	2·7	0	0·3	1·2	1·0	0	0	2·5	2·0	0	6·3	12·7
	Sunnabile group	1·0	1·5	0·2	0	0	0	4·0	2·0	0	1·0	3·0	1·7	0	0	4·8	1·2	0	2·7	17·7
9 months old.	Saretha group	1·0	3·4	5·4	2·7	0·3	0	0·3	0	0·7	0	0·3	0·3	0	0·5	2·3	7·0	0·3	12·8	11·7
	Sunnabile group	1·0	4·5	4·7	0·9	0	0	0·2	0·5	0	0	0·5	0	0	0	5·0	2·5	0	11·1	8·7

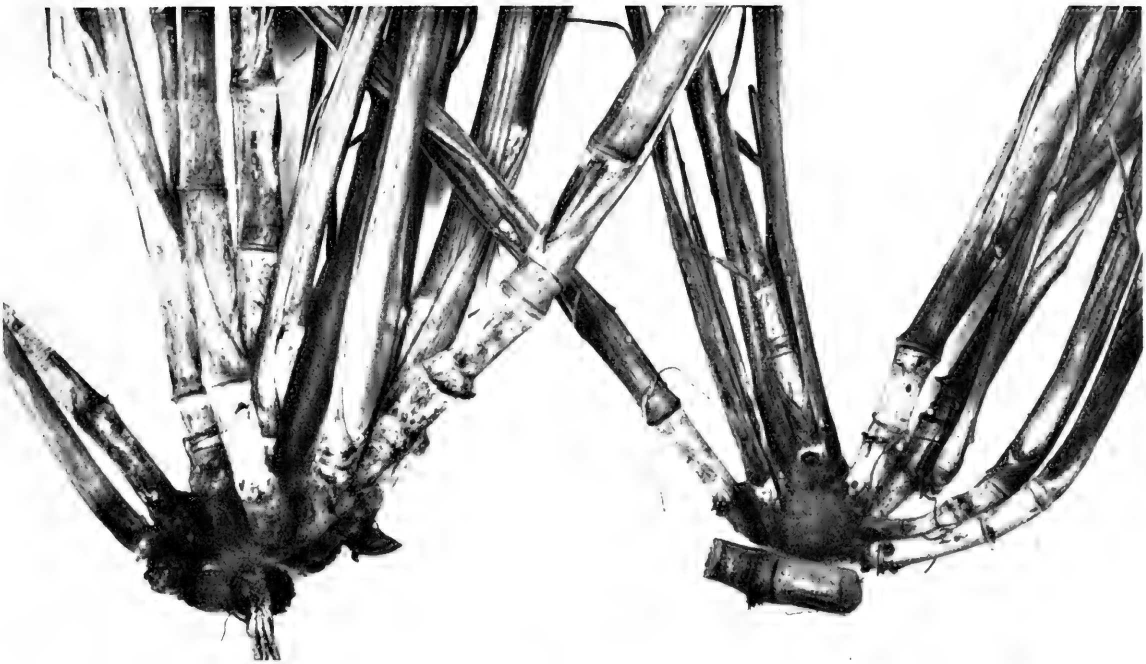
From this table the following interesting conclusions can be drawn:—

(1) The Saretha class of canes matures earlier than the Sunnabile, the number of canes forming at 4 months being 6·3 and 2·7 respectively. But

the Sunnabile group at this period shows a greater number of shooting buds—the figures being 17·7 for Sunnabile and 12·7 for Saretha. I have selected *Saretha* and *Kaghze* stools, of the same age and dissected at the same time, to show the difference in rate of maturing. Photographs of the dissections are to be seen in Plate IV.

(2) The order of branching extends further in the Saretha group, branches of the fourth order being found in members of this series, whereas none are present in the Sunnabile varieties beyond the third order. This fact is of some importance as suggesting a more primitive character in the Saretha varieties, in that, generally speaking, the more primitive a cane, the higher the order of its branches. This will be clear from the following. The wild Saccharums dissected have canes formed of branches up to the fifth order, whereas the thick cane varieties are usually content with the second or third order. The groups of Indian canes fall between these two extremes, and I have constructed the following conventional formulæ for the clumps at maturity in each case :—

	a	*b*	*c*	*d*	*e*	*f*
Wild Saccharums	1	2	3	3	2	1
Saretha class	1	3	5	3	1	
Sunnabile class	1	5	5	1		
Thick, tropical canes	1	3 (1 ?)				



Dissected stools of two cane varieties, four months old, to show the rate of development of cane-forming shoots. The upper figure is of *Saretha*, two buds from one set. The branches are maturing much more rapidly than in *Kaghze* which is shown in the lower figure (three buds from one set.)

IV. NOTE ON A METHOD OF BUILDING UP AN IDEAL CANE BY AVERAGING MEASUREMENTS AT SUCCESSIVE JOINTS.

Averaging the length of the organs at successive joints of the cane presents many difficulties, the chief of which is that the canes are of different lengths and do not contain the same number of joints. Some of these difficulties have been alluded to in a previous Memoir* where it was decided that, while six canes were insufficient for reliable averages to be obtained, measurements of twenty would at any rate demonstrate the presence of early and late classes of canes in the crop. The latter number has been adopted in all subsequent measurements, and a considerable amount of time has been devoted to the elucidation of the problem. This number is considered sufficient to rule out the occasional abnormal variations and, if the selection of canes is carefully checked, will, it is held, give fair averages from which the mode of growth can be ascertained. It is recognized that soil, manuring, rainfall and temperature, will have considerable influence, but if these are equal for all varieties, the intrinsic differences in growth will make themselves apparent in comparisons. It has transpired that environment has a considerable effect upon growth in length of the organs at different parts of the cane, and characteristic curves have been obtained in a series of canes grown at Taliparamba, on the west coast, and Samalkota, on the east coast, of the Madras Presidency. It is possible, from a glance at the curve of growth, to say at once in which of these two localities any variety has been planted. This fact makes it all the more necessary, in comparisons, to study all the canes at the same place and under the same conditions. We cannot safely compare the growth curve of one cane grown in North India with that of another grown at Coimbatore.

The twenty canes are chosen at haphazard, but the collector will obviously pass over such as are meagre and stunted, and the average will, therefore, be somewhat higher than in the whole crop. The object aimed at is to obtain twenty average canes which have become fully developed. When one considers that these twenty canes will vary greatly in general height, in the number of the joints and in other respects to be referred to below, it would seem well-nigh

* Mem. I, p. 35.

impossible to obtain fair averages of successive joints, but the results of the method here employed have this that is satisfactory, that the curves ultimately obtained exhibit considerable uniformity in each variety grown in the same place, and that there are well marked differences in the curves of different varieties, a study of which has added yet another character by which the Sunnabile and Saretha groups may be distinguished.

The organs measured are the joints (internodes), leaf sheaths and laminas. The twenty canes are cut at ground level and laid out on a table and the laminas are first measured in succession from the lowest joint upwards towards the apex, until a leaf is reached only 1 ft. in length. The sheaths of these leaves are next measured in the same way and the cane is then stripped, and the joints are measured until those are reached which are only one-tenth of an inch in length. In each separate joint the measurement is thus recorded of its own length and that of its leaf sheath and lamina, commencing with the lowest above ground and continuing until the youngest joints at the apex are reached. There are always three or four leaf organs measured in excess of joints, in that some joints less than one-tenth of an inch in length already have fairly long leaves, but the exact position of any leaf on the stem can be readily fixed by counting from the base upwards. All measurements are made with a foot rule divided into tenths of an inch.

In each variety we thus get detailed length measurements of the organs in twenty canes. The measurements of individual canes are then written in lines across the page, those of different canes being placed one above the other in vertical columns, all commencing with the joint immediately above the ground. They are thus arranged in a table, and in this table the cane with the longest basal joint is placed first, that with the next longest basal joint next and so on, a space being dropped between the first and last ten canes. The upper ten have longer basal joints and the lower shorter basal joints, and, if there is a marked difference in the number of joints in the upper and lower series, we have an indication that the variety is characterized by early and late canes.* The lengths of leaf sheath and lamina are treated in the same manner, the cane with the longest basal *joint* being again placed first, so that we have the twenty canes arranged in the same order in each series and can, at any moment, pick out from the tables the length of any joint and of its leaf sheath and lamina. We thus have ample material for the study of any correlations existing between the length of the joint and the organs belonging to it. (It may be pointed out,

* *See* previous section p. 26.

in passing, that other characters have been studied in the same twenty canes, *e.g.*, length of leafy shoot, width of leaf, thickness of cane in various parts, and the canes here too are arranged in the same order.)

The problem immediately before us is to construct an ideal cane as far as length of organs is concerned, representative of the twenty measured, and, for the purpose of illustration, I have selected the length measurements of the leaf sheaths in twenty *Khari* canes, given in the table at the end of this section. It will be seen from this table that, while there are 41 sheaths in one cane, there are only 26 in another, and that there are all gradations between these two extremes. The average number of sheaths in the twenty canes is 32, and, consequently, only this number of averages is required in the ideal cane. We obtain it in the following way. The last eight measurements are regarded as those of more or less immature organs, and, forming the close of the series, are retained intact. These are placed at the end of each line, blank columns being left for the inclusion of the whole 41 of the longest cane (No. 19). The last eight columns are thus present in all the canes, but the ninth from the end is only present in one cane, the longest. Working backwards, the next column is found in two canes, the 13th in four canes, and so on, until, at the 24th from the end, we again get all the canes represented. These two points, the 24th and 8th from the top of the cane, or the 18th and 34th from the base, are marked by arrows pointing towards one another. The averages of the columns between these two arrows are not truly representative, in that the shorter canes are left out, and, in those that have organs, these are at varying distances from the top, and they become less and less representative the further we proceed from base to apex. To bring the total number of measurements to 32, nine columns have to be left out, and the nine selected are those immediately preceding the last eight, as these measurements are taken from the smallest number of canes and are only representative of the longer ones. These nine columns are placed in brackets, and are no longer taken into consideration, and we are merely concerned in striking averages of the first 24 and last 8 columns. It will now be found that there may be a sudden break in the series from the 24th to the 25th column, namely, where the omissions have taken place. It is necessary to smooth out this break and make the fall to the last eight gradual. This is the first alteration which it is found necessary to make in the curve. But there is another point to be considered. In each series the lowest members are short, these are succeeded by longer and longer ones until a maximum is reached, after which a decline follows, until, in the terminal immature members, there is a rapid fall. As these maxima are reached at different points in canes of different lengths, the process of averaging largely rules them out. And this question of maxima is complicated by the not infrequent appearance of second or even third and fourth maxima, as if there was a more or less defined periodicity in the growth in length of the parts. In the general summation, these secondary maxima are also mostly ruled out. This is a serious drawback, but, on the other hand, local, excessive variations, in individual canes, which may be due to many causes, are also ruled out, which is not such a disadvantage. It is thus quite possible to have a flat summation curve, in which the individual canes show several maxima and great individual variations from joint to joint. But these maxima should, as far as possible, be represented in the ideal cane, and their inclusion is one of the chief difficulties in our problem.

The following method, although somewhat arbitrary, has been designed to give each maximum when possible its value, it being inevitable that all of them are much less marked in the summation series than in the individual canes. In the table, each cane is studied as regards its maxima, and these are indicated by dots. Lines are then drawn between the maxima in adjoining canes, and dotted lines if the canes are not next to one another. By this system the general trend of maxima in the whole series can be seen at a glance. In the table given as an example, there is a certain amount of periodicity of growth, and three separate maxima are often present. The first six and the last ten canes of the table agree very closely in their periodicity. Attention is now paid to the summation series at the bottom representing the averages of the columns. If this series shows maxima in the right places, as judged by the rows of dots and lines, and this is not infrequently the case, the figures are left intact, providing that there is no sudden jump to the last eight immature members because of the removal of unrepresentative columns. If the maxima are not shown where they would be expected, or if there is an unjustifiable break in the curve just before the last eight, as is often the case, arbitrary alterations are made. But this is carefully safeguarded by making the alterations chiefly in the non-representative series between the arrows. The amount of actual change is, however, very little, as will be seen from the typical, but rather simple, case shown in the table. Two maxima are duly reflected in the average series (the second maximum representing the second and third of the individual canes merged into one), and it is merely necessary to alter a few numbers, so that there is a less sudden fall, in the figures, to the last eight, than is justified from a study of the whole twenty in this region.

Cane No.	Base			Apical, immature region								Number of sheaths
1	13·0	14·3		10·3	10·1	9·5	9·3	2·8	0·4	0·2	0·1	28
2	..	..		11·9	11·2	10·0	9·2	4·5	0·5	0·2	0·1	30
3	..	13·7	·8 11·3	10·8	10·6	10·0	9·2	4·9	0·5	0·2	0·1	37
4	11·5	..		12·0	11·0	10 0	9·9	7·6	1·1	0 3	0·1	26
5	..	12·6		10·3	9·4	9·2	8·2	2·8	0·4	0·2	0·1	35
6	14·5	15·2		11·3	10·8	9·0	8·4	3·6	0·4	0·2	0·1	34
7	11·7	13·5		10·5	9·9	9·8	7·4	1·0	0·3	0 2	0·1	28
8	12·6	..		11·8	10·0	10·5	8·6	3·9	0·7	0·3	0·1	31
9	11·3	10·5		10·3	9·2	9·0	8·1	2·5	0·4	0·2	0·1	29
10	12·0	13·0		12·7	10·3	9·6	7·5	1·2	0·6	0·3	0·1	27.
												30·5
11	12·5	14·1		10·4	11·4	7·7	7·1	6·4	0·9	0·2	0·1	33
12	10·1	12·0		10·3	9·8	9·4	8·5	4 0	0·5	0 2	0·1	29
13	11·0	12·2	0 10·4	9·3	9·3	7·7	7·5	2·4	0·4	0·2	0·1	37
14	..	14·0	0 11·0 10·4 9·7 10·0	9·5	8·2	8·2	7·9	3·5	0·4	0·2	0·1	40
15	13·0	13·		13·8	12·7	10·8	7·4	1·2	0·3	0·2	0·1	28
16	..	10·		10·6	10·8	9·6	8·5	5·7	1·2	0 3	0·1	30
17	9·6	11·		12 0	11·3	10·1	9·1	3·9	0·4	0 2	0·1	35
18	..	..		10·0	10·0	9·9	6·9	0·9	0·4	0 2	0·1	33
19	..	10·	5 12·6 12·7 11·0 11·2 11·7	10·3	10·0	9·3	8·3	3·4	0·4	0·2	0·1	41
20	..	..	·8	11·1	11·0	9·8	7·3	1·9	0·4	0·2	0·1	36
												34·2
Averages of 20	11·9	12	·4 11·3 11·6 10·4 10·3 11·7)	11·0	10·4	9·5	8·2	3·4	0·5	0·2	0·1	32·3
			omitted.									
Corrected ..	11·9	12		11·0	10·4	9·5	8·2	3·4	0·5	0·2	0·1	32

KHARI. *Lengths of leaf-sheaths in successive joints in twenty canes.*

(Measurements in inches)

Cane No.	Base — First maximum — Second maximum — Third maximum	Apical, immature region	Number of sheaths
1	13·0 14·3 14·5 .. 15·0 14·4 13·5 12·8 11·8 11·7 11·9 11·8 13·4 13·7 13·8 13·9 13·2 11·8 13·0 11·5	10·3 10·1 9·5 9·3 2·8 0·4 0·2 0·1	28
2	. . . 12·7 13·2 13·8 14·0 13·7 14·2 13·9 13·8 14·8 14·0 14·4 13·7 14·5 15·0 13·9 14·5 13·4 11·7 11·7	11·9 11·2 10·0 9·2 4·5 0·5 0·2 0·1	30
3	. 13·7 . 13·7 14·0 15·5 13·7 11·7 12·0 12·6 12·8 12·5 12·0 12·0 12·2 11·7 13·0 14·0 13·5 13·3 12·7 13·3 12·3 12·0 12·5 12·2 10·5 10·8 11·3	10·8 10·6 10·0 9·2 4·9 0·5 0·2 0·1	37
4	11·5 .. 13·9 14·0 13·5 12·7 12·5 11·2 9·7 11·8 12·0 12·8 13·5 13·4 13·4 13·3 13·6 12·3	12·0 11·0 10·0 9·9 7·6 1·1 0·3 0·1	26
5	. 12·6 13·7 13·0 13·8 14·5 13·8 14·0 14·0 11·5 12·0 13·0 13·3 13·0 11·8 10·7 12·0 13·0 12·1 12·7 10·8 11·8 15·0 13·7 11·9 11·3 10·9	10·3 9·4 9·2 8·2 2·8 0·4 0·2 0·1	35
6	14·5 15·2 14·0 15·2 13·0 13·0 10·9 11·3 13·0 13·4 14·4 13·7 14·1 14·0 13·4 13·3 13·0 14·5 13·7 13·0 13·5 12·7 12·0 12·2 12·4 12·1	11·3 10·8 9·0 8·4 3·6 0·4 0·2 0·1	34
7	11·7 13·5 13·8 14·0 14·2 14·0 14·4 12·2 11·2 12·5 13·0 13·1 12·6 13·5 13·0 13·0 13·4 13·3 11·2 11·4	10·5 9·9 9·8 7·4 1·0 0·3 0·2 0·1	28
8	12·6 .. 15·0 14·9 14·2 14·0 14·5 14·4 11·5 11·8 13·0 12·3 13·9 12·6 14·4 14·2 14·1 13·5 14·2 14·5 12·0 13·4 12·4	11·8 10·0 10·5 8·6 3·9 0·7 0·3 0·1	31
9	11·3 10·5 12·0 13·0 13·0 13·2 13·4 13·0 12·5 11·0 11·5 12·5 13·3 13·0 13·5 12·7 12·7 12·1 12·6 11·5 11·5	10·3 9·2 9·0 8·1 2·5 0·4 0·2 0·1	29
10	12·0 13·0 13·5 13·0 11·7 12·5 14·9 14·5 14·1 15·1 15·0 14·1 14·5 14·0 13·8 14·3 13·2 13·4 13·0	12·7 10·3 9·6 7·5 1·2 0·6 0·3 0·1	27
			30·
11	12·5 14·1 14·6 14·1 14·0 13·6 14·6 13·5 12·8 13·1 13·4 14·0 14·5 13·2 13·0 13·7 13·0 14·0 15·5 14·3 13·1 12·0 13·0 12·2 11·5 11·3 10·9	10·4 11·4 7·7 7·1 6·4 0·9 0·2 0·1	33
12	10·1 12·0 13·0 13·0 14·0 14·6 14·5 12·0 12·0 13·2 12·6 12·8 13·5 14·3 13·5 13·0 12·0 13·5 13·0 12·3 11·7	10·3 9·8 9·4 8·5 4·0 0·5 0·2 0·1	29
13	11·0 12·2 12·1 12·0 13·7 14·4 13·7 14·0 13·7 13·0 10·5 11·0 12·3 14·0 13·0 11·6 13·6 13·1 13·5 13·5 14·1 14·0 13·0 12·7 12·5 11·5 12·0 11·0 10·4	9·3 9·3 7·7 7·5 2·4 0·4 0·2 0·1	37
14	. 14·0 .. 13·9 14·0 14·5 12·0 12·7 13·7 14·5 14·1 13·9 13·6 13·0 13·3 12·0 13·7 14·1 14·0 14·1 14·0 13·2 12·2 13·0 12·0 12·5 11·4 11·0 11·0 10·4 9·7 10·0	9·5 8·2 8·2 7·9 3·5 0·4 0·2 0·1	40
15	13·0 13·4 13·3 11·2 11·8 12·8 12·5 13·4 14·5 14·6 13·3 12·5 12·0 11·4 7·6 5·4 8·2 11·2 12·5 13·5	13·8 12·7 10·8 7·4 1·2 0·3 0·2 0·1	28
16	.. 10·8 .. 13·8 13·4 12·7 13·0 13·6 14·0 13·5 11·7 11·5 12·0 12·2 10·8 13·3 13·7 13·7 13·0 13·4 13·0 12·0	10·6 10·8 9·6 8·5 5·7 1·2 0·3 0·1	30
17	9·6 11·4 11·8 11·2 11·7 13·0 13·5 12·8 12·2 11·5 13·0 13·4 13·5 12·9 13·5 12·7 13·6 13·4 13·5 13·0 12·0 13·0 13·0 13·2 13·0 13·1 13·0	12·0 11·3 10·1 9·1 3·9 0·4 0·2 0·1	35
18	. . . 11·0 12·7 13·0 13·5 13·7 14·0 14·1 13·8 11·0 11·1 13·4 13·0 12·2 12·7 13·6 13·0 13·5 12·0 12·6 11·4 12·0 11·0	10·0 10·0 9·9 6·9 0·9 0·4 0·2 0·1	33
19	. 10·7 11·2 11·5 12·4 12·2 12·4 13·0 13·5 14·0 13·7 13·8 13·0 13·2 11·7 11·0 10·0 .. 13·0 12·7 13·4 13·0 13·1 12·0 12·3 12·5 12·1 11·5 12·6 12·7 11·0 11·2 11·7	10·3 10·0 9·3 8·3 3·4 0·4 0·2 0·1	41
20	. .. 11·4 11·5 12·7 13·0 13·0 14·2 14·1 13·5 13·6 13·0 13·7 11·5 9·5 11·3 12·1 11·5 11·3 12·0 14·5 13·8 14·5 13·2 13·5 13·3 12·2 12·8	11·1 11·0 9·8 7·3 1·9 0·4 0·2 0·1	36
	→ ←		31·2
Averages of 20	11·9 12·8 13·2 13·0 13·3 13·5 13·4 13·1 12·9 13·0 13·0 12·9 13·2 13·1 12·6 12·4 12·8 13·1 13·2 13·0 12·7 12·8 12·7 12·6 (12·3 12·2 11·6 11·4 11·3 11·6 10·4 10·5 11·7)	11·0 10·4 9·5 8·2 3·4 0·5 0·2 0·1	32·
	altered to 12·4 12·1 11·8; (…) omitted.		
Corrected	.. 11·9 12·8 13·2 13·0 13·3 13·5 13·4 13·1 12·9 13·0 13·0 12·9 13·2 13·1 12·6 12·4 12·8 13·1 13·2 13·0 12·7 12·4 12·1 11·8	11·0 10·4 9·5 8·2 3·4 0·5 0·2 0·1	32

First maximum — Second and third maxima fused.

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CURVES OF LENGTHS OF SUCCESSIVE LEAF SHEATHS IN KHARI CANES. THE 4th, 8th AND 19th IN THE PRECEEDING TABLE, i.e., THE SHORTEST, MEAN & LONGEST AS FAR AS NUMBER OF JOINTS ARE CONCERNED, AND THE IDEAL CURVE OBTAINED FROM THE AVERAGES OF THE WHOLE TWENTY IS ADDED IN RED.

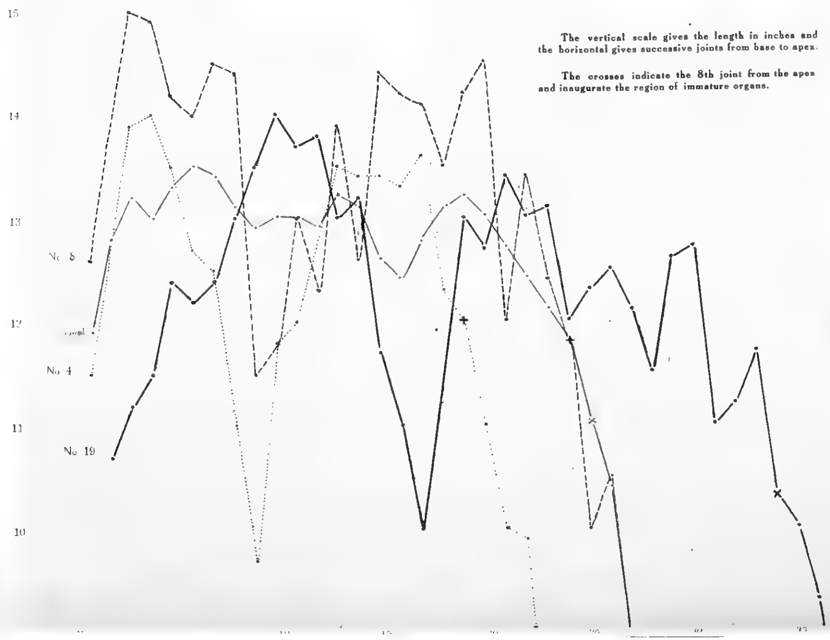


CHART I.

Many summation series have been allowed to stand unaltered, in others the last few numbers have been altered to allow a reasonable drop to the last eight, in others it has been found necessary to emphasize a maximum or to indicate a late maximum by the increase of one or two figures in the non-representative columns. In doing this, it is borne in mind that the averages of a series such as this are much more uniform than the individuals comprising it, whether early or late, long or short, as explained above.

In obtaining the averages for the typical cane representing the whole Saretha or Sunnabile group, exactly the same procedure has been adopted, but, in place of the figures for individual cane varieties, the summation series of all the varieties are placed in the table, these varieties being of the same age and growing at the same place, under similar conditions. Similar precautions are taken as to the average number of organs, the position of the maxima and the smoothness of the series at the end. As will be seen in the sequel, the method is of service, in that, not only do varieties differ from one another in these series, but the whole groups of Saretha and Sunnabile forms show differences which are of value in distinguishing them.

But long series of figures are difficult to follow, and they have, accordingly, been plotted out in curves in which the characteristics of growth can be detected at a glance (Chart I). As examples of such curves, are appended those, representing the lengths of leaf sheaths in *Khar*, in the shortest and longest canes (Nos. 4 & 19) of the twenty measured and in one which has the average number of joints (No. 8). Added to these is the ideal summation curve of the whole twenty canes examined. This latter is of mean length, is much more uniform than the curves of the individual canes, in that excessive variations from joint to joint have been ruled out, and the early and late maxima are indicated, although greatly reduced. The last few, immature organs are not all shown, and the crosses indicate where they commence. For other length curves, reference may be made to the paragraphs in Section V, dealing with the length of the several organs in different parts of the cane.

V. DETAILED LIST OF CHARACTERS IN WHICH DIFFERENCES HAVE BEEN NOTED, WITH TABLES OF MEASUREMENTS FOR THE INDIVIDUAL VARIETIES OF THE SARETHA AND SUNNABILE GROUPS.

The following is the list of cane varieties dealt with in this paper, with the locality from which they were obtained. They are arranged in groups, and the Saretha group is divided into its red and brown sections, and in each set the varieties with thinnest canes are placed first (as judged by one of the crop experiments in 1917). The varieties in the Sunnabile group are placed approximately opposite to those of similar thickness in the Saretha series. The names of places in brackets are those of the farms from whence the varieties were immediately obtained.

	Saretha Group *Katha* (brown) *Section*		Sunnabile Group
cm.		cm.	
1·3	*Raksi* (Shahjahanpur), Barabanki	1·3	*Teru*, Gurdaspur
1·4	*Katha*, Gurdaspur *Ramui* (Shahj.), Barabanki *Lalri*, Panipot	1·4	*Rakhra* (Shahj.), Barabanki
1·5	*Chin*, Aligarh *Chunnee*, Shahjahanpur * *Baraukha*, Cawnpore	1·5	*Ekar*, Jullunder *Dhaulu*, Gurdaspur
1·6	*Kansar*, Gurdaspur	1·6	*Kaghze* (Aligarh), Pilibhit *Ketari* (Sabour), Patna
1·7	† *Chynia*, Barah, N. Bihar *Burra Chunnee* (Shahj.), Bareilly		
1·8	*Saretha* (brown) (Partabgarh), Aligarh		

* There are many *Baraukhas* and this is, I fancy, a local Cawnpore name for a *Chin*-like cane grown there.

† This form is quite different from the *Chynia* around Pusa in Bihar, a form belonging to the Pansahi group.

cm.	Saretha Group	cm.	Sunnabile Group
	Mesangan (green) *Section.*		
1·4	*Mesangan*, Jullundor		
1·7	*Saretha* (green) (Jubbulpore), Aligarh *Jaganathia*, Barah, N. Bihar		
1·8	*Khari* (Sabour), Burdwan	1·8	*Bansa* (Sabour), Manbhum
1·9	*Hullu Kabbu* (Hagari), North-western part of Madras	1·9	*Bansi* (Nagpur), Bombay *Sunnabile* (Jubbulpore), Bombay
2·0	*Ganda Cheni*, Mysore	2·0	**Putli Khajee* (Barah), Assam ?
2·1	*Kalkya* (Manjri), Bombay	2·1	*Khadya* (Manjri), Bombay *Naanal*, Tanjore *Hotte Cheni*, Mysore
		2·2	*Dhor*, Seoni, Central Provinces
		2·6	*Mojorah* (Jorhat), Assam

* The origin of this cane is obscure. It was obtained as an Assam cane at Barah estate in Bihar, but the Assam Agricultural Department have not met with it. It is a very distinct cane.

A study of this list brings out two facts. In the first place, the thinner canes, generally, are found in the Punjab and United Provinces, and we come across thicker varieties as we pass south-east to Assam and down the Peninsula. Secondly, the Saretha group has the largest proportion of its members in the first named Provinces, being absent or only occurring sporadically in Bengal, Assam, and the South. The Sunnabile group, on the other hand, has its greatest development in the latter tract and occurs only sporadically in the United Provinces. It is interesting to note that each group is fairly well represented by a few primitive forms in the Punjab. The order of arrangement, according to the thickness, here given, will be followed in the tables at the end.

Erectness of Young Shoots.

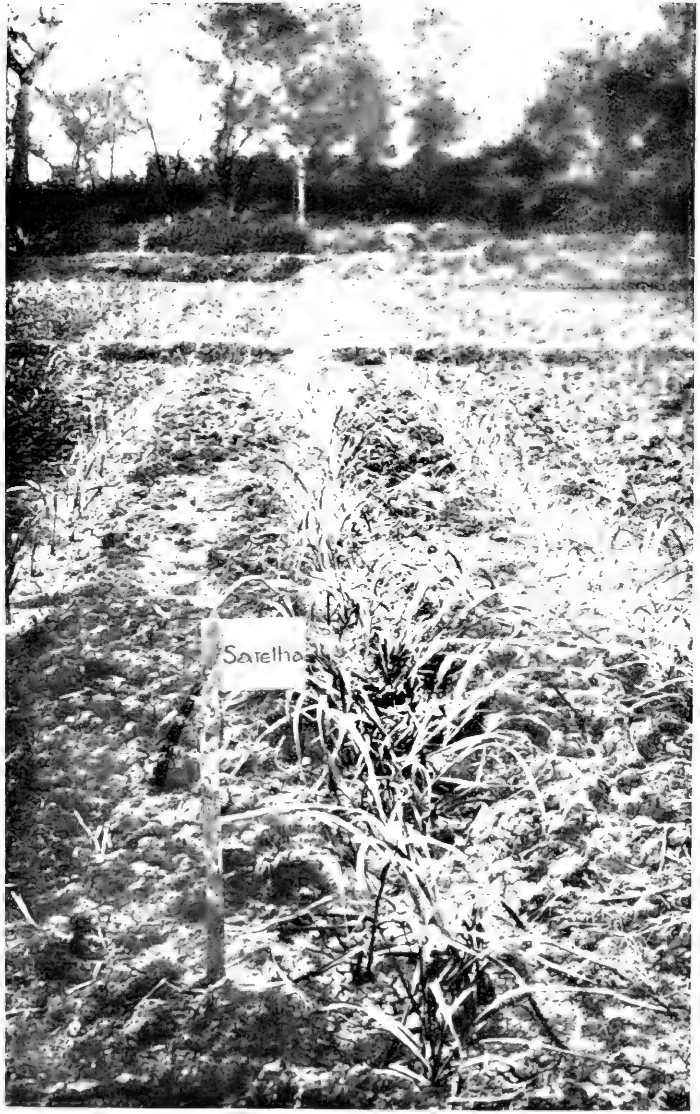
There is a marked difference in the Saretha and Sunnabile groups in this respect. Considerable attention has been paid to this character for several years past, in the study of varieties and seedlings grown in the Cane-breeding Station. Observations have demonstrated that it is a stable character in the varieties and that it is inherited by seedlings from their parents (*Mem.* 2.

pp. 36-39). *Saretha* and its class are characterized by considerable obliqueness in the young shoots, approaching *Saccharum spontaneum* in this respect, where, on any river bank, numerous seedlings may be seen which are at first perfectly flat on the ground. The members of the Sunnabile group, on the other hand, tend to produce rather erect young shoots. Observations were made on all the indigenous Indian varieties growing on the farm in 1915-16, when the plants were 5-6 months old, and figures have been extracted for the varieties now being considered. In each row of young canes the deviation of the shoots from the vertical was measured by a clinometer, such as is used in measuring the dip of strata in geology. Two figures are recorded for each variety and indicate the extremes met with. For example, *Naanal* 0°—25° means that, while some of the shoots were vertical, the greatest deviation of the shoots from it was 25°. Taking the two series and striking averages, 14 members of the Saretha group gave 13°—67° against 5°—30° for the 12 Sunnabile varieties measured, the extremes in the two groups being 10°—80° and 0°—45° respectively. This character is not an *absolute* one, and there are cases of overlapping. *Putli Khajee* and *Mojorah*, for instance, in the Sunnabile group, are distinctly oblique (Plate V).

Habit and Mode of Growth.

The Sunnabile and Saretha groups differ a good deal in general appearance in the field, although this character is not easily reduced to measurement. It is, moreover, difficult to determine the exact period when comparative observations should be recorded. These thin varieties, when grown in a few rows, soon require propping to keep them in their respective plots, and as soon as this is done all observations as to habit have to be given up. An exact study of habit has thus been largely precluded on the Cane-breeding Station.

The Saretha varieties are generally characterized by a spreading if not sprawling habit, the outer branches extending widely over the plot, and the growth is irregular and untidy (Plate VI). It is easy, on the other hand, to keep Sunnabile varieties within the limits of their plots ; there is a tendency to a strict, erect habit and the branches at the base are closer together. In this, as in other respects, the Saretha series resemble *Saccharum spontaneum* in their habit. And this relative erectness of the two groups is emphasized by the character of the leaf tips. In the description of Punjab canes (*Memoir* 1) it was noted that the leaves of *Katha*, *Saretha*, *Kansar* and *Lalri* soon became bent at a sharp angle near the end, whereas this character was absent in *Dhaulu*.



Erectness of young shoots. On the left, *Saretha* has widely spreading, oblique shoots and, on the right, *Naanal*, of the Sunnabile group, has shoots more or less erect. On the left of the *Naanal* row is another of *Saretha*.

The whole series of Saretha varieties grown on the Cane-breeding Station.

The *Chin* plot with branches bending towards the observer.

THE SPREADING HABIT OF THE SARETHA GROUP.

Fig, 1.

Fig. 2.

Habit and mode of growth. Fig. 1. *Saretha* and Fig. 2. *Sunnabile* as types of their respective groups. In the former the habit is sprawling (towards the observer) and the leaf tips are bent. In the latter the growth is strict and the leaf tips are erect.

These appearances seem to be more or less general in the groups. The varieties in the Sunnabile group generally have strict, bayonet-like leaf ends, and when the leaves bend, they do so in a broad continuous curve. This character of the leaf ends adds not a little to the general strictness of habit of the group, as contrasted with that of Saretha (Plate VII).

Tillering.

The indigenous canes of India are well known to have much greater tillering power than the thicker canes of the tropics and, in well grown clumps, as many as fifty canes are by no means uncommon. All the varieties grown at Coimbatore in the two groups were examined with regard to this character at crop time, but this related only to *canes*, the shoots not yet forming canes being omitted. Another observation was, however, made for a different purpose in which all the shoots above one foot in length were counted in five members of each group.

(1) Each varietal plot consisted of three rows, twenty feet long, and there were ten stools in each row. Owing to other demands, only one row (that is ten clumps) was available for cane counting at harvest. The figures obtained were generally low, owing presumably to the poor growth in the plots during this season. The Saretha class, generally, had more canes than the Sunnabile. The greatest number of canes was found in *Raksi* (27 per clump), while *Ramui* and *Burra Chunnee* followed with one less in each. In the Sunnabile group, the greatest number of canes was found in *Bansa*, where there were 17. Several varieties of each series were specially poorly grown or destroyed by rats, but the general tendency was marked. The average number of canes per stool was 15 in the Saretha group and 12 in the Sunnabile.

(2) In connection with another piece of work, the canes and shoots over one foot in length were counted in a series of varieties during each month of the growing season, the last counting taking place just before harvest. In this series five of the Saretha and five of the Sunnabile groups were included, besides varieties belonging to other groups. The following are the results of the last counting.

Saretha series: *Chin* 29, *Saretha* 28, *Khari* 24, *Hullu Kabbu* 22, *Ganda Cheni* (poorly grown) 16.

Sunnabile series: *Kaghze* 20, *Bansa* 18, *Sunnabile* 17, *Naanal* 15, *Dhor* (poorly grown) 12.

The average numbers of canes and shoots over one foot in length in the two series were 24 and 16 respectively. But certain other points may be noted in these figures. It will be seen, if reference is made to the list of varieties at the commencement of this section, that in each series the amount of tillering is the exact converse of the thickness of the cane in the variety, that is, the thicker canes have fewer branches. Also, the thicker varieties of the Saretha group, *Khari, Hullu Kabbu* and *Ganda Cheni*, belonging to the Mesangan section, are intermediate between *Chin* and *Saretha*, belonging to the Katha section, and the Sunnabile group.

We are justified by the figures in stating that the tillering of the Saretha group is greater than that in the Sunnabile, and this result is in accordance with the idea already expressed that the former group contains more primitive varieties.

Dissection of Stools.

The mode of branching appears to differ in the Sunnabile and Saretha groups. This has been demonstrated by a dissection of the stools in six varieties of each group, and the branching is seen to extend to a higher order in the latter group. For a discussion of this difference, reference may be made to the preceding special note on the subject (Section III).

Flowering, Anthesis, Seed-formation.

There is perhaps no character in which the Saretha and Sunnabile groups differ more widely from one another than in their frequency of flowering, the proportion of open anthers found in the arrows and the ease with which seedlings can be raised from them. The following are the results obtained during the exceptionally favourable season of 1915-16, when 35 indigenous Indian canes flowered on the farm. *Saretha, Lalri, Katha, Kansar,* all flowered profusely, a matter of special interest because I believe that the last three, being Punjab canes, have never been known to flower before. In the same group, *Chin, Baraukha, Hullu Kabbu, Khari, Mesangan* and *Cheni* also flowered. In each of these ten varieties some at least of the arrows had over 90% of the anthers open. Between 3,000 and 4,000 seedlings were obtained from them, but this number could easily have been multiplied ten times if it was thought advisable to do so. It may be mentioned that, in North India, a few canes flower sporadically every year and these are usually *Khari* and *Saretha* of this group, and they are practically the only canes which do so, as it has been found safe, when noting cane arrows in a plot, to assume that either *Saretha* or *Khari* is present. Turning to the Sunnabile group, *Dhor* and *Kaghze* flowered in 1915-16; none of their stamens were open and, in the pans sown, not a single seedling germinated. None of the other members of the group flowered. The capacity for flowering and the fertility of the arrows would thus appear to be an important character in the separation of the two groups.

Since writing the above, the 1916-17 results have become available. In the Saretha group, *Katha, Lalri, Mesangan, Kansar, Chin, Chunnee, Saretha* (green) and *Saretha* (brown), *Hullu Kabbu* and *Ganda Cheni* flowered. The last named had 62% of anthers open in the arrows and all the rest over 80%. *Hullu Kabbu* and *Ganda Cheni* did not produce seed which germinated but, wherever the others were sown, they produced masses of seedlings. In the Sunnabile group, *Dhaulu, Ekar, Hotte Cheni, Kaghze, Putli Khajee* and *Mojorah,* all produced a few arrows, but in none of these were any of the anthers open and no seedlings were obtained in the pans sown. Here too, then, the thicker members of the Mesangan group showed an approximation to the Sunnabile group.

Number of Dead Leaves, Length of Cane bearing them, Length of Living Shoot, and Total Length of Plant.

The general height of canes in the field is not readily discernible in small plots where the plants are grown in a few rows. The heavy nodding masses have to be supported, and, this being especially the case with thin varieties, they lose more of their height than the thicker ones. But certain observations have been recorded which give us information on this point in an indirect way. These observations are detailed in the heading of this section, twenty canes being carefully measured in each variety as usual. In the 1915-16 crop, seven varieties of the Saretha group and ten of the Sunnabile were thus studied before the plots were destroyed. But the canes had been over twelve months in the ground, the plants were overgrown and the end portions were twisted and shooting, so that the leafy shoots were frequently drying and irregular. It was accordingly decided to repeat the observations on the 1916-17 crop at an earlier date, especially as a much larger number of varieties had been separated out as belonging to the two groups. Eighteen members of the Saretha group and fifteen of the Sunnabile were examined when about nine months old, and the leafy shoots were intact and vigorous, while the canes were still comparatively straight. But in this case, as noted elsewhere, the growth in many of the varieties in both sections was very poor and the figures must be considered as distinctly below the average. In spite of these drawbacks, the general agreement of the proportional figures in the two sets of observations justifies the belief that there are real differences in the Saretha and Sunnabile groups in the characters mentioned. This may be seen from a study of the appended table.

		Number of joints with dead leaves		Length of part of cane with dead leaves		Length of shoot with living leaves		Total length of plant	
		Extremes in the group	Average	Extremes in the group	Average	Extremes in the group	Average	Extremes in the group	Average
1915-16 over-ripe	Saretha group	21—23	23	6′ 11″—8′ 2″	7′ 7″	5′ 8″—7′ 1″	6′ 5″	13′ 2″—15′ 1″	14′ 0″
	Sunnabile group	29—38	32	6′ 10″—9′ 1″	7′ 5″	4′ 4″—6′ 11″	5′ 11″	11′ 4″—15′ 2″	13′ 4″
1916-17 9 months old	Saretha group	12—17	15	3′ 3″—5′ 5″	4′ 8″	5′ 2″—8′ 0″	6′ 7″	9′ 7″—13′ 2″	11′ 3″
	Sunnabile group	13—20	16	2′ 9″—5′ 7″	4′ 2″	4′ 4″—7′ 1″	5′ 11″	7′ 8″—12′ 5″	10′ 1″

It appears from the table that, at any given period, there are more joints with dead leaves in the Sunnabile group, but, in spite of this, the portions bearing these dead leaves are longer in the Saretha series. From this it appears that the lower joints are longer in the Saretha group. In the dead leaf portion, at twelve months or over, 23 Saretha joints measure 7′ 7″ while 32 Sunnabile only reach 7′ 5″, while at nine months 15 of the former measure 4′ 8″ while 16 of the latter only reach 4′ 2″. Further, the living leafy shoot is uniformly longer in the Saretha series by 6″ or 8″, and thus we are prepared for the independent results obtained in the measurements of the total lengths of the plants of the two series laid out on the ground. At crop time the average length of the Saretha series was 14′ 0″ to 13′ 4″ for the Sunnabile series, while the difference was greater at nine months when the figures were 11′ 3″ and 10′ 1″ respectively. These results tally with those given later, when it is shown that the average cane, joint and leaf are longer in the Saretha group than in the Sunnabile series.

Cane Measurements.

(1) *Length of stripped cane, number of joints, average length of mature joints, average thickness of cane, and cane module.*

These characters have been noted at various times and in various places, but, for the sake of comparison, two only of these sets of observations will be considered here, in that the varieties were grown together in adjoining plots under similar conditions. The first set of figures was obtained in the 1916 crop when seven of the Saretha and 10 of the Sunnabile groups were measured and the second was obtained in the 1917 crop when 18 of the Saretha and 15 of the Sunnabile group were grown. The measurements are summarized in the following table, where in each variety 20 canes were measured in detail from ground level to the young growing point.

Average cane measurements in the Saretha and Sunnabile groups.

	SARETHA GROUP		SUNNABILE GROUP	
	1916 crop 13 months old 7 varieties	1917 crop 9 months old 18 varieties	1916 crop 13 months old 10 varieties	1917 crop 9 months old 15 varieties
Length of stripped cane ...	97·2″	75·9″	92·1″	64·0″
Number of joints ...	33	26	40	27
Average length of mature joints	3·9″	3·8″	2·3″	3·0″
Average thickness of cane ...	0·67″	0·66″	0·77″	0·74″
Cane module	146	115	119	87

The length of stripped cane, from ground level to the first joint at the apex one-tenth of an inch in length, is constantly greater in the Saretha series, whereas the average number of joints is as constantly less in this group. It is not therefore surprising to note that the average length of mature joints (omitting the last eight, immature ones at the apex) is greater in the Saretha than in the Sunnabile group.

The thickness of cane has been averaged as described in the next paragraph, and there is a close approximation between the results obtained and those taken more casually, in a general survey of the whole of the canes of each variety at crop time, when they were laid out on the ground. The canes of the Sunnabile group are, on the average, thicker than those of the Saretha series. And this fact, taken with their comparative shortness, causes the cane module (length divided by thickness) to show a greater difference still. The cane module is much higher in the Saretha group, indicating that, as a class, the canes are thinner and longer than those of the Sunnabile varieties.

(2) *Ovalness and thickness in different parts of the cane.* The estimation of these is based upon the same series of measurements. To obtain the

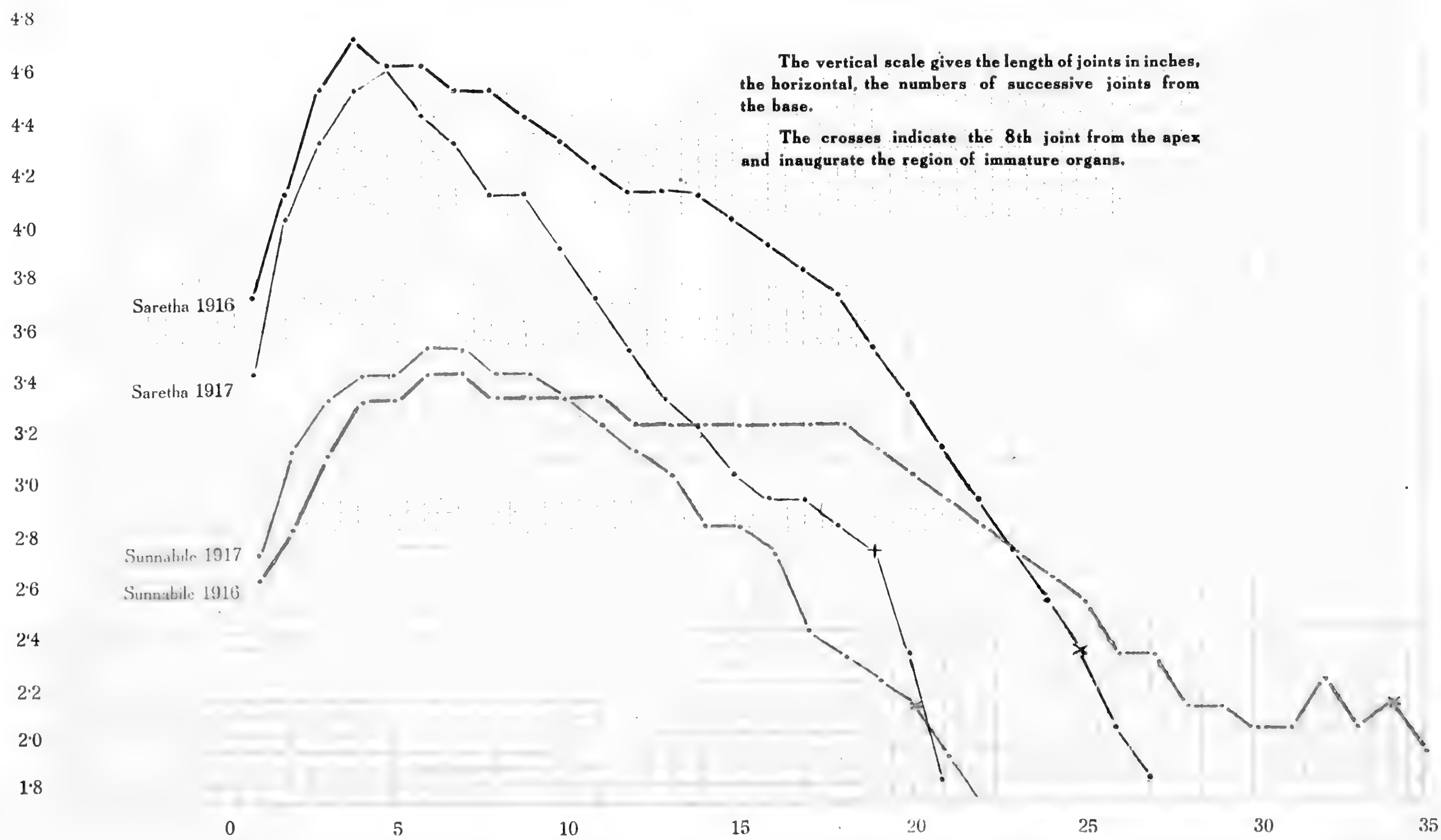
thickness, each cane is measured in three places, at the base, in the middle and at the highest mature joint, and these measurements are made, by means of calipers, in two directions, median or in the plane of the bud, and lateral, or at right angles to it.

—	Saretha Group		Sunnabile Group	
	1916 crop cm.	1917 crop cm.	1916 crop cm.	1917 crop cm.
Base	1·60-1·69	1·67-1·72	1·85-1·93	1·83-1·90
Middle	1·66-1·74	1·70-1·75	1·88-1·99	1·88-1·96
Top	1·63-1·70	1·51-1·56	1·89-2·03	1·67-1·75

Of these figures the first is always lateral, and it is seen that ovalness is a constant character, the median thickness being always greater than the lateral. There is little difference beween the two groups in ovalness, but Sunnabile canes are slightly more so than Saretha. It was noted in examining the canes that a few of the thinner Saretha varieties had almost cylindrical canes—a rather rare phenomenon—and this probably accounts for the difference in the averages. As to thickness in different parts, at nine months, the middle of the cane is thickest, then the base, while the apex is thinnest. This thinness of the apex is less pronounced in the mature canes (1916 crop) and, indeed, conditions are reversed and the apex is thicker than the base in both series. This is especially noteworthy in the Sunnabile series, where the apex is thickest in ripe canes and the base the thinnest. Thickening of the apex in Indian canes is by no means an unusual character, and it is probably the Saretha series rather than the Sunnabile which is exceptional in this respect.

(3) *The variation in the length of joint in different parts of the cane* can best be studied in the accompanying curve, in Chart II, which represent a summation of the curves of all the varieties in each group. As before, there are two sets of measurements, those of the 1916 and 1917 crops, and in each case 20 canes were taken in each variety and the length of successive joints measured from ground level to the apex, until a joint only one-tenth of an inch was reached. It will be obvious that the preparation of these curves has entailed a very considerable amount of labour. To measure the joints in a variety whose 20 canes average 32 joints each, means 640 individual measurements, and the summation series of 7 such varieties means 4,480 measurements. The Sunnabile curve of 1916 is based on 8,200 measurements, while that of the 1917 series is the result of a yet greater number of measurements.

CURVES SHOWING THE AVERAGE LENGTHS OF SUCCESSIVE JOINTS FROM BASE TO APEX, IN THE SARETHA AND SUNNABILE GROUPS IN THE 1916 AND 1917 CROPS.



The vertical scale gives the length of joints in inches, the horizontal, the numbers of successive joints from the base.

The crosses indicate the 8th joint from the apex and inaugurate the region of immature organs.

The following are the average lengths of joints of Saretha and Sunnabile in the two seasons, in inches:—

1916 crop. Saretha series. 7 varieties. 3·7, 4·1, 4·5, 4·7, 4·6, 4·6, 4·5, 4·5, 4·4, 4·3, 4·2, 4·1, 4·1, 4·1, 4·0, 3·9, 3·8, 3·7, 3·5, 3·3, 3·1, 2·9, 2·7, 2·5, 2·3, 2·0, 1·8, 1·5, 1·0, 0·5, 0·2, 0·1.

Sunnabile series. 10 varieties. 2·6, 2·8, 3·1, 3·3, 3·3, 3·4, 3·4, 3·3, 3·3, 3·3, 3·3, 3·2, 3·2, 3·2, 3·2, 3·2, 3·2, 3·2, 3·1, 3·0, 2·9, 2·8, 2·7, 2·6, 2·5, 2·3, 2·3, 2·1, 2·1, 2·0, 2·0, 2·2, 2·0, 2·1, 1·9, 1·7, 1·4, 0·8, 0·4, 0·2, 0·1.

1917 crop. Saretha series. 18 varieties. 3·4, 4·0, 4·3, 4·5, 4·6, 4·4, 4·3, 4·1, 4·1, 3·9, 3·7, 3·5, 3·3, 3·2, 3·0, 2·9, 2·9, 2·8, 2·7, 2·3, 1·8, 1·4, 1·0, 0·5, 0·2, 0·1.

Sunnabile series. 15 varieties. 2·7, 3·1, 3·3, 3·4, 3·4, 3·5, 3·5, 3·4, 3·4, 3·3, 3·2, 3·1, 3·0, 2·8, 2·8, 2·7, 2·4, 2·3, 2·2, 2·1, 1·9, 1·7, 1·3, 0·8, 0·4, 0·2, 0·1.

But these figures convey comparatively little to the mind, and they are accordingly plotted out in curves where the black lines refer to the Saretha and the red ones to the Sunnabile group. The thinner lines, in each case, refer to the nine months (1917) crop, and the heavy lines to the fuller grown 1916 crop.

(4) *Curves.* The two Saretha curves resemble one another in their high commencement, their rapid ascent and steady decline after an early maximum. The Sunnabile curves, on the other hand, start lower, have a more gradual ascent to a lower, later maximum, are more tardy in their descent and ultimately cross the Saretha curves. The curves are lower, flatter and longer in the Sunnabile series. In the Saretha series, the joints are longer at the base and rapidly increase in length to the 4th or 5th joint, after which they steadily decline to the apex. In the Sunnabile series, on the other hand, the basal joints are of average length, they become longer upwards till the 6th or 7th joint and after that gradually decrease in length, with occasional sections in which succeeding joints are of equal length. There are more joints in the Sunnabile series, so that before the immature, apical joints are reached, they overtake the Saretha series and are at the end longer than these. In the 1916 canes the 23rd joints are equal and the succeeding ones in the Sunnabile curve are longer, to the end. These general characters of the curves of joint length

in the two groups of canes should be borne in mind, because they are more or less repeated in the length curves of the leaf-sheath and lamina, and emphasize the fact that the organs in varieties of the Saretha series are longer than those in the Sunnabile group, and that the maximum development takes place earlier in the former group in all cases. The Saretha cane develops more rapidly in all its parts.

We have now at our disposal the data on which to build the ideal cane for each group, in that we know the relative length of joint in each, as well as the variations in thickness at different points, and to complete the picture a reference may be made to a preceding paragraph where the thickness of the canes in different regions is discussed. In preparing such a scheme for an ideal cane, it must of course be borne in mind that these particular curves refer only to canes of the two groups grown in the Cane-breeding Station. The growth of canes of any one variety varies considerably with climate and soil, as has been abundantly demonstrated by measurements taken at various places in North and South India. But the main differences between the two groups, shown by the measurements and curves, appear to hold good wherever the canes are grown under identical conditions.

Colour of Cane.

Observations on the colour of canes are extremely difficult, and the results are often confusing. This is not only due to the fact that the colour of a joint varies constantly with its age, but also that it is affected by the presence or absence of bloom (which is often partially rubbed off), and the blushing of parts which have become accidentally uncovered by the leaf-sheaths and exposed to the sun and weather. Furthermore, the colour of some canes is known to change considerably after being cut, while it does not in others, and the same applies to canes taken from one locality to another, where some assume a totally different tone in the new conditions. The present summary is based upon a series of observations at different stages of growth in the canes harvested in 1916 and 1917 in the Cane-breeding Station, checked to a large extent by notes on their colour in the localities from which they have been collected. The views of different observers have been collated, and these latter included general, bulk observations made in the field and detailed analyses, joint by joint, in the laboratory.

One of the first results of this study has been the discovery of a distinct cleavage, in the Saretha group, into those which develop brown markings on the stem and those that do not. The former include most of the thin, primitive canes of the Punjab and neighbouring parts of the United Provinces, whereas the latter consist chiefly of the thicker canes of Bihar, Assam, and the Peninsula. But, just as, in the Saretha and Sunnabile groups, prototypes were met with in *Katha* and *Dhaulu* of the Punjab, so here, a primitive, green cane of the Saretha group is met with growing with these, namely, *Mesangan*.

The brown canes of the Saretha series, which may be termed the Katha section, are as follows, in the order of thickness:—*Rakhra, Katha, Ramui, Lalri, Chin, Chunnee, Baraukha, Kansar, Chynia, Burra Chunnee, Saretha.* Those of the Mesangan section are *Mesangan, Saretha* (often called *Dhaur Saretha*), *Jaganathia, Khari, Hullu Kabbu, Ganda Cheni, Kalkya.* With the exception of *Mesangan*, the whole of its group are almost as thick or thicker than the thickest of the Katha section. This division of the Saretha group into two sections appears to be a real one, for, although united in most characters and opposed to the Sunnabile group in these, they differ in a number of characters, in that the Mesangan section often tends to occupy an intermediate position between the Katha section and the Sunnabile group.

In the following description of colour in the stem, it will be found convenient to consider the growth ring and the root zone separately. The rest of the joint will be studied, in succession, as to its general tone of colour, striping, black incrustations (cell outgrowths), bloom, blackening (fungus on bloom), and corky markings. The two sections of the Saretha group will, as far as possible, be taken together, differences between them being pointed out where they have been observed.

(1) *General colour.* Saretha group. Colour much obscured in the lower parts by weathered bloom, and usually dirty there. Brown, bone yellow, green or grey, occasionally light purple (brown, covered by bloom) at the base, passing upwards to yellow, glaucous green, green yellow or grey, and finally to greyish or glaucous or whitish green or even white at the top owing to excessive bloom. In the Mesangan section the browns are absent or extremely rare and, consequently, the joints are rarely light purple. The brown occurs as patches, or streaks or a general tone, and increases with age. It is therefore more marked in the lower parts of the mature cane.

Sunnabile group. Brownish stone-coloured or glaucous yellow, occasionally green, below, passing upwards to clear light stone or greenish yellow, with distinct green patches at places where the cane is bent; finally, to clear stone yellow, occasionally greenish yellow or dull green, at the top. *Putli Khajee* is a vivid grass green cane and *Ketari* has a general greenish tinge, when compared with the rest.

(2) *Striping.* The observations on this point must be considered incomplete, for, with only 10 to 20 canes examined, it is quite possible that the character may have escaped notice, and may be only very occasionally present. Striping has not been met with in any of the Katha section of the Saretha group, four out of seven of the Mesangan section have shown it, while it has been noted, usually with great ease, in fourteen out of fifteen of the Sunnabile group, *Dhaulu* alone appearing to be without it (in the observations recorded). This striping is extremely faint and consists of fine purple lines on the lower parts of the canes.

(3) *Black incrustations.* This is a marked character in all the varieties of the Saretha group and is totally absent in the Sunnabile series. It is therefore a prime character. Its nature has long been a puzzle, but a series of sections have demonstrated that it is caused by the enlargement and protrusion of certain epidermal cells whose contents assume a brown and ultimately charcoal black colour. It is an obvious roughness on the surface and hence has the appearance of an incrustation, and was at first thought to be caused by the bites of minute insects or mites; but no exuviæ of any kind have been found. It occurs typically in the groove—which is absent in the Sunnabile group—but may extend to all parts of the joint, and sometimes occurs in such masses that it gives a characteristic colouring to the whole cane, especially in its upper part. It is worth while recording that a similar black or brown incrustation is very commonly met with on the stems of *Saccharum spontaneum*, including the Dacca water form.

(4) *Bloom.* The waxy layer of the epidermis appears as thick layers of bloom in the Saretha class, especially in upper parts of the canes. It is sometimes difficult to make out the limits of the bloom band, because of the extent to which this layer of bloom descends over the joint, and it is not uncommon for the whole upper part of the cane to become grey or even white because of it. The Katha section has more bloom than the Mesangan and this adds to the differences of the two sections in colour. The bloom bands, excepting in the case noted above, are rather distinct in the group, but become obscured by weathering in the lower parts of the cane. In the Sunnabile group the bloom is not heavy and it descends over the cane surface to a much less degree. The bloom bands are not usually so conspicuous, but this is partly due to the yellow colour of the canes; in *Putli Khajee*, a bright green cane, the bands stand out very distinctly. The quantity of bloom on the canes of the two groups varies very consistently and this character is therefore one of some importance.

(5) *Blackening* is induced by the growth of a minute fungus upon the bloom or waxy layer of the outer walls of the epidermis, and is present in all canes. Although variations in blackening have not at present been studied in different localities and climates, it would be natural to suppose that, where there are thicker masses of wax on the stem, the blackening would be more widely spread and denser. This, however, does not appear to be the case, although there is a considerable difference in its occurrence in the Sunnabile and Saretha groups. In the varieties of the latter, with large quantities of bloom, blackening is fairly common, but it is rather faint and diffused, as if the cane surface had been lightly smudged with soot. On the other hand, in almost all of the Sunnabile group the blackening, whether abundant or comparatively scarce, is intense and sharply circumscribed, contrasting markedly with the bright yellow stems. Blackening of the stem is thus a character of some use in separating the two groups.

(6) *Corky markings.* These are, as already intimated, essentially splits in the epidermal layers, although it usually requires a lens to determine this fact. They were called " ivory markings " in Memoir 1, but the present term appears to be more suitable. It appears possible that the locality in which a cane is grown may have considerable influence on their development, in that canes, which were noted as having very few corky markings in their native habitat, have developed them copiously at Coimbatore and *vice versâ.* Corky markings cannot therefore usually be considered a character of much importance in classification. When we remember, however, the black incrustations which are so uniformly present in the Saretha series and as constantly absent in the Sunnabile varieties, it is worth while examining the corky markings of the two groups more carefully, as in each case we have to do with the epidermal layer of the cane stem. A careful study of the corky markings, in the different varieties comprised in the two groups, has convinced me that there *is* a difference in their mode of development, although this is not easy to express. For one thing, these markings are, with few exceptions, much more abundant and striking in the members of the Sunnabile group. And there seems to be a difference in their mode of development, as will be seen from the following. There appear to be three different modes of occurrence in the cane varieties under discussion.

(*a*) Long, thick, parallel lines, rather widely separated and extending from the base of the bloom band about two-thirds down the length of the joint. This form is practically universal in the Sunnabile series although not noted in the Saretha varieties. It not infrequently happens that, in a cane with comparatively few corky markings, a joint is met with high up, which is simply crowded with them, but the meaning of this is not apparent.

(*b*) Short, fine, wavy, closely packed markings, occurring hereand there over the joint, and those at the top sometimes passing into the bloom band. This form is more frequently met in the Saretha series, although it also occurs between the strong parallel lines in some Sunnabile varieties.

(*c*) Short, irregular splits, obvious to the naked eye as such, which appear as cracks through the bloom band. These cracks are unlike the corky markings mentioned above, but are presumably of the same nature, in that the other forms sometimes pass into them. They are present in many varieties of both series. *Hotte Cheni* has been singled out as a form in which all of these forms of corky markings are abundant.

(7) *The colour of the growth rings and root zones*, like the bloom band, sometimes adds considerably to the general effect of the cane colour. Thus the strong white bloom bands, contrasting with the brilliant green of *Putli Khajee*, give it a very striking appearance. In the same way the effect of the colour in the growth rings and root zones depends on the general tone of the cane, and the bright green colour of these bands in *Putli Khajee* makes it difficult to distinguish them. The colour of the growth rings depends a good deal on exposure, the general tendency being for them to assume a darker colour in exposed joints. This is especially noticeable in the brown canes of the Katha section of the Saretha series, where the colour is usually strongest at the upper and lower margin of the ring. This dense browning of the growth rings adds considerably to the general brown effect of the cane colour. The colour at this part of the joint is usually rather lighter in the green canes of the Mesangan section. but the contrast with the glaucous green or glaucous yellow of the rest of the joint often renders them distinct. In the Sunnabile group, on the other hand, the growth rings are distinctly fainter, being often rather brownish yellow than brown. They are usually most clearly seen in the middle of the cane, where they contrast sharply with the clear stone yellow, but they are obscured below by their similarity to the general cane colour. In the younger parts, the growth rings assume a greener tinge. This is especially the case in the canes of the Katha series, where they are often narrow and distinctly depressed. They are green or brown green in the young joints of the Mesangan section and often more brown than green in the Sunnabile group, where also the depressed character is less evident. The root zones are not usually very conspicuous, often taking on the colour tone of the rest of the cane. They are, however, generally paler or yellower. They may be

described as brownish cream below, gradually becoming a lighter cream colour and often bloomed in the young joints at the top. The root zones of the Sunnabile group appear generally to blush a bright green on exposure, and are then very striking, as the eyes remain a clear yellow. There are traces of this green blushing in the Mesangan section of the Saretha group, but it appears to be absent in the brown canes of the Katha section.

Joint Characters.

The characters of the joint have been largely included in the preceding description of the cane as a whole. Such are the number of joints in the cane, their average thickness and length and the thickness and length in different parts, the colour of the joint, including bloom band, root zone and growth ring. A great deal of time has been spent in observations in the shape of the joint and descriptions have been recorded from time to time on the aspect of the joint both in the median and lateral planes. But, although it is felt that there are differences, these are not very striking or easy to put down clearly. For one thing, the shape of the joint varies a good deal with its length, differences in diameter at various points being emphasized in shorter joints, and this introduces a further disturbing element in the analyses. There are, however, a few other points, not yet dealt with, in which joint differences have been noted in the varieties of the Sunnabile and Saretha groups.

(1) *Groove.* The presence or absence of a groove or depression immediately above the bud, often considered of minor moment, turns out to be a character of first importance in our comparison. The groove is always present or indicated in the Saretha group, while it has at present never been met with in any variety of the Sunnabile group. The groove varies, it is true, a great deal in its development, sometimes extending distinctly from the bud to the bloom band above, and at others merely indicated by a flattening of the surface or a small depression above the bud, the rest of the joint being evenly rounded. It is worth while drawing attention again to the black incrustations already described, as there seems to be a distinct connection between these and the groove, and both are characteristic of Saretha canes.

(2) *Circlet of hairs.* The vestiture of the leaf scar appears to offer useful distinguishing characters. This might have been expected, because we have elsewhere been led to consider the circlet of hairs, with its attendant scar band of felt, as suggesting a primitive relationship. This circlet of hairs is well developed in and characteristic of all the members of the Saretha series. There is some evidence that its development varies to some extent with climatic

the eyes in the latter are uniformly disposed in two or three rows. The growth rings are narrower in the Sunnabile series and the root zones are wider, and often contain more rows of root eyes, the lowest of which is separable from the rest and has eyes of a considerably larger size.

Bud Characters.

In comparing varieties of sugarcane, one always turns to the bud, as an organ in which it is safe to find differences in one form or another. The buds have therefore been subjected to a careful scrutiny in all the varieties under consideration. In both classes they are distinctly small, often not exceeding the growth ring in length and, consequently, such differences as exist must be packed up into small compass. Furthermore, on separating the Katha (brown) from the Mesangan (green) sections of the Saretha group, the latter is found to be transitional between the Katha section and the Sunnabile series, and this introduces complications which were not understood until the two Saretha sections had been separated. In the nature of things, the study of such small buds has tended to become microscopic, and such differences as have been noted are likely to be less useful in separating the two classes in the field. The comparatively dry climate in which the canes are grown at Coimbatore does not admit of much shooting of the buds, and this character is generally absent, excepting at the tops of canes which have flowered; and, as we have seen, the Saretha group flower much more freely and regularly than the Sunnabile series. This shyness of shooting is, however, of great advantage for our general study, in that the buds, although mature, are resting.

(1) *Bursting.* In the Saretha group, the bursting of the buds is generally apical, as indicated by the convergence of the veins of the lowest bud scale. Occasionally buds show dorsal or more frequently high dorsal bursting, but these are usually low down on the cane and are practically confined to the Mesangan section. In the Sunnabile group the bursting of the buds is dorsal, with occasional exceptions in the upper part of the cane.

(2) *Size.* All the varieties, excepting *Mojorah,* have small buds. They are smallest in the thin canes of the Katha section, while the thicker members of the Mesangan section and the Sunnabile group have practically equal sized buds. The average variations in length are as follows :—Katha section 0·17″—0·3″, Mesangan section 0·22″—0·32″, Sunnabile group 0·22″—0·32″, from which average lengths of 0·23″, 0·27″, 0·27″ may be deduced. This seems to indicate a close relationship between thickness of cane and length of bud, but a study of the individual varieties shows a fair number of exceptions, and it cannot be

taken as a general rule. The relation between the width of root zone and the length of bud is, however, more instructive. The following are the proportional figures—root zone to bud :—Katha section 0·22″ : 0·23″, Mesangan section 0·25″ : 0·27″, Sunnabile group 0·34″ : 0·27″. In the latter group the buds appear to be shorter than in the Saretha series as a whole and this appearance is explained by their frequent failure to reach the growth ring in the lower parts of the cane. The bud in the Sunnabile group is also lengthened by the addition of the flanges, which often form a broad ring round the apex, which is not the case in the Saretha series. In the Saretha group, the buds usually reach the growth ring in the lower part of the cane and exceed it in the upper. In the Sunnabile series the bud often fails to reach the growth ring below, and comparatively rarely exceeds it above.

(3) *Form.* In form the buds of the different members of the two groups vary a good deal. On the whole those in the Saretha group are more pointed and may often be described as ovate, whereas (partly because of the border flanges) in the Sunnabile series they are more oval. In both groups the buds are occasionally truncate and in the Sunnabile varieties sometimes even emarginate at the apex.

(4) *Colour marks.* The buds in both series are frequently marked by dark brown colorations. These marks are found more frequently at the base and along the edges of the scale in the Saretha group, whereas in the Sunnabile varieties it is the flange surface which is usually browned and this causes the colour marks to converge upwards like the head of an arrow.

(5) *Place of origin.* All the buds arise at the leaf scar, at any rate in the lower part of the cane, and there is no trace of cushion. There is, however, a steady tendency in the Sunnabile series for the upper buds to arise a little above the scar. The Mesangan section is transitional in this character to the Katha section, where this higher origin of the bud has not been observed. It will be remembered that the high origin of the buds and the appearance of a cushion are characteristic of the Pansahi group of canes.

(6) *Flanges.* There are marked differences between the two groups in the flanges of the lowest scale of the bud. In the Saretha group they are usually narrow, their outline is not readily traced and is often obscured by bristles. In the Sunnabile group they are, on the other hand, well seen, being fairly broad and often free of bristles, and forming a broad border round the apex of the bud.

(7) *Bristles.* Bristles are fairly well developed and sometimes abundant in the Saretha group but are sparse, irregular or almost absent in most of the Sunnabile series

(8) *Basal patches.* These are well and typically formed in most of the Saretha series, often consisting of closely parallel, curled or crisped patches of shining white hairs, on each side of the lower part of the bud. They are, with few exceptions, poorly developed in the Sunnabile series, where they are often indicated by a pubescence or roughness in which it is difficult to make out individual hairs. In one or two varieties, however, they are well developed and conspicuous, as in *Putli Khajee* and, to a less extent, in *Bansi.*

(9) *Minute black hairs.* These were first observed when comparing *Katha* with *Dhaulu* of Gurdaspur. Their presence or absence is found to be a general character for the two groups of which these varieties are the prototypes. They are practically absent in the Katha section, generally present in small numbers in the Mesangan group, and usually abundant in all parts of the bud in the Sunnabile series.

The study of the buds in the Saretha and Sunnabile varieties has led us into a series of minute and apparently unimportant characters. It should here be emphasized that the bud is practically an epitome of the vegetative shoot of the cane, and there is little doubt that the descriptions given err, not on the side of the minuteness, but in being less microscopic than they ought to have been. The excuse for this is that there has not been sufficient time to carry the observations further, and that, perhaps, the more general descriptions recorded above will serve the purpose of this paper. We have seen in each character examined that differences have been recorded, whether in bursting, size, colour marks, origin, flanges, or hairs on the bud, and this has justified the large amount of time spent on this part of the cane plant.

Leaf Sheath.

The leaves of the sugarcane offer a perfect mine of characters whereby the different varieties may be distinguished, and there is little doubt that many more would reward a patient study in other directions. There is evidence that microscopic features such as the siliceous protrusions from the epidermal cells, the numbers and arrangement of the stomata, and so forth, would offer differences and, doubtless, a study of the anatomy of the leaves would add to these. The characters dealt with here are macroscopic and hardly require the use of a low-powered hand lens. With the exception of the detailed measurements given later, most of them can be readily observed in the field. The leaf sheath is treated separately from the lamina and the ligule and ligular processes are included in it. The following are its more obvious characters.

(1) *Colour.* This is complicated by the fact that a large portion of the leaf sheath in the growing shoot is covered by those lower down on the stem.

The colour of this covered portion is usually yellow or green or a mixture of the two. Bloom is usually absent in this covered portion. When the leaf sheath is exposed, it assumes some form of green colour, this depending largely on the quantity of bloom present. Differences occur in the varieties of each group, and it has not been found possible to introduce uniformity in the groups. In the Katha section the colour of the exposed leaf sheath is a dark bluish green, turning greyish green where there is bloom. In the Mesangan section the colour is grey green to full green, while in the Sunnabile group there is a good deal of variation but the greens are often light in tone.

(2) *Bloom.* A similar lack of uniformity in the members of each group is met with in the quantity of bloom on the leaf sheath. Katha and Mesangan sections show hardly any bloom, and, in the former especially, the exposed part of the sheath is frequently shiny. Bloom is slightly more developed in the members of the Sunnabile group and there is a good deal in *Bansi*. Small patches of bloom are not infrequently present on what are called below "transverse bars," where small swollen cross veins pass from one longitudinal vein to the next, and the bloom patches are sometimes the only indication of their presence.

(3) *Scarious border.* When the leaf sheath becomes old, its edges turn a light brown or straw colour. This sometimes takes place very early in the life of the sheath, and shows up clearly against the general green colour. I have termed it the *scarious border*. It is especially present in all the members of the Sunnabile group, where even the youngest leaf sheaths exposed already show signs of withering at the edges. In the Katha section the scarious border is absent in the young shoot, while in the Mesangan section it shows signs, here and there, of commencing early but to nothing like the extent in the Sunnabile series.

(4) *Colour of young edges.* Besides the scarious border, there is another respect in which the edge of the leaf sheath exhibits distinguishing characters. It is quite possible that the two colorations are connected, but they are distinct phenomena and are frequently present at the same time in a sheath. The edge of the young leaf sheath has a different tone of colour to the rest. In the Katha section it is light coloured, sometimes white, and often transparent. It is also light coloured in the Mesangan section. In the Sunnabile group, on the other hand, the young edge is often of a red brown colour as far up as it can be seen, while this colour always makes its appearance very early. It is sharply marked off from the adjoining green, and is frequently limited outwards by a white border.

(5) *Tuft of hairs.* This is met with, in varying degree, in all canes. It arises in the two upper angles of the leaf sheath where it merges into the lamina, and not infrequently extends downwards on the edge of the sheath and upwards along the lamina. It is sometimes very conspicuous and silky white. This tuft of hairs is not very greatly developed in either group. It is small in the Katha section and is not usually decurrent along the edge of the sheath. It is meagre in the Mesangan section, slightly descending or not, but descends freely in *Hullu*. In the Sunnabile group the tuft of hairs is small to moderate, it is usually decurrent and sometimes very freely so.

(6) *Spines on the back.* Siliceous hairs, frequently adpressed and always directed upwards, are a marked feature of the leaf sheath in many varieties of cultivated and wild Saccharums, and, indeed, are sometimes a factor to be reckoned with in harvesting the canes. They appear to be totally absent in both sections of the Saretha group, but are characteristic of members of the Sunnabile series. One of the two specimens of *Khadya*, however, received from Bombay, appears to be glabrous. The spines are usually concentrated in a small, dense group in the middle of the back of the sheath, rather high up, but have been occasionally recorded near the upper part of the two edges. Occasionally they are not visible, but can be quickly detected by passing the hand gently down the sheath.

(7) *Venation.* This is often well marked in the leaf sheath, and consists, typically, of fine, parallel lines extending down its whole length. They are particularly well seen in the covered part of the sheath, forming dull lines on the yellow background. In the uncovered portion, they are especially well seen in the Katha section, where they are clear and rather fine and numerous. They are moderately distinct in the Mesangan section, but are irregular, often thickish, and indistinct in the Sunnabile series.

(8) *Transverse bars.* These, as stated above, are also veins, forming cross connections between the longitudinal ones, chiefly in the upper part of the leaf sheath. They are typically present in *Saccharum spontaneum* and seedlings obtained by crossing it with cultivated canes. They are often thick and swollen and present the appearance of having been flattened by the pressure of the leaf sheath. Varieties in the Katha section usually have them well developed, although they are not always very distinct, and sometimes only represented by strong patches of bloom. The transverse bars are less marked in the Mesangan section and are usually absent in Sunnabile varieties or merely indicated by small splashes of darker green.

It is perhaps worth while drawing attention here to the continued resemblances between the Katha section of the Saretha group and the wild *Saccharum spontaneum*, and also to the transitional position so often seen of the Mesangan section between the Katha and Sunnabile varieties. This would suggest a line of evolution along which the cultivated sugarcane has been selected, having its origin in a primitive form somewhat similar to a Katha variety, and passing through some such form as a Sunnabile variety, already differentiated to a certain extent and in some respects approaching the higher forms of cultivated canes.

(9) *Ligular processes.* These are upward scarious extensions of the edges of the leaf sheath on either side of the base of the lamina, provided with a rudimentary fibrovascular system, and are usually most prominent on the inner margin of the sheath. They are clearly connected with the ligule which passes into them at its edges and this suggests that the ligule is morphologically an overlapping portion of the leaf sheath at its point of junction with the lamina. The Katha varieties usually have well developed ligular processes. They occur as long, sharp teeth, usually reaching an inch in length and occasionally extending to double that length, when they form a striking and characteristic feature. They are not usually present in the Mesangan section, although *Ganda Cheni* has been noted as having occasional ligular processes up to half an inch in length. In the Sunnabile group they are reduced to the usual blunt angle, which soon becomes scarious, owing to the notching in the margin where the sheath and lamina unite.

(10) *Ligule.* This is treated here because of the possibility indicated above of its being part of the leaf sheath, and its intimate relation to the ligular processes. It is narrow in both groups, although varying a little in this respect in the Mesangan section and the Sunnabile group. In the Katha section the ligule is usually flat or slightly depressed in the middle of its upper margin and deeply depressed on its lower. In the middle it is distinctly broader than at the edges and there is often a small triangular or diamond-shaped portion here which is termed a *lozenge*, but this is not always present. The ligule in the Mesangan section is flat or arched above and deeply depressed below. There is usually a lozenge, although this is sometimes absent. The typical ligule of Sunnabile varieties is arched above, often with a flat depression in the middle and slightly depressed below. The two margins are often nearly parallel and the lozenge is thus absent.

The setæ on the upper margin of the ligule present more striking differences, as is often the case with hairs and hair-like structures. They are extremely small in the Saretha group, irregular, sparse and not infrequently deciduous or absent in the Katha section, but occasionally more abundant in the Mesangan varieties. In the Sunnabile group they are strongly developed and are usually long, and there are often a few scattered, very long setæ, standing out in the middle of the ligule.

(11) *Clasping stem at base.* In the varieties in the Saretha group the leaf sheath at its base clasps the stem more widely, although the differences are not great. This is in accordance with observations made when comparing *Katha* and *Dhaulu of Gurdaspur.* The extent of encirclement is expressed in terms of the circumference of the stem, thus, 1·00 would indicate that the leaf sheath just encircles the stem once and 1·50 would show that it goes one and a half times round. The figures obtained for 8 Saretha and 10 Sunnabile varieties measured in 1916 are 1·45 and 1·35 respectively—roughly the sheath passes one and a half times round in Saretha and one and one third in Sunnabile. In the larger series examined in 1917 the difference is reduced, although it is in the same direction. The figures are 1·46 for Saretha and 1·39 for Sunnabile groups. The Katha section clasps the stem most widely, 1·48 being its figure: the Mesangan section gives the figure 1·43 and the Sunnabile group 1·39.

(12) *Width at base.* The Sunnabile varieties, in spite of less encirclement of the stem by the base of the sheath, have wider sheath bases, and here too the Mesangan section is intermediate between the Katha section and the Sunnabile group. The average widths of the base of the leaf sheath are, for 1916, Saretha group 3·09″, Sunnabile group 3·37″; for 1917, Katha section 2·79″, Mesangan section 3·16″ and Sunnabile group 3·26.″

(13) *Width at apex.* Here too, the sheaths are wider in the Sunnabile group, falling into line with a greater thickeness of stem and greater width of leaves. The 1916 measurements show averages of 1·23″ for Saretha and 1·34″ for Sunnabile groups: in 1917 the figures being 1·22″ and 1·30″ respectively. But a variation is to be noted in the Mesangan section, which is not in this case at all intermediate between the Katha section and the Sunnabile group. The width at the apex of Mesangan section averages 1·40″, that of Katha section 1·11″, while the Sunnabile group is intermediate with 1·30″.

(14) *Length of mature leaf sheath.* The length of leaf sheath appears to differ less definitely in the Saretha and Sunnabile groups than that of joint and lamina. In fact, while it is distinctly longer in Saretha in the 1916 measurements of mature canes, little difference has been noted in those of 1917. This may be due to the fact that the maxima are rather late and that, in the immature canes of the latter crop, the full length of the leaf sheaths had not

been obtained, but this interpretation is open to doubt. The results of the measurements are as follow :—1916, based on averages of 20 canes of each variety, Saretha 12·4″, Sunnabile 11·6″ : 1917, measurements of 20 canes, Saretha 11·9″, Sunnabile 11·9″ : measurements of 10 canes in the laboratory, Saretha 11·95″, Sunnabile 12·02″. The agreement of the two 1917 measurements is very close.

(15) *Module.* This empirical expression is obtained by dividing the average length by the greatest width, that at the base. It is designed to give some idea of the shape of the leaf sheath and is included because it has been found so useful in the cane and the lamina. We have seen that the sheath is wider at the base in the Sunnabile group, while the length of the sheath, longer in the 1916 results in Saretha, is practically the same in the two groups in 1917 measurements. It is not surprising that the Sunnabile sheath has a lower sheath module. Also that this module is higher in the Mesangan section than in the Sunnabile group. The figures are, for 1916, Saretha group 4·0 ; Sunnabile 3·5 ; for 1917, Saretha 4·1, Sunnabile 3·7—figures which show sufficient agreement. The figures in the Katha and Mesangan sections of the Saretha group, in 1917, are 3·8 and 4·4 respectively.

(16) *Number of sheaths per cane.* The sheaths are, as might be expected, more numerous in the Sunnabile group, although there is little difference in the poorer grown 1917 crop. The figures were, in 1916, Saretha 35, Sunnabile 45 ; in 1917, Saretha 29, Sunnabile 30, the figures for the Katha and Mesangan sections being 30 and 28 respectively.

(17) *The variations in sheath length in different parts of the cane.* As in the length of joint, the length of sheath was measured by foot rule divided into tenths of an inch, in 20 canes of each variety, both in 1916 and 1917. In 1916, 7 varieties of the Saretha group and 10 of the Sunnabile were measured, and the canes were over-ripe. In 1917, the number of varieties were 18 and 15 respectively, but some of these have been ruled out, in that it was not possible to obtain fair averages because of the large number of missing sheaths. It is natural that differences would be lessened in the latter case and, perhaps, more reliance is to be placed on the 1916 results. The following are the averages obtained in the 1916 measurements, the lengths of sheaths being recorded, from base to apex, in inches.

1916. Saretha group. 12·2, 12·6, 12·9, 13·0, 13·2, 13·3, 13·2, 13·2, 13·1, 12·9, 12·7, 12·6, 12·5, 12·4, 12·3, 12·3, 12·2, 12·2, 12·3, 12·3, 12·0, 11·9, 11·8, 11·6, 11·5, 11·4, 11·2, 11·0, 10·8, 10·1, 8·8, 5·2, 1·3, 0·3, 0·1.

Sunnabile group. 11·1, 11·3, 11·5, 11·5, 11·7, 11·6, 11·7, 11·8, 11·9 11·8, 11·8, 11·8, 11·8, 11·7, 11·6, 11·8, 11·9, 12·0, 12·1, 12·1, 12·0, 12·0, 11·9, 11·9, 11·8, 11·7, 11·7 11·5, 11·3, 11·3, 11·3, 11·1, 10·9, 10·7, 10·8, 10·9, 10·7, 10·3, 9·6, 7·7, 3·3, 0·8, 0·2, 0·1.

These figures plotted out on curves, show some interesting characters (Chart III).

(18) *Curves.* In the Saretha group, in 1916, the curve commences high, ascends steeply to an early maximum, then descends steadily with a slight indication of a second maximum half way down, and the curve leaves the paper considerably sooner than that of the Sunnabile group. The curve of the latter commences low, rises gradually to a first maximum and attains its highest point very late. It crosses the Saretha curve about half way along its course and then descends steadily but less steeply than in Saretha and shows an indication of a final small maximum before it leaves the paper. The crosses mark the position of the eighth sheath from the end, and those beyond may, for convenience, be considered all immature and need not concern us. The curve in Sunnabile is much longer, the number of sheaths before the last eight being 37 as against the 27 in Saretha. Comparing the two curves, that of Sunnabile is longer, lower, flatter, characters which we noted in the curves of the lengths of joint in the identical sets of canes. In fact, there is considerable similarity between leaf sheath and joint length curves in any cane although this resemblance is not close enough to establish a definite correlation between joint and leaf sheath.

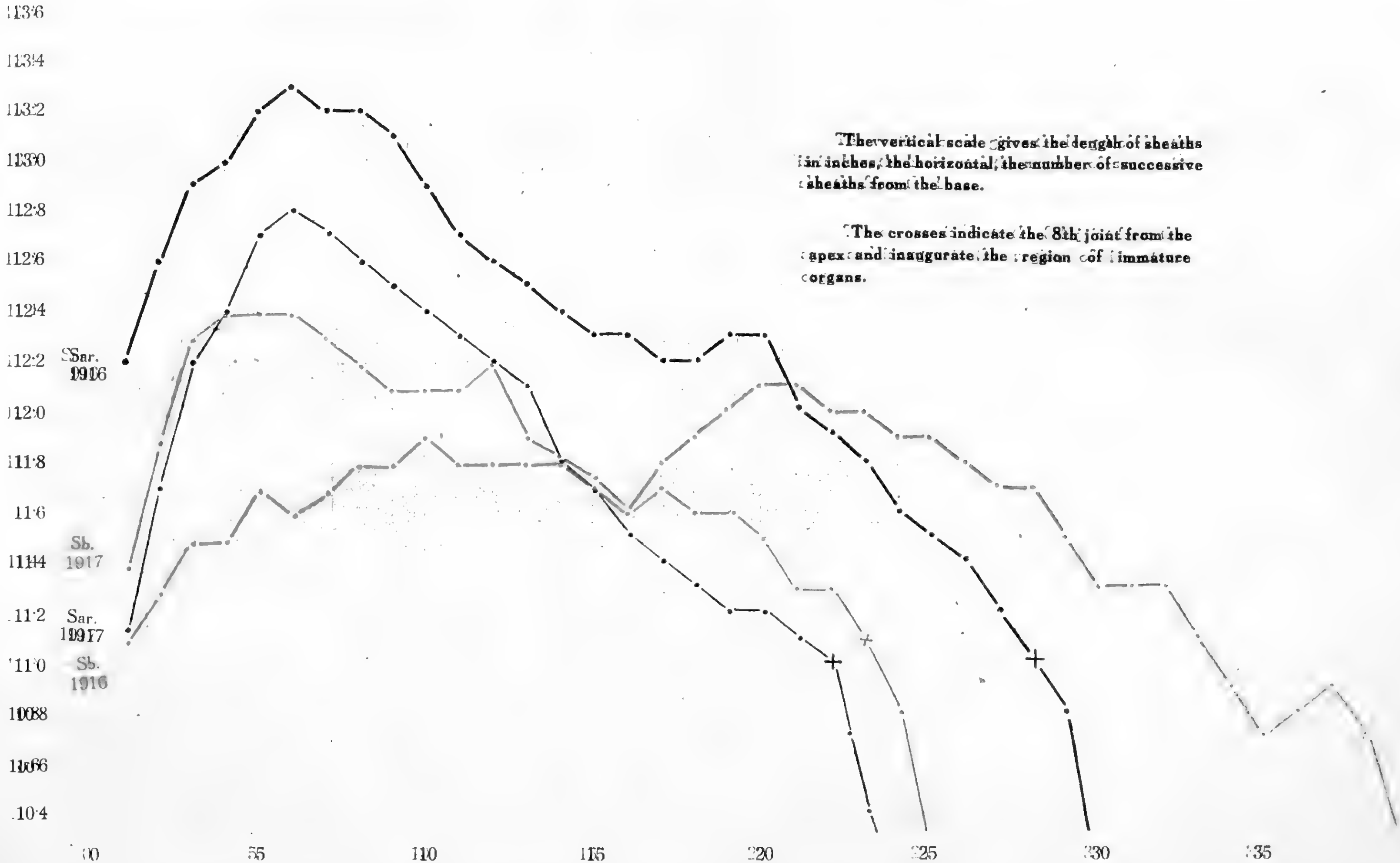
The 1917 measurements were taken in a much larger number of varieties in each group and the canes were measured when only nine months old, to ensure the presence of sheaths and leaves in good condition. But, unfortunately, the growth was poor in most of the varieties and especially so in one or two—being nothing like so good as in the previous year. The number of joints and consequently of leaf sheaths were much below the average and, generally, normal differences were much reduced. The following are the figures obtained in 1917 for lengths of successive leaf sheaths.

Saretha group ; averages of 18 varieties with 20 canes in each variety in inches :

11·1, 11·7, 12·2, 12·4, 12·7, 12·8, 12·7, 12·6, 12·5, 12·4, 12·3, 12·2, 12·1, 11·8, 11·7, 11·5, 11·4, 11·3, 11·2, 11·2, 11·1, 11·0, 10·4, 9·7, 8·5, 5·1, 1·3, 0·2, 0·1.

CHART III.

CURVES SHOWING THE AVERAGE LENGTHS OF SUCCESSIVE LEAF SHEATHS FROM BASE TO APEX, IN THE SARETHA AND SUNNABILE GROUPS IN THE 1916 AND 1917 CROPS.



Sunnabile group ; averages of 15 varieties :

11·4, 11·9, 12·3, 12·4, 12·4, 12·4, 12·3, 12·2, 12·1, 12·1, 12·1, 12·1, 11·9, 11·8, 11·7, 11·5, 11·7, 11·6, 11·6, 11·5, 11·3, 11·3, 11·1, 10·8, 9·7, 6·2, 2·1, 0·6, 0·2, 0·1.

Upon comparing the curves plotted from these figures, the first matter for notice is their extreme shortness, the Sunnabile excess number being reduced to one sheath, as was the case in the joints. The Sunnabile curve is, it is true, lower, flatter, longer, as was the case with the 1916 curves, it reaches a lower maximum than the Saretha and crosses it about half way along its course ; but there is far more resemblance between the curves of the two groups in 1917. In one particular is this especially noticeable. The three lowest sheaths are actually longer in the Sunnabile group, instead of being much shorter, and the initial rise in length is much steeper than was to be expected. This may be due to the conditions of growth, which may have affected the varieties of the two groups differently, but it is only fair to state that these initial sheaths were often absent or not susceptible of measurement, and the averages for the first few are accordingly much less reliable. Nevertheless the 1917 curve for the Sunnabile varieties is rather steeper than usual in this group and approximates in this respect to that of the Saretha group. Considering all things, more reliance is to be placed on the curves obtained in 1916, and the general differences noted in it hold, in a diminished degree, with those obtained in the immature canes of 1917. In the circumstances detailed above, I should feel inclined to build up the ideal cane rather from the 1916 curve, with the proviso that the differences between the length of leaf sheath in different parts of the canes in the two groups may be somewhat exaggerated in these curves.

Curves have been prepared for the Katha and Mesangan sections of the Saretha group. These show that the latter section, consisting of larger canes, only resembles the Sunnabile series in the number of leaf sheaths. In other respects the curve approaches nearer to that of the 1916 measurements in the Saretha group, it is higher and steeper than that in the Katha section.

Lamina.

The leaf blade or lamina has been subjected to a rather more exhaustive study than the leaf sheath, as it presents details of form which are absent in the latter. In no part of the plant is it more evident that a real difference exists in the two groups in the length and shape of organs, and the elaboration of this point has taken a good deal of time. For one thing, the differences between the

1916 and 1917 crops , so noticeable in the joint and leaf sheath, appear to have had less play in the lamina, and the similarity of the figures obtained in different observations is sometimes very striking. The persistence of differences in roughness, hairiness, venation, etc., would tempt one to make a series of observations with stomata, but this has not been accomplished, yet the surmise may be hazarded that one more useful distinguishing character may be expected from a study of these. The characters studied naturally divide themselves into those which are capable of measurement and those which are not. The latter, which are less complicated are taken first.

(1) *Channelling.* This infolding of the leaf at the base is a marked character of the Saretha group, in which it resembles the wild *Saccharum spontaneum.* The channelling is chiefly developed in the midrib but is not confined to it, and the lamina takes a more or less distinct part in all the varieties of the group. In the Sunnabile series the channelling is not usually so marked and it is confined to the midrib, while the lamina is flat to the base.

(2) *Callus.* This term is applied to the region of the lamina on each side of the midrib just above the ligule. It corresponds with the transverse marks of lighter colour on the back of the leaf. This part of the leaf differs a good deal in the two groups under discussion. The callus is not well marked in varieties of the Saretha series, it is usually covered by waxy outgrowths and is often puberulous or pubescent. In the Sunnabile group, it is more marked, often very distinct on each side, sometimes raised. It is usually covered by a dense or shaggy pubescence and sometimes has long hairs at the sides nearest the leaf edge. A study of the transverse marks, on the other hand, has not yielded any appreciable differences in the two groups.

(3) *Scabrous feel.* This is often a marked character at the tip of the leaf. It is especially noticeable on the upper, ventral aspect, in the members of the Sunnabile group. If one passes the fingers downwards in this region, the roughness of the leaf, depending on small siliceous points projecting upwards, reminds one of shagreen. There is also considerable, but less marked, roughness on the lower or dorsal side of the leaf tip. One marked exception, however, occurs, the leaf ends being practically glabrous in *Putli Khajee.* This is in fact similar to the Saretha group generally. The scabrous feel is very slighs or absent above in this group and the roughness below is slight. In this character of the leaves the Saretha series, as usual, resembles *Saccharum spontaneum* in such specimens as have been examined.

(4) *Serrature.* Here also the greater hairiness or harshness of the leaves is noticeable in the Sunnabile group. With the exception of *Putli Khajee,* the serrature of the leaves is strong, harsh and persistent. In the Saretha series (as in *Saccharum spontaneum*), it is usually soft, fine and more or less deciduous. In the Sunnabile series the leaves, thus, have spines on the back of the sheath, rough callus, strong scabrous feel at the leaf tip and harsh persistent serrature, while the ligular setæ are strong and frequently long: in the Saretha series the leaves are glabrous or almost so in all these respects, and one would feel tempted to suspect a correlation between the development of strong hairs in all parts of the leaf. But the anomalous position of *Putli Khajee* suggest caution. It has spines on the back of its leaf sheath while its serrature agrees with that of the Saretha varieties. So also, in one of the two specimens of *Khadya* received from Bombay the leaf sheath is glabrous, and in the other it is spiny, and the glabrous-sheathed form agrees in other respects with the rest of the Sunnabile group.

(5) *Number of laminas.* As in the sheaths there are many more laminas in the Sunnabile group in 1916, but about the same in the two groups in 1917. The numbers in 1916 are, in Saretha 36, and in Sunnabile 45, whereas in 1917 the respective numbers are 29 and 30.

(6) *Length of lamina in different parts of the cane.* Here, as in the sheath, we have been led to consider the 1916 measurements as more in keeping with the known characters of the groups. The following are the figures obtained from the same canes which were measured for length of joint and length of leaf sheath :—

Average length of successive laminas, 1916, in inches :

Saretha group.	37, 39, 42, 45, 48, 51, 52, 53, 54, 55, 56, 55, 56, 56, 56, 57, 57, 57, 57, 56, 57, 57, 57, 57, 56, 55, 55, 54, 54, 53, 51, 48, 45, 37, 26, 17, 8.
Sunnabile group.	30, 33, 36, 38, 40, 42, 43, 44, 45, 46, 46, 46, 47 47, 47, 47, 47, 47, 47, 47, 47, 48, 48, 48, 48, 48, 48, 48, 47, 48, 47, 47, 47, 46, 45. 45, 44, 43, 42, 40, 38, 35, 24, 20, 15, 8.

(7) *Curves.* These figures have been plotted out in curves as usual (Chart IV). The curve in the Saretha group, in 1916, is higher, shorter, steeper at the ends than that in the Sunnabile group, agreeing in these respects with the curves of length joints and leaf sheath. The curve starts higher in the Saretha group

and ascends more rapidly. The maximum is reached in 15 joints in Saretha, against 21 joints in Sunnabile, and is 9″ greater. A comparison, however, of the lamina curve with those of joint and sheath, shows certain fundamental differences. With steep rise and fall the lamina curve remains more or less horizontal at the top and thus presents a generally flattened appearance, which appears to be characteristic of all mature lamina curves. Once the region of full grown leaves is reached, there is little variation in length from joint to joint, rendering difficult all attempts at finding correlations between the lengths of leaves and other organs in different parts of the canes. In both the joint and sheath curves, on the contrary, the rise is very rapid at first and, once the maximum has been reached, a continuous descent follows. The sheaths and joints are longest in the young cane and become continuously shorter as growth proceeds.

A study of the 1917 crop, in which a considerably larger number of varieties were studied in each group, bears these remarks out. But, as in the case of joint and sheath, the effect of immaturity and poorer growth is shown, and the curves are much lower and shorter and, so to speak, cut off in the middle, because of the fewness of organs developed. The following are the measurements obtained :—

Average length of successive laminas, 1917, nine months old, in inches:

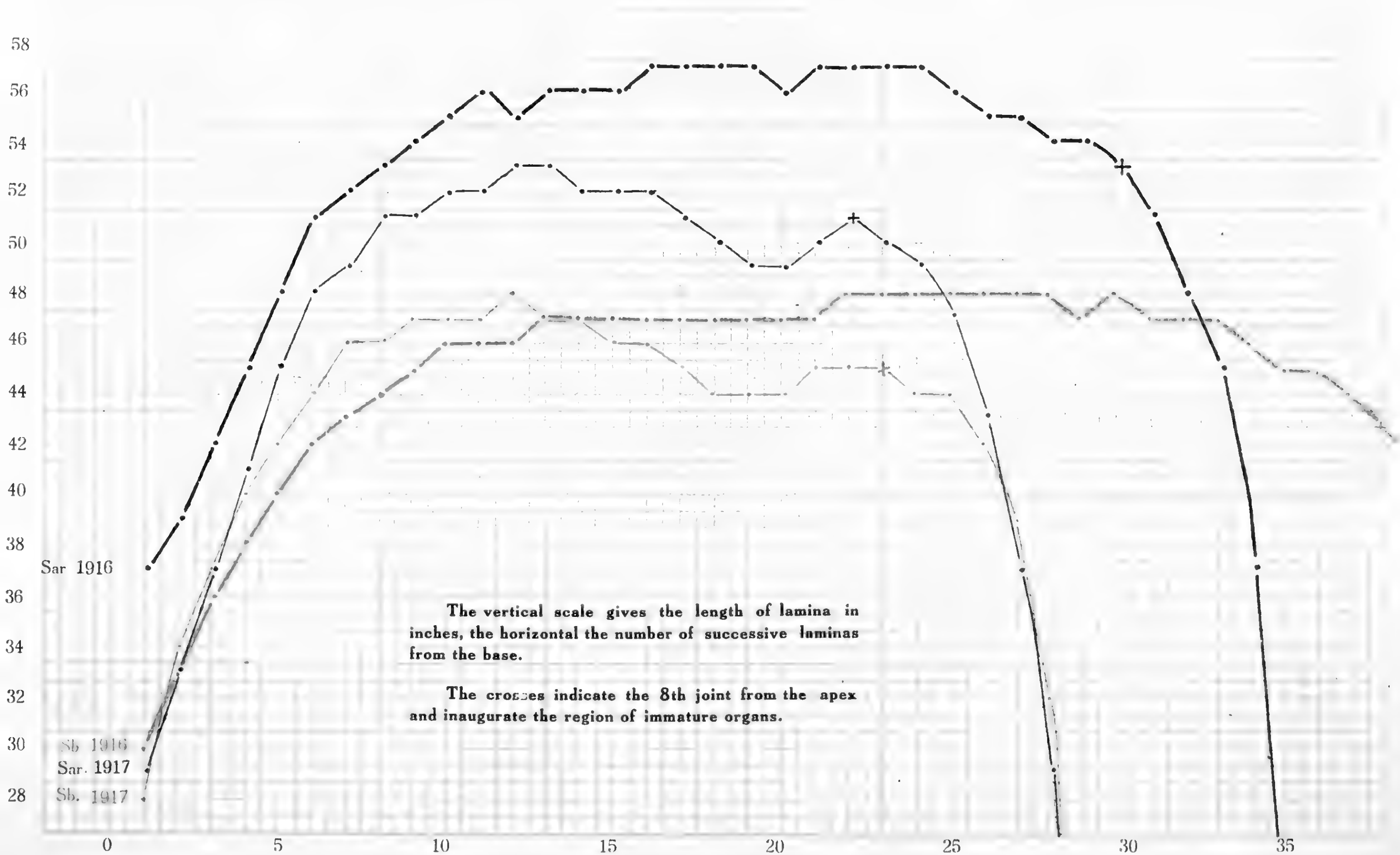
Saretha group. 29, 33, 37, 41, 45, 48, 49, 51, 51, 52, 52, 53, 53, 52, 52, 52, 51, 50, 49, 49, 50, 51, 50, 49, 47, 43, 37, 29, 21.

Sunnabile group. 28, 34, 37, 40, 42, 44, 46, 46, 47, 47, 47, 48, 47, 47, 46, 46, 45, 44, 44, 44, 45, 45, 45, 44, 44, 42, 39, 32, 21, 18.

(7) *Average length of mature lamina.* This was obtained from the above two series, leaving out the last 8 as possibly immature. The lengths in 1916 were, for Saretha 4′ 5″ and for Sunnabile 3′ 9″, and in 1917 Saretha 4′ 0″ and Sunnabile 3′ 8″. The leaves in the Saretha series are distinctly longer. A reference to the curves will show that it is possible that the lower figures in the nine months curves may be due to the fact that the longest had yet to come when the canes were measured. The maxima in lamina curves are considerably later than in joint and sheath curves, and the shortness of lamina in 1917 may not therefore be due entirely to poorer growth. The Mesangan section consists of much larger cane varieties than the Katha, and this is reflected in the length of lamina. In 1917 the average in the Katha section was 3′ 10″ and that of the Mesangan 4′2″, so that in this respect the intermediate nature of the latter section between the Katha section and the Sunnabile series cannot be gauged by mere length in inches.

CHART IV.

CURVES SHOWING THE AVERAGE LENGTHS OF SUCCESSIVE LAMINAS FROM BASE TO APEX, IN THE SARETHA AND SUNNABILE GROUPS IN THE 1916 AND 1917 CROPS.



(8) *Width of leaf.* This varies along the length of the leaf and, in order to institute a just comparison, it has been found necessary to fix on the greatest width, in the measurements. This was estimated by spreading out the leafy shoot and selecting the widest leaf present. The figures therefore refer to the extreme width of the leaf. In 1916 the average extreme width was 1·5″ in the Saretha, and 1·8″ in the Sunnabile groups, while in 1917 the figures were 1·3″ and 1·7″ respectively. As in the case of length of leaf, it is possible that, here too, the widest leaves were still undeveloped in the measurements of the immature canes of 1917. The leaves in the Sunnabile group are considerably wider than those in the Saretha group. The Mesangan section appears to be intermediate between the Katha section and the Sunnabile group, but it must be remembered that it consists of bigger canes ; the figures in 1917 were Katha section 1·2″, Mesangan 1·5″.

(9) *Leaf module.* This expression signifies here, as elsewhere, length divided by breadth. It is built up with the aid of figures contained in the last two paragraphs and is therefore average length divided by average extreme width. As might be expected, from our knowledge that the organs are longer and narrower in the Saretha series, the differences in the two groups are marked. The 1916 figures are Saretha 35, Sunnabile 25, and, in 1917, Saretha 37 and Sunnabile 26, resemblances sufficiently close to rule out all differences in vigour of growth. In spite of the poorer growth in 1917, the form of the leaf appears to have remained normal. The Mesangan section again occupies an intermediate position, the figures in 1917 being, Katha section 38, and Mesangan 33.

(10) *Leaf shape.* These are the main measurements of the lamina. But it was felt that the figures did not express obvious differences in *shape.* Most of the Saretha leaves show a marked narrowing above the base and the widest part of the Sunnabile leaf is, on the whole, lower down the length of the leaf than in the Saretha group. A series of width measurements were therefore made in the laboratory, in ten leaves of each variety, at different distances from the base. These distances were empirically selected at 1″, 6″, 12″ and at the widest part, wherever that was, and its distance from the base noted. It was surmised that these measurements would be sufficient for the purpose and that, from them, we should be able to form a correct idea of the form of the leaf in each class. To complete the picture, it was necessary to note the full length of each leaf measured, but this was unfortunately not appreciated in the 1916 measurements, and the omission has been filled in by taking the length of leaf obtained from the general curves of 20 canes measured in that year. The following are summaries of these measurements, it being noted

that *Khadya*, which was examined at a different time from the rest, has been omitted from the Sunnabile series.

Laboratory measurements of laminas in 10 canes of each variety, in inches.

	Width at base	At 1″	At 6″	At 12″	Widest place	Distance from base to widest place	Total length of leaf	REMARKS
1916								
Saretha group ...	0·95	0·79	0·88	1·03	1·39	25″	(4′ 5″)	Total length in 1916 taken from field measurements of 20 canes.
Sunnabile group ...	1·03	1·11	1·19	1·47	1·73	19″	(3′ 9″)	
1917								
Katha section ...	0·84	0·69	0·77	0·89	1·14	23·5″	4′ 3″	
Mesangan section ...	1·10	0·94	1·01	1·13	1·45	28·8″	4′ 10″	
Saretha group ...	0·94	0·79	0·87	0·98	1·26	25·6″	4′ 5″	
Sunnabile group ...	0·98	1·01	1·24	1·46	1·66	19″	3′ 10″	

From a study of this table we are able to draw a certain number of conclusions.

(*a*) In the Saretha group the narrowest part is 1″ above the base of the leaf. There is a marked pinching in above the base and the reverse is, if anything, the case in the Sunnabile series. Taking as an expression of this narrowing, $\frac{\text{width at base}}{\text{width at 1'' from base}}$ we get the following :—

1916. Saretha group $\frac{95}{79}$, Sunnabile $\frac{103}{111}$.

1917. Katha section $\frac{84}{69}$, Mesangan section $\frac{110}{94}$ } Average $\frac{94}{78}$, Sunnabile $\frac{98}{101}$.

(*b*) The widest part of the leaf is lower down (19″ from the base) in the Sunnabile series than it is in Saretha (25″ from the base), and the figures for the two years show marked similarity. But the Sunnabile leaf is shorter, and, to determine the proportional position of the widest part, it becomes necessary to include the average total length of leaf. Using as an expression of this the formula, $\frac{\text{distance from base to widest part}}{\text{total length of leaf}}$, we have as follows :—

1916.	Saretha group	·47	Sunnabile group	0·40
1917.	Katha section	.46		
	Mesangan section	·50		
	Saretha group	·48	Sunnabile group	0·41

Roughly, in the Saretha series, the widest part is half way up the leaf, and two-fifths of the way up in the Sunnabile. This emphasizes the shortness and broadness of the leaves in the latter series.

(*c*) A further expression of this feature may be obtained by an estimation of the rate of widening in the leaf, per unit of length. This upward gradient can be put in figures as follows :—

Upward gradient $= \frac{\text{greatest width—least width}}{2}$ in the distance from widest to narrowest part. The narrowest part may be safely taken as 1″ above the base in each case, so that the distance referred to in the formula will be the distance above the base of the widest part, less 1″. Working out the figures by the formula, we obtain the following for 1917. The actual total length of leaves was not taken in 1916.

1917.	Katha section	Gradient of	1 in 100
	Mesangan section		1 in 109
	Saretha group		1 in 102
	Sunnabile group		1 in 55

Thus the upward gradient of widening in the leaf is practically twice as steep in the Sunnabile series as it is in the Saretha.

The downward gradient, from the widest point to the tip of the leaf, may be obtained in a similar manner, the formula being $\frac{\text{extreme width}}{2}$ in the difference between total length and distance of widest point from base of leaf. The 1917 figures give us the following :—

1917.	Katha section	1 in 48
	Mesangan section	1 in 40
	Saretha group	1 in 44
	Sunnabile group	1 in 33

The downward gradient is considerably steeper than the upward, but there is less difference in the two groups, that of the Saretha leaves being three-fourths that of the Sunnabile, instead of nearly one-half.

From the above study of leaf measurements we have thus succeeded in extracting new and stable differences in the form of the average leaf in the two groups, and this gives important support to the reality of the grouping of the varieties concerned. We are in a position to draw the outline of a typical leaf in each group, but the length is so enormously greater than the width, that some sort of compromise is necessary. I have accordingly drawn the two leaves to scale, multiplying the width by ten, and the diagram shows the differences exaggerated, in the form of two greatly fore-shortened outlines.

OUTLINES OF LEAVES IN THE SARETHA AND SUNNABILE GROUPS, GREATLY FORE-SHORTENED. THE NARROWER, LONGER LEAF IS THAT OF THE SARETHA GROUP.

(11) *The midrib.* This is much more prominent in the Saretha leaves than in the Sunnabile, in this respect pointing to a marked resemblance in the former to the leaves of *Saccharum spontaneum.* To give an exact expression

of this relative prominence, the width of the midrib was measured at the same time and place as the width of the lamina in the above table. The midrib may be studied from two standpoints, firstly, its own intrinsic width, and, secondly, the relation this bears to that of the lamina.

(*a*) Width of midrib in different parts of the leaf.

		At 1″	At 6″	At 12″	At widest part of leaf	Distance from base to widest place
1916.	Saretha group	0·19	0·20	0·17	0·09	25″
	Sunnabile group .	0·18	0·17	0·15	0·11	19″
1917.	Katha section	0·17	0·16	0·14	0·08	23·5″
	Mesangan section ...	0·20	0·20	0·19	0·12	28·8″
	Saretha group	0·19	0·18	0·16	0·09	25·6″
	Sunnabile group ...	0·13	0·14	0·13	0·10	19″

We see from these figures that the midrib is distinctly wider in the leaves of the Saretha series all the way up, and this is the more noticeable when we remember that the leaves are wider in the Sunnabile group, especially in this lower part of the leaf.

(*b*) *Relative width of lamina and midrib.* To give expression to this the width of lamina has been divided at each point by the width of midrib. The following figures give the quotients :—

		At 1″	At 6″	At 12″	At widest part of leaf	Distance of widest part from base
1916.	Saretha group ...	4·2	4·4	6·0	15·4	25″
	Sunnabile group ...	5·5	7·1	11·4	16·7	19″
1917.	Katha section ...	4·1	4·8	6·3	14·2	23·5″
	Mesangan section ...	4·7	5·0	5·9	12·1	28·8″
	Saretha group ...	4·2	4·8	6·1	14·0	25·6″
	Sunnabile group ...	7·8	8·9	11·2	16·6	19″

And the table gives a useful expression of the comparative inconspicuousness of the midribs in the Sunnabile series.

TABLES OF MEASUREMENTS.

Average Measurements of Twenty Canes.

Varieties in the Saretha group, 1917, 9 *months old.*

	Number of joints with dead leaves	Length of cane with dead leaves	Length of living shoot	Total length of plant	Maximum width of leaf	THICKNESS OF CANE (Centimetres) (The thickness of cane was measured by calipers) — Bottom		Middle		Top (mature)		Average of the six preceding measurements
						Lateral	Median	Lateral	Median	Lateral	Median	
Katha Section												
Raksi ...	17	5′ 2″	5′ 9″	10′ 11″	1·0″	1·39	1·42	1·34	1·36	1·13	1·16	1·30
Katha ...	13	4′ 1″	5′ 11″	10′ 0″	1·0″	1·44	1·48	1·40	1·45	1·27	1·32	1·39
Ramui ...	15	4′ 7″	5′ 10″	10′ 5″	1·2″	1·51	1·51	1·53	1·59	1·35	1·40	1·49
Lalri ...	14	5′ 1″	6′ 8″	11′ 8″	1·2″	1·31	1·37	1·38	1·45	1·36	1·42	1·38
Chin ...	15	4′ 7″	6′ 0″	10′ 7″	1·2″	1·57	1·62	1·57	1·64	1·45	1·49	1·56
Chunnee ...	17	4′ 5″	5′ 2″	9′ 7″	1·0″	1·52	1·57	1·57	1·62	1·43	1·48	1·53
Baraukha ...	15	4′ 8″	6′ 4″	10′ 11″	1·3″	1·62	1·68	1·65	1·71	1·47	1·52	1·61
Kansar ...	14	5′ 3″	6′ 10″	12′ 1″	1·4″	1·59	1·64	1·61	1·66	1·49	1·54	1·59
Chynia ...	13	4′ 5″	7′ 2″	11′ 6″	1·3″	1·72	1·77	1·70	1·75	1·51	1·56	1·67
Burra Chunnee ...	16	3′ 3″	7′ 3″	10′ 5″	1·4″	1·73	1·75	1·72	1·76	1·60	1·63	1·70
Saretha (brown) ...	15	4′ 10″	6′ 5″	11′ 3″	1·3″	1·65	1·74	1·74	1·79	1·64	1·69	1·71
Average of section	15	4′ 7″	6′ 4″	10′ 11″	1·2″	1·55	1·60	1·56	1·62	1·42	1·47	1·54
Mesangan Section												
Mesangan ...	15	4′ 3″	6′ 2″	10′ 5″	1·1″	1·59	1·65	1·59	1·66	1·48	1·54	1·59
Saretha (green) ...	16	4′ 9″	6′ 5″	11′ 3″	1·3″	1·61	1·66	1·70	1·74	1·51	1·59	1·64
Jaganathia ...	12	4′ 6″	7′ 3″	11′ 9″	1·6″	1·68	1·74	1·78	1·82	1·56	1·61	1·70
Khari ..	16	5′ 4″	7′ 2″	12′ 5″	1·5″	1·99	2·05	1·98	2·04	1·68	1·74	1·91
Hullu Kabbu ...	12	4′ 4″	7′ 5″	11′ 9″	1·5″	1·86	1·92	1·95	2·01	1·66	1·71	1·85
Ganda Cheni ...	14	5′ 3″	8′ 0″	13′ 2″	1·9″	2·09	2·14	2·16	2·21	1·78	1·83	2·03
Kalkya ...	15	5′ 5″	6′ 8″	12′ 2″	1·8″	2·17	2·25	2·21	2·30	1·85	1·92	2·12
Average of section	14	4′ 10″	7′ 0″	11′ 10″	1·5″	1·86	1·92	1·91	1·97	1·65	1·91	1·83
Average of group	15	4′ 8″	6′ 7″	11′ 3″	1·3″	1·67	1·72	1·70	1·75	1·51	1·56	1·65

Average Measurements of Twenty Canes.

Varieties in the Sunnabile group, 1917, 9 *months old.*

	Number of joints with dead leaves	Length of cane with dead leaves	Length of living shoot	Total length of plant	Maximum width of leaf	THICKNESS OF CANE (Centimetres) (The thickness of cane was measured by calipers)						
						Bottom		Middle		Top (Mature)		Average of the six preceding measurements
						Lateral	Median	Lateral	Median	Lateral	Median	
Teru ...	13	3′ 6″	4′ 9″	8′ 5″	1·4″	1·18	1·24	1·16	1·23	1·14	1·25	1·18
Rakhra ...	13	3′ 10″	6′ 5″	10′ 4″	1·5″	1·28	1·35	1·41	1·54	1·42	1·25	1·42
Ekar ...	17	4′ 7″	6′ 4″	10′ 9″	1·5″	1·47	1·56	1·54	1·65	1·39	1·48	1·51
Dhaulu ...	15	3′ 10″	5′ 10″	9′ 8″	1·4″	1·34	1·39	1·35	1·41	1·21	1·25	1·32
Kaghze ...	14	3′ 9″	7′ 1″	10′ 9″	1·6″	1·59	1·67	1·68	1·78	1·62	1·93	1·71
Ketari ...	18	4′ 1″	4′ 4″	8′ 5″	1·6″	1·43	1·47	1·51	1·52	1·46	1·52	1·65
Bansa ...	20	5′ 2″	4′ 10″	9′ 11″	1·8″	1·65	1·71	1·81	1·88	1·68	1·75	1·75
Bansi ...	13	3′ 6″	6′ 10″	10′ 1″	1·8″	2·06	2·11	2·12	2·17	1·83	1·89	2·03
Sunnabile ...	15	3′ 11″	5′ 8″	9′ 7″	1·9″	2·05	2·12	2·03	2·17	1·88	1·94	2·03
Putli Khajee ..	18	5′ 7″	6′ 10″	12′ 5″	1·8″	2·17	2·24	2·33	2·41	1·97	2·03	2·19
Khadya ..	17	4′ 7″	6′ 4″	10′ 11″	1·7″	2·24	2·31	2·30	2·38	1·88	1·93	2·17
Naanal ..	19	4′ 9″	6′ 2″	10′ 11″	1·6″	2·10	2·15	2·16	2·21	1·81	1·86	2·05
Hotte Cheni ..	16	4′ 8″	6′ 3″	10′ 11″	1·9″	2·24	2·31	2·30	2·36	1·97	2·03	2·20
Dhor ...	13	2′ 9″	4′ 11″	7′ 8″	1·9″	2·03	2·09	1·91	2·01	1·56	1·59	1·86
Mojorah ..	13	3′ 11″	6′ 6″	10′ 5″	2·5″	2·68	2·80	2·65	2·75	2·24	2·34	2·68
Average of group ...	16	4′ 2″	5′ 11″	10′ 1″	1·7″	1·83	1·90	1·88	1·96	1·67	1·75	1·85
Average of Saretha group	15	4′ 8″	6′ 7″	11′ 3″	1·3″	1·67	1·72	1·70	1·75	1·51	1·56	1·65

Average Measurements of Twenty Canes.

Varieties in the Saretha and Sunnabile groups, 1916, 13 *months old.*

	Number of joints with dead leaves	Length of cane with dead leaves	Length of living shoot	Total length of plant	THICKNESS OF CANE (Centimetres) (The thickness of cane was measured by calipers)						
					Bottom		Middle		Top (mature)		Average of the six preceding measurements
					Lateral	Median	Lateral	Median	Lateral	Median	
Saretha Group											
Baraukha	23	8′ 2″	5′ 8″	13′ 10″	1·34	1·40	1·29	1·31	1·30	1·27	1·32
Ganda Cheni ...	21	7′ 11″	7′ 1″	15′ 1″	1·8[illegible]	1·96	1·97	2·13	1·94	2·10	1·82
Chin	25	7′ 5″	6′ 1″	13′ 6″	1·36	1·45	1·29	1·35	1·34	1·36	1·36
Hullu Kabbu ...	21	7′ 9″	6′ 9″	14′ 6″	1·91	2·02	2·00	2·11	1·93	2·07	2·01
Jaganathia ...	23	7′ 1″	6′ 2″	13′ 3″	1·61	1·71	1·70	1·77	1·74	1·84	1·73
Khari	22	6′ 11″	6′ 4″	13′ 2″	1·72	1·81	1·78	1·86	1·61	1·68	1·74
Saretha	28	7′ 10″	7′ 0″	14′ 10″	1·43	1·50	1·59	1·65	1·54	1·58	1·55
Average of group ...	23	7′ 7″	6′ 5″	14′ 0″	1·60	1·69	1·66	1·74	1·63	1·70	1·67
Sunnabile Group											
Bansa	38	8′ 10″	4′ 8″	13′ 8″	1·54	1·61	1·73	1·76	1·74	1·93	1·72
Bansi	32	6′ 10″	5′ 1″	11′ 11″	1·65	1·73	1·67	1·74	1·67	1·76	1 70
Dhor (Harrai) ..	30	7′ 3″	6′ 5″	13′ 8″	1·96	2·03	2·04	2·15	1·99	2·05	2·04
Dhor (Seoni) ..	31	7′ 7″	6′ 5″	14′ 0″	2·14	2·22	2·30	2·39	2·17	2·26	2·25
Kaghze	32	6′ 10″	5′ 1″	11′ 11″	1·59	1·67	1·71	1·83	1·75	1·89	1·74
Ketari	30	7′ 0″	4′ 4″	11′ 4″	1·80	1·85	1·70	1·78	1·78	1·92	1·80
Naanal	29	7′ 0″	6′ 11″	13′ 10″	2 08	2·15	2·01	2·10	1·94	2·09	2·06
Putli Khajee	29	9′ 1″	6′ 1″	15′ 2″	1·98	2·15	2·00	2·15	2·07	2·31	2·11
Rakhra	31	7′ 4″	5′ 5″	12′ 8″	1·83	1·90	1·74	1·84	1·78	1·90	1·83
Sunnabile	30	6′ 11″	5′ 8″	12′ 7″	1·94	2·05	1·95	2·10	2·00	2·14	2·03
Average of group ...	32	7′ 5″	5′ 11″	13′ 4″	1·85	1·93	1·88	1·99	1·89	2·03	1·93

Average Measurements of Twenty Canes.

Varieties in the Saretha group, 1916 and 1917.

	1917 crop (9 months old)							1916 crop (13 months old)						
	Number of joints in cane up to ·1″	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module	Number of joints in cane up to ·1″	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module
				In.	In.	cm.					In.	In.	cm.	
Katha Section														
Raksi	26	29	29	3·7	79·9	1·30	154	...	...	...	...	...	...	...
Katha	28	31	31	3·3	73·6	1·39	132	...	...	...	...	...	...	...
Ramui	25	27	27	3·6	70·4	1·49	118	...	...	...	...	...	...	...
Lalri	25	28	28	4·1	81·0	1·38	147	..	...	...	...	...	...	...
Chin	30	34	34	3·2	77·3	1·56	124	36	39	39	3·4	96·3	1·36	177
Chunnee	30	33	33	2·9	69·9	1·53	118	...	...	...	...	...	...	...
Baraukha	25	28	28	3·8	74·9	1·61	116	32	34	35	4·3	102·9	1·32	195
Kansar	26	28	28	4·3	86·6	1·59	136	...	...		...	...	...	...
Chynia	26	28	28	4·0	81·8	1·67	122	...	...	...	...	...	...	...
Burra Chunnee ...	28	33	33	2·4	54·3	1·70	80	...	...	...	...	...	...	...
Saretha (brown) ...	27	...	...	3·9	79·4	1·71	116	42	46	47	3·1	106·5	1·55	172
Average of Katha Section	**27**	**30**	**30**		**75·4**	**1·54**	**122**	...	..	...	...	...	...	...
Mesangan Section														
Mesangan	26	29	29	3·4	70·0	1·59	110	...	..	...	..	...	...	...
Saretha (green) ...	30	33	33	3·4	84·1	1·64	125	...	...	...	...	...	...	.
Jaganathia ...	22	25	25	4·3	74·1	1·70	109	31	34	37	3·7	85·9	1·73	124
Khari	23	28	28	4·0	73·4	1·91	96	29	31	33	3·9	101·2	1·74	145
Hullu Kabbu ...	21	24	24	4·5	73·2	1·85	99	29	32	34	4·4	92·2	2·01	115
Ganda Cheni ...	22	26	26	4·6	75·6	2·03	97	28	32	33	4·5	95·4	1·82	131
Kalkya	27	...	34	4·1	83·1	2·12	98	...	...	...	...	...	...	...
Average of Mesangan section	**24**	**28**	**28**	...	**76·6**	**1·83**	**112**	...	..	...	...	..	...	..
Average of Saretha group	**26**	**29**	**29**	**3·8**	**75·9**	**1·65**	**115**	**32**	**35**	**37**	**3·9**	**97·2**	**1·67**	**146**

Average Measurements of Twenty Canes.

Varieties of the Sunnabile group, 1916 *and* 1917.

	1917 crop (9 months old)							1916 crop (13 months old)						
	Number of joints in cane up to 1"	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module	Number of joints in cane up to 1"	Number of sheaths	Number of laminas	Average length of joints	Length of stripped cane	Average thickness of cane	Cane module
				In.	In.	cm.					In.	In.	cm.	
Teru	25	29	29	2·7	53·8	1·18	114							
Rakhra	24	29	28	3·4	62·2	1·42	109	40	43	46	2·9	92·4	1·83	128
Ekar	26	31	31	3·3	69·7	1·51	115	...	...	...	...	...	.	...
Dhaulu	28	32	32	2·8	62·4	1·32	118	31	...	..	2·8	65·3	...	...
Kaghze	25	30	30	3·2	66·0	1·71	96	39	43	43	2·6	80·4	1·74	116
Ketari	25	...	...	2·9	58·8	1·65	89	38	43	44	2·8	85·2	1·80	118
Bansa	29	...	...	3·1	75·6	1·75	108	43	48	49	3·1	107·4	1·72	156
Bansi	27	30	30	2·8	61·2	2·03	75	42	46	47	2·6	88·3	1·70	130
Sunnabile	27	32	32	3·0	66·0	2·03	81	44	47	47	2·6	94·1	2·03	116
Putli Khajee ...	29	...	...	3·6	84·7	2·19	97	35	40	41	3·8	105·2	2·11	125
Khadya	29	34	34	2·8	70·6	2·17	81	...	...	...	...	...	...	...
Naanal	31	34	34	2·7	6[illegible]·3	2·05	83	42	47	47	3·0	103·4	2·06	125
Hotte Cheni ..	29	31	33	2·2	52·0	2·20	59	...	...	...	...	...	...	...
Dhor	20	24	24	2·8	41·2	1·86	55	43	45	47	2·9	99·5	2·25	111
Mojorah	24	28	28	3·6	67·3	2·68	63	...	...	...	.	..	...	...
Average of Sunnabile group	27	30	30	3·0	64·0	1·85	87	40	45	46	2·9	92·1	1·93	119
Average of Saretha group	26	29	29	3·8	75·9	1·65	115	33	35	37	3·9	97·2	1·67	146

	Leaf Sheath			
	Clasping stem in terms of circumference	Width at base	Width at top	
Katha section				
Raksi	1·46	2·37	1·02	
Katha	...	3·04	1·15	
Ramui	1·49	2·72	1·26	
Lalri	1·45	2·78	1·17	
Chin	1·36	2 60	1·10	
Chunnee ...	1·44	2·60	1·20	
Baraukha ...	1·44	2·50	1·20	1
Kansar	1·55	3·05	1·34	1
Chynia	1·57	2·98	1·25	1
Burra Chunnee ...	1·51	2·65	1·33	1
Saretha (brown) ...	1·50	3·42	1·23	1
Average of section	**1·48**	**2 79**	**1·11**	**1**
Mesangan section				
Mesangan ...	1·49	2·60	1·25	1
Saretha (green) ...	1·50	3·35	1·37	1
Jaganathia ...	1·44	3·01	1·27	
Khari	1·39	3 08	1·29	1
Hullu Kabbu ...	1·42	3·06	1·42	1
Ganda Cheni ...	1·40	3·62	1·65	1
Kalkya	1·38	3·43	1·53	1
Average of section	**1·43**	**3·16**	**1 40**	**1**
Average of group ...	**1·46**	**2·93**	**1·22**	**11**

Average Measurements of Ten Leaves.

Varieties of the Saretha group, 1917.

(Measurements in Inches.)

	Leaf Sheath: Clasping stem in terms of circumference	Leaf Sheath: Width at base	Leaf Sheath: Width at top	Leaf Sheath: Length	Leaf Sheath: Module	Lamina: Width at base	Lamina at 1″	Midrib at 1″	Lamina at 6″	Midrib at 6″	Lamina at 12″	Midrib at 12″	Lamina at widest	Midrib at widest	Distance from base to widest part	Total length	Proportional height of widest part	Module
Katha section																		
Raksi	1 46	2 37	1·02	9·40	4 0	0·63	·50	·15	·56	·15	·69	·11	·90	·06	21	3′ 9″	·47	50
Katha	...	3·04	1 15	10 20	3·3	0·78	·63	·15	·66	·14	·79	·12	·98	·07	22	3 9″	·49	46
Ramui	1·49	2 72	1 26	10·30	3 8	0·92	·71	·18	·78	·18	·59	·16	1·06	·09	23	4′ 3″	·45	51
Lahi	1·45	2·78	1·17	11·07	4·0	0 82	·71	·15	·77	·15	·79	·15	1·24	·06	28	4′ 4″	·54	42
Chin	1·36	2 60	1·10	8 90	3 4	0·77	·68	·15	·81	·14	1·02	·12	1·19	·08	18	3′ 10″	·39	39
Chunnee .	1·44	2 60	1·20	8·70	3·3	0 80	·73	·17	·82	·15	·95	·13	1·03	·10	17	3′ 9″	·38	44
Baraukha ..	1·44	2·50	1·20	11·50	4 6	0·80	·68	·17	·77	·17	·86	·15	1·11	·07	25	4 7″	·46	50
Kansar	1 55	3·05	1·34	10·90	3·6	0·93	·81	·17	90	·15	1·07	·15	1·41	·08	27	4′ 8″	48	40
Chynia	1·57	2·98	1·25	12·30	4·1	0·87	69	·17	80	·17	·88	·15	1 25	·08	28	4′ 11″	48	47
Burra Chunnee ..	1·51	2 65	1·33	12·50	4 7	0·98	·79	·19	·87	·20	·98	·16	1·24	·11	24	4′ 4″	·46	42
Saretha (brown) ..	1·50	3·42	1·23	12·40	3·6	0·92	·68	·17	·78	·16	·87	·14	1·08	·08	25·6	4′ 4″	·50	48
Average of section	1 48	2 79	1·11	10 74	3 8	0 84	·69	17	·77	·16	89	·14	1·14	·08	23·5	4′ 3″	·46	45
Mesangan section																		
Mesangan ...	1·49	2·60	1 25	12·90	5·0	1·05	·88	·17	·93	·16	1·02	·15	1·12	·09	21	4′ 1″	·43	44
Saretha (green) ...	1·50	3 35	1·37	14·30	4·3	1·15	1·00	·15	1·07	·14	1·19	·14	1·22	·11	18 6	4 0″	·40	39
Jaganathia ..	1·44	3·01	1·27	3 50	4·5	1 02	·83	·22	·89	·22	1·01	·21	1 65	·07	39	5′ 0″	·65	36
Khari	1·39	3 08	1·29	13 25	4·3	1·04	·88	·19	1·00	·19	1·13	·18	1·58	·10	32	5′ 0″	·53	38
Hullu Kabbu ...	1·42	3 06	1·42	14 65	4 8	1·06	·89	·19	·91	·18	1 05	·18	1·45	·11	30	5′ 3″	·48	43
Ganda Cheni ...	1 40	3·62	1·65	14·85	4·1	1·21	1·09	·23	1·21	·24	1·34	·21	1·75	·19	33	5 3″	·52	36
Kalkya	1 38	3·43	1·53	13·40	3·9	1 20	1 00	·27	1·07	·27	1·18	·25	1·41	·15	28	5′ 0″	·47	42
Average of section	1 43	3 16	1 40	13·84	4·4	1·10	·94	·20	1·01	·20	1·17	·19	1·45	·12	28·8	4 10″	·50	40
Average of group .	1·46	2·93	1·22	11·95	4·1	0 94	·79	·19	·87	·18	·98	·16	1·26	·09	25·6	4 5″	·48	43

Teru ... ...
Rakhra ... ...
Ekar ... ...
Dhaulu ... ...
Kaghze ... ...
Ketari ... ...
Bansa ... ...
Bansi ... ...
Sunnabile ...
Putli Khajee ...
Naanal ... ...
Hotte Cheni ...
Dhor ... ...
Mojorah ...
Average of group
Average of Saretha group

Average Measurements of Ten Leaves.

Varieties of the Sunnabile group, 1917.

(Measurements in inches.)

	Leaf Sheath					* Lamina								
	Clasping stem in terms of the circumference	Width at base	Width at top	Length	Module	Width at base	Lamina / Midrib at 1″	Lamina / Midrib at 6″	Lamina / Midrib at 12″	Lamina / Midrib at widest	Distance from base of widest part.	Total length	Proportional height of widest part	Module
Teru	1·40	2·36	0·88	10·2	4·3	·65	62 / ·10	·86 / ·10	1·09 / ·09	1·26 / ·08	18	3′ 7″	·42	34
Rakhra	1·55	2 65	1·05	12·2	4·6	·73	·73 / ·11	·98 / ·12	1·19 / ·11	1·32 / ·07	20	3 4″	·50	30
Ekar	1·43	2·86	1·06	12·9	4·5	·80	·50 / ·16	1·09 / ·14	1·32 / ·13	1·52 / ·11	17	3 11″	·36	31
Dhaulu	1·40	2·86	0·96	12·4	4·3	·67	·63 / ·10	·92 / ·11	1·22 / ·08	1·35 / ·06	17	3′ 5″	·41	30
Kaghze	1·37	2·77	1·09	12·3	4·4	·77	·84 / ·12	1·07 / ·12	1·27 / ·11	1·39 / ·07	19	4′ 0″	·40	35
Ketari	1·37	3 08	1·28	12·5	4·0	·99	·98 / ·14	1·18 / ·16	1·36 / ·15	1·50 / ·11	17	3′ 7″	·40	29
Bansa	1·37	3·27	1·34	10·5	3·2	1·01	1·12 / ·16	1·27 / ·16	1·45 / ·16	1·62 / ·10	21	4 2″	42	31
Bansi	1·37	3·30	1·28	10·6	3·2	·99	·99 / ·12	1·45 / ·12	1·66 / ·10	1·83 / ·06	17	3′ 9″	·38	24
Sunnabile ...	1·33	3·27	1·19	11·1	3 4	·92	·88 / ·13	1 23 / ·13	1 58 / ·11	1·84 / ·09	18	3′ 5″	·44	22
Putli Khajee ...	1·37	3·89	1·75	13·3	3·4	1·48	1·49 / ·19	1·50 / ·18	1·56 / ·16	1·90 / ·10	25	4′ 3″	·49	27
Naanal	1·36	3·55	1·56	12·70	3 6	1·08	1·12 / ·14	1·33 / ·16	1·51 / ·16	1·74 / ·12	20	4′ 3″	·39	29
Hotte Cheni ...	1·33	3·70	1·44	12·5	3·4	1·15	1·15 / ·13	1·32 / ·16	1·57 / ·16	1·83 / ·11	21	3 11″	·45	26
Dhor	1·40	3·32	1·39	10·5	3·2	1·08	1·14 / ·14	1·40 / ·16	1 71 / ·14	1·84 / ·11	18	3′ 10″	·39	24
Mojorah .	1·36	4·70	1·92	14·4	3·1	1·40	1·60 / ·15	1·79 / ·20	2·05 / ·17	2·27 / ·17	18	4′ 4″	·35	23
Average of group	1 39	3 26	1 30	12·0	3 7	·98	1 01 / 13	1 24 / ·14	1 46 / ·13	1 66 / 10	19	3 10″	41	28
Average of Saretha group	1·46	2 93	1·22	11 95	4·1	·94	·79 / ·19	87 / ·18	98 / ·16	1·26 / 09	25 6	4 5″	48	43

* These figures are not truly consistent, being obtained from different sets of measurements.

Ave

	Leaf Sheath			
	Clasping stem	Width at base	Width at top	Length *
Saretha group				
Baraukha ...	1·45	2·80	1·25	11·7
Ganda Cheni ...	1·43	3·02	1·44	14·5
Chin	...	2·78	1·02	9·7
Hullu Kabbu ...	1·45	3·24	1·28	13·7
Jaganathia ...	1·46	3·44	1·15	12·6
Katha	1·51	3·22	1·16	...
Khari	1·36	3·22	1·40	12·9
Saretha ...	(·150)	3·00	1·11	12·0
Average of Saretha group	1·45	3·09	1·23	(12·4)*
Sunnabile group				
Bansa	(1·21)	3·38	1·35	12·0
Bansi	1·33	2·92	1·17	10·1
Dhaulu	1·43	2·68	1·0?	...
Dhor (Harrai) ...	1·33	3·44	1·50	11·4
Dhor (Seoni) ...	1·45	3·83	1·66	12·3
Kaghze	1·33	3·08	0·99	12·6
Ketari	...	...	...	10·7
Mojorah ...	1·39	4·74	(1·70)	...
Naanal	1·33	3·36	1·22	12·6
Putli Khajee ...	1·38	3·64	1·72	13·7
Rakhra	1·37	2·86	1·29	11·1
Sunnabile ...	(1·30)	3·14	1·16	10·8
Average of Sunnabile group.	1·35	3·37	1·34	(11·7)*

* These figures are not t

Average Measurements of Ten Leaves.

Saretha and Sunnabile groups, 1916.

(Measurements in inches.)

	Leaf Sheath					* Lamina												
	Clasping stem	Width at base	Width at top	Length *	Module *	Width at base	Lamina / Midrib 1" fr. base: Lamina	Midrib	Lamina / Midrib 6" fr. base: Lamina	Midrib	Lamina / Midrib 12" fr. base: Lamina	Midrib	Lamina / Midrib At widest place: Lamina	Midrib	Distance from base to widest part	Total length *	Proportional height of widest part *	Module *
Saretha group																		
Barsukha ...	1·45	2·80	1·25	11 7	4 2	·84	64	·18	·75	·16	·91	·13	1 14	·07	24	4′ 2″	·48	44
Ganda Cheni ...	1·43	3 02	1·44	14 5	4 8	1·15	·94	·20	1·02	·23	1·15	·22	1 75	·11	34	5′ 0″	·57	34
Chin	...	2·78	1·02	9·7	3·5	·62	·62	·16	·82	·18	1·10	·13	1 28	·11	16	3′ 10″	·39	56
Hullu Kabbu ...	1·45	3 24	1·28	13 7	3·1	1 09	·88	·19	·93	·21	1·14	·18	1·58	·11	23	4′ 9″	·40	36
Jaganathia ...	1·46	3 44	1·15	12·6	3·1	1·03	·77	·24	·78	·25	·90	·25	1 57	·09	37	4′ 6″	67	34
Katha	1·51	3·22	1·16	..	...	·73	63	·15	·66	·16	·79	·13	1 61	·05	21	..		
Khari	1·36	3 22	1·40	12 9	4 0	1·17	·95	·26	1·09	·23	1·25	·21	1 63	·12	27	4′ 10″	·47	36
Saretha ...	(·150)	3·00	1·11	12·0	4 0	·95	·85	·17	·95	·16	1 00	·13	1 13	·09	19	4′ 1″	·39	43
Average of Saretha group	1 45	3 09	1·23	(12 4)*	(3 8)*	·95	·79	·19	·88	·20	1 03	17	1 39	·09	25	(4′ 5″)*	(·47)*	(38)*
Sunnabile group																		
Bansa	(1 21)	3·38	1·35	12 0	3 6	...	1·01	·24	1·15	·22	1 36	·19	1 50	13	22	3′ 11″	·47	31
Bansi	1·33	2 92	1·17	10 1	3 5	·99	·84	·18	1·12	·15	1·60	·16	1 78	·12	15	3′ 3″	·38	22
Dhaulu	1·43	2·68	1·00	...	...	·66	·70	·13	·94	·12	1·15	·10	1 22	·08	14	..		
Dhor (Harrai) ..	1 33	3 44	1·30	11·4	3 3	1·02	1·02	·16	1·19	·18	1 51	·16	1 75	·12	19	4′ 1″	·38	28
Dhor (Seoni) ..	1·45	3·83	1 66	12 3	3·2	1·30	1·29	·22	1·45	·23	1 65	·21	2 07	·13	23	4′ 5″	·43	26
Kaghze	1·33	3 08	0 99	12 6	4 1	·72	·73	·13	·87	·15	1 17	·14	1 37	·08	18	3′ 8″	·42	32
Ketari	...	...	...	10·7	...	...	...		...		..		...		...	3′ 2″		
Mojorah ...	1 39	4·74	(1·70)	...	...	1·45	1·46	·26	1 76	·19	1 92	·19	2 25	·16	20	..	...	
Naanal	1·33	3 36	1·22	12·6	3 8	...	...	...	...	...	..	...	...	...	...	3′ 11″	.	
Puth Khajee ...	1·38	3·64	1·72	13 7	3 8	1·34	1·19	·22	1·22	·21	1·47	·17	2·67	·09	23	4′ 5″	43	26
Rakhra	1·37	2 86	1·29	11·1	3 7	·90	·79	·14	1 02	·15	1·16	·12	1·39	·08	18	3′ 6″	·43	30
Sunnabile ...	(1·30)	3·14	1·16	10·8	3 4	·88	·92	·15	1·20	·14	1·71	·11	1·86	·08	18	3′ 5″	·44	22
Average of Sunnabile group.	1·35	3 37	1 34	(11·7)*	(3 6)*	1 03	1·10	·18	1·19	·17	1·47	·15	1 73	·11	19	(3′ 9″)*	(·42)*	(27)*

* These figures are not truly consistent, being obtained from different sets of measurements.

Katha section

Raksi	..	4·4	4·
Katha	..	3·4	4·
Ramui	..	3·5	3·
Lalri	..	3·6	4·
Chin	..	3·5	3·
Chunnee	..	3·1	3·
Baraukha	..	3·3	3·
Kansar	..	4·1	4·
Chynia	..	3·8	4·
Burra Chunnee		3·0	3·
Saretha	..	4·0	4·
Av. of section		3·6	4·
Mesangan section			
Mesangan	..	3·2	4·
Saretha	..	3·5	4·
Juganathia	..	3·1	3·
Khari	..	2·9	3·
Hullu Kabbu		3·0	4·
Ganda Cheni		2·6	3·
Kalkya	..	3·4	4·
Av. of section		3·1	3·
Av. of group	..	3·4	4·

Average lengths of successive joints. Varieties of the Saretha Group, 1917.

(Measurements in inches)

																															Number of joints
Katha section																															
Raksi ..	4·4	4·7	4·8	5·2	4·7	4·1	4·0	3·9	4·1	3·7	3·5	3·0	2·5	2·5	2·7	2·9	3·1	3·0					3·0	2·7	2·3	2·2	1·9	0·7	0·2	0·1	26
Katha ..	3·4	4·3	4·5	4·4	4·2	4·2	4·1	4·0	3·7	3·8	3·6	3·1	2·7	2·5	2·5	2·5	2·5	2·4	2·3	2·1			1·9	1·6	1·2	0·9	0·6	0·3	0·2	0·1	28
Ramui ..	3·5	3·6	3·8	4·0	4·0	3·8	3·7	3·4	3·6	3·7	3·7	3·8	3·6	3·4	3·4	3·1	3·0						2·4	1·9	1·6	1·4	1·0	0·5	0·2	0·1	25
Lalri ..	3·6	4·4	4·8	4·8	5·0	5·1	4·4	4·1	4·3	4·3	4·0	3·7	3·7	3·5	3·3	3·3	3·3						3·2	2·7	2·1	1·3	1·0	0·7	0·3	0·1	25
Chin ..	3·5	3·9	4·5	4·4	4·4	4·5	4·3	4·1	3·9	3·6	3·3	3·3	3·3	2·8	2·8	2·5	2·6	2·2	2·1	1·9	1·7	1·6	1·4	1·1	1·0	1·1	0·8	0·4	0·2	0·1	30
Chunnee ..	3·1	3·7	4·0	4·1	4·3	4·2	4·0	3·7	3·3	3·1	2·9	2·5	2·2	2·5	2·3	2·1	2·1	1·9	2·0	2·0	1·9	1·6	1·5	1·3	1·1	1·0	0·8	0·4	0·2	0·1	30
Baraukha ..	3·3	3·8	4·0	4·3	4·2	4·3	4·1	4·3	4·4	4·0	3·4	3·2	3·5	3·6	3·1	3·2	3·3						2·6	1·8	1·3	1·3	0·9	0·4	0·2	0·1	25
Kansar ..	4·1	4·8	5·1	5·0	5·1	5·1	5·0	4·6	4·6	4·2	4·2	4·0	3·8	3·6	3·8	3·6	3·4	2·9					2·9	2·3	1·6	1·0	0·8	0·4	0·2	0·1	26
Chynia ..	3·8	4·4	4·4	4·5	4·6	4·5	4·4	4·3	4·6	4·2	3·7	3·4	3·8	3·7	3·6	3·5	3·3	3·1					2·9	2·1	1·9	1·5	0·9	0·4	0·2	0·1	26
Burra Chunnee	3·0	3·0	2·8	2·8	3·0	2·8	2·7	2·7	2·5	2·3	2·1	2·0	2·2	2·2	2·3	2·2	2·0	1·9	1·8	1·8			1·7	1·3	1·0	0·8	0·7	0·4	0·2	0·1	28
Saretha ..	4·0	4·8	4·9	5·0	4·9	4·8	4·6	4·1	3·8	3·6	3·4	3·2	2·7	2·6	2·9	3·1	3·0	2·9	2·6				2·4	1·8	1·3	1·1	1·1	0·5	0·2	0·1	27
Av. of section	3·6	4·1	4·3	4·4	4·4	4·3	4·1	3·9	3·9	3·7	3·4	3·2	3·1	3·0	3·0	2·9	2·9	2·5	2·4				2·4	1·9	1·5	1·2	1·1	0·5	0·2	0·1	27
Mesangan section																															
Mesangan ..	3·2	4·2	4·7	4·4	4·1	3·7	3·6	4·1	4·3	4·0	3·4	2·6	2·4	2·3	2·2	2·4	2·5	2·4					2·3	2·3	1·9	1·3	0·9	0·5	0·2	0·1	26
Saretha ..	3·5	4·0	4·5	4·5	4·5	4·1	3·8	3·7	3·6	3·5	3·3	3·0	2·9	2·9	2·7	3·0	3·1	2·9	2·8	2·7	2·6	2·5	2·6	2·6	2·0	1·4	0·7	0·4	0·2	0·1	30
Juganathia ..	3·1	3·8	4·2	5·0	5·0	4·6	4·5	4·5	4·5	4·6	4·2	4·0	4·1	3·9									3·6	3·6	3·0	2·0	1·1	0·5	0·2	0·1	22
Khari ..	2·9	3·3	3·8	4·2	4·7	4·6	4·8	4·4	4·4	4·2	4·2	4·2	3·8	3·7	3·4								3·1	3·2	2·8	1·9	1·1	0·4	0·2	0·1	23
Hullu Kabbu	3·0	4·0	3·9	4·2	5·0	5·2	5·1	4·7	4·6	4·7	4·8	4·6	4·4										4·7	3·9	2·6	1·9	1·1	0·5	0·2	0·1	21
Ganda Cheni	2·6	3·4	4·4	5·5	5·6	4·7	5·0	4·7	5·2	5·0	5·0	4·7	4·5	4·3									4·2	3·4	2·6	1·8	1·1	0·6	0·2	0·1	22
Kalkya ..	3·4	4·0	4·8	4·8	4·8	5·0	5·0	4·7	4·9	4·3	4·3	4·2	4·1	3·9	3·8	3·4	2·9	2·4	1·9				1·5	1·2	1·1	1·0	0·7	0·4	0·2	0·1	27
Av. of section	3·1	3·8	4·3	4·7	4·8	4·6	4·5	4·4	4·5	4·3	4·2	3·9	3·7	3·5	3·4	3·2							3·1	2·9	2·3	1·6	1·0	0·5	0·2	0·1	24
Av. of group ..	3·4	4·0	4·3	4·5	4·6	4·4	4·3	4·1	4·1	3.9	3·7	3·5	3·3	3·2	3·0	2·9	2·9	2·8					2·7	2·3	1·8	1·4	1·0	0·5	0·2	0·1	26

For curves of the Saretha and Sunnabile group averages, see pages in Detailed List of Characters.

Teru	3·2
Rakhra	3·8
Ekar	3·2
Dhaulu	3·2
Kaghze	2·2
Ketari	2·4
Bansa	2·9
Bansi	2·3
Sunnabile	2·8
Putli Khajee	2·7
Khadya	2·1
Naanal	1·9
Hotte Cheni	2·6
Dhor	2·5
Mojorah	3·1
Av. of group	2·7

Average lengths of successive joints. Varieties of the Sunnabile Group, 1917.

(Measurements in inches)

																																Number of joints
Teru	3·2	3·1	3·2	3·4	3·6	3·9	3·7	3·5	3·0	2·6	2·3	2·1	1·9	1·7	1·7	1·5	1·5							1·7	1·9	1·6	1·3	0·7	0·4	0·2	0·1	25
Rakhra	3·8	4·1	4·1	4·0	3·8	3·8	3·9	3·7	3·5	3·1	3·0	3·1	2·8	2·4	2·2	2·4								2·2	2·0	1·6	1·3	0·7	0·4	0·2	0·1	24
Ekar	3·2	3·4	3·5	3·7	3·8	3·9	4·0	3·8	3·6	3·4	3·2	3·0	2·9	2·7	3·1	2·9	2·7	2·5						2·6	2·4	2·3	1·6	0·8	0·4	0·2	0·1	26
Dhaulu	3·2	3·3	3·7	3·5	3·2	2·9	3·0	3·1	3·4	3·1	2·8	2·5	2·2	2·0	2·3	2·5	2·3	2·3	2·1	2·1				1·8	1·5	1·3	1·0	0·6	0·4	0·2	0·1	28
Kaghze	2·2	3·1	3·6	3·7	3·5	3·3	3·5	3·7	3·8	3·5	3·3	3·1	2·9	2·9	2·8	2·8	2·5							3·1	2·8	2·5	1·8	0·9	0·4	0·2	0·1	25
Ketari	2·4	2·8	3·1	3·5	3·5	3·1	2·8	3·1	3·2	3·3	3·4	3·0	2·7	2·6	2·6	2·4	2·2							2·0	1·7	1·9	1·5	1·1	0·6	0·2	0·1	25
Bansa	2·9	3·2	3·4	3·6	3·7	3·7	3·7	3·3	3·2	3·3	3·3	3·5	3·4	3·2	3·0	2·7	2·7	2·7	2·6	2·5	2·4			2·4	2·1	1·9	1·5	0·9	0·5	0·2	0·1	29
Bansi	2·3	2·6	2·8	2·9	3·0	3·0	3·1	3·4	3·2	3·1	3·1	3·0	2·9	2·8	2·9	2·7	2·5	2·3	2·1					1·9	1·5	1·5	1·1	0·7	0·5	0·2	0·1	27
Sunnabile	2·8	3·1	3·2	3·3	3·0	3·1	3·1	3·4	3·4	3·6	3·4	3·1	3·0	2·9	2·9	2·7	2·7	2·6	2·4					2·0	1·8	1·6	1·2	0·9	0·5	0·2	0·1	27
Putli Khajee	2·7	3·3	3·4	3·6	3·7	3·9	3·9	3·9	3·9	4·0	4·1	4·0	3·8	3·7	3·5	3·4	3·4	3·3	3·4	3·8	3·2			2·5	2·0	1·6	1·2	0·8	0·4	0·2	0·1	29
Khadya	2·1	2·5	2·9	3·2	3·3	3·4	3·5	3·3	3·2	3·1	3·1	3·1	3·1	3·0	2·8	2·7	2·6	2·5	2·4	2·1	1·9	2·0	1·8	1·3	1·4	1·6	1·3	0·7	0·4	0·2	0·1	31
Naanal	1·9	2·3	2·3	2·4	2·8	3·1	3·1	3·0	2·8	2·8	2·9	3·2	3·2	3·0	2·7	2·8	2·8	2·8	2·6	2·6	2·5	2·1	1·8	1·6	1·6	1·3	0·9	0·7	0·4	0·2	0·1	31
Hotte Cheni	2·6	3·2	3·2	3·3	3·3	3·5	3·5	3·6	3·6	3·7	3·6	3·5	3·5	3·3	3·3	3·4	2·9	2·5	2·3	2·0	1·8			1·6	1·4	1·2	0·9	0·6	0·4	0·2	0·1	29
Dhor	2·5	2·9	3·0	3·2	3·2	3·0	2·7	2·6	2·6	2·6	2·5	2·4												1·9	1·8	1·6	1·2	0·8	0·4	0·2	0·1	20
Mojorah	3·1	3·6	3·9	4·4	4·2	4·2	4·3	4·2	4·2	3·8	3·4	3·3	3·3	3·0	2·8	2·5								2·2	1·9	1·6	1·6	1·0	0·5	0·2	0·1	24
Av. of group	2·7	3·1	3·3	3·4	3·4	3·5	3·5	3·4	3·4	3·3	3·2	3·1	3·0	2·8	2·8	2·7	2·4	2·3	2·2					2·1	1·9	1·7	1·3	0·8	0·4	0·2	0·1	27

E

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A

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B

D

D

K

K

N

P

R

S

A

Average Lengths of Successive Joints, 1916.

(Measurements in inches)

Saretha group				Number of joints
Baraukha	..	3·9 4·6 5·0 5·3 5·0 5·0 4·6 4·4 4·3 4·0 4·1 4·1 4·3 4·6 4·9 4·9 4·5 4·5 4·4 4·1 3·7 3·2 2·9 2·6	2·3 2·2 1·9 1·9 1·5 0·6 0·3 0·1	32
Ganda Cheni	..	4·0 4·4 5·0 5·5 5·4 5·1 4·9 4·9 4·6 4·7 4·9 4·9 5·0 5·2 5·1 4·5 3·9 3·8 3·4 3·2	2·6 2·2 1·7 1·3 0·8 0·4 0·2 0·1	28
Chun	..	3·4 4·1 4·7 4·7 4·8 4·6 4·6 4·7 4·4 4·1 3·5 3·6 3·5 3·5 3·5 3·2 3·1 3·0 2·8 2·5 2·4 2·7 3·0 3·0 2·6 2·3 2·1 1·9	1·7 1·4 1·5 1·2 1·0 0·5 0·3 0·1	36
Hullu Kabbu	..	4·4 4·5 4·9 5·2 5·1 5·1 5·2 5·4 5·4 5·6 5·2 4·9 4·8 4·6 4·2 4·2 4·0 3·5 3·0 2·7 2·3	2·1 2·2 2·1 1·9 0·9 0·4 0·2 0·1	29
Jaganathia	..	3·4 4·0 4·4 4·7 4·6 4·5 4·4 4·0 4·0 3·9 3·6 3·5 3·7 3·6 3·5 3·7 4·0 3·7 3·7 3·2 2·7 2·6 2·5	2·0 1·7 1·7 1· 1·0 0·5 0·2 0·1	31
Khari	..	3·5 3·9 4·0 4·2 3·9 3·8 4·1 4·5 4·4 4·6 4·5 4·4 4·0 4·3 3·9 4·1 3·9 3·8 3·4 3·0 2·6	2·1 1·9 1·5 1·2 0·9 0·5 0·2 0·1	29
Saretha	..	3·2 3·4 3·4 3·3 3·7 4·0 3·8 3·6 3·5 3·3 3·5 3·6 3·3 2·9 2·9 2·9 3·1 3·2 3·7 4·0 4·1 4·0 3·7 3·5 3·6 3·3 3·0 2·6 2·2 1·8 1·6 1·5 1·6 1·7	2·0 2·1 1·9 1·6 1·1 0·4 0·2 0·1	42
Av. of Group	..	3·7 4·1 4·5 4·7 4·6 4·6 4·5 4·5 4·4 4·3 4·2 4·1 4·1 4·1 4·0 3·9 3·8 3·7 3·5 3·3 3·1 2·9 2·7 2·5	2·3 2·0 1·8 1·5 1·0 0·5 0·2 0·1	32

Sunnabile group				
Binsa	..	3·0 3·3 3·5 3·3 3·5 3·7 3·8 3·7 3·5 3·4 3·4 3·5 3·4 3·3 3·2 3·5 3·4 3·4 3·3 3·4 3·3 3·2 3·1 3·0 2·9 2·7 2·6 2·5 2·5 2·4 2·3 2·2 2·1 2·1 2·0	1·9 1·6 1·6 1·3 0·8 0·4 0·2 0·1	43
Binsi	..	2·2 2·4 2·5 2·5 2·5 2·4 2·6 2·7 2·6 2·5 2·4 2·6 2·9 3·0 3·2 3·0 2·9 2·9 2·8 2·8 3·0 2·8 2·6 2·6 2·6 2·7 2·5 2·5 2·3 2·5 2·4 2·6 1·9 1·9	1·8 1·7 1·4 1·2 0·9 0·5 0·2 0·1	42
Dhor (Harrai)	..	2·6 2·8 3·1 3·3 3·2 3·2 3·0 3·0 3·3 3·0 2·9 3·1 3·1 3·1 3·1 3·1 3·2 3·3 3·1 2·9 2·7 2·7 2·6 2·6 2·6 2·7 2·6 2·4 2·3 2·2 2·3 2·5	2·3 2·2 2·1 1·5 0·9 0·5 0·2 0·1	40
Dhor (Seoni)	..	2·8 2·9 3·0 3·1 3·2 3·4 3·3 3·2 3·2 3·2 3·3 3·3 3·1 3·0 3·2 3·2 3·4 3·4 3·3 3·2 3·0 3·0 3·0 2·9 2·6 2·5 2·4 2·5 2·3 2·2 2·3 2·4 2·4 2·3	2·1 1·9 1·7 1·3 0·8 0·4 0·2 0·1	43
Kaghze	..	2·3 2·6 2·9 3·3 3·5 3·2 3·1 3·1 3·2 3·4 3·3 3·1 3·1 3·2 3·3 2·9 2·7 2·8 2·8 2·6 2·5 2·4 2·1 1·8 1·5 1·4 1·6 1·6 2·0 1·7 1·4	1·7 1·8 1·7 1·3 0·7 0·4 0·2 0·1	39
Ketari	..	2·5 2·8 3·3 3·6 3·6 3·8 3·8 3·5 3·5 3·4 3·4 3·4 3·2 3·0 3·1 3·0 2·8 2·9 2·7 2·5 2·3 2·2 2·3 2·0 2·1 2·0 2·0 2·0 2·4 2·1	2·1 2·0 1·8 1·3 0·8 0·4 0·2 0·1	38
Naanal	..	2·7 3·0 3·3 3·6 3·7 3·7 3·7 3·6 3·5 3·5 3·6 3·3 3·3 3·2 3·1 3·0 3·1 3·1 3·0 3·0 2·9 2·9 2·8 2·8 2·7 2·7 2·7 2·7 2·6 2·6 2·6 2·5 2·4 2·5	2·5 2·2 1·9 1·4 0·8 0·4 0·2 0·1	42
Puth Khajee	..	2·9 3·2 3·6 3·9 3·9 4·1 4·4 4·4 4·4 4·5 4·5 4·3 4·2 4·3 4·3 4·5 4·4 4·2 4·2 3·9 3·5 3·4 3·2 2·8 2·6 2·4 2·3	2·3 2·1 1·8 1·4 0·8 0·5 0·2 0·1	35
Rakhra	..	2·2 2·4 3·0 3·0 3·1 3·3 3·5 3·6 3·6 3·4 3·2 3·1 3·2 3·1 2·9 2·8 2·9 3·0 3·0 2·9 3·1 3·0 2·8 2·7 2·6 2·6 2·5 2·5 2·4 2·4 2·3 2·3	2·3 2·1 1·8 1·4 0·8 0·4 0·2 0·1	40
Sunnabile	..	2·8 2·7 2·8 3·0 3·1 2·9 2·8 2·7 2·7 2·8 2·7 2·5 2·5 2·6 2·7 2·8 2·8 2·8 2·9 2·9 2·8 2·8 2·7 2·8 2·8 2·5 2·5 2·3 2·4 2·1 2·1 2·1 2·2 2·3 2·2 2·0	1·8 1·8 1·8 1·6 0·9 0·4 0·2 0·1	44
Av. of Group	..	2·6 2·8 3·1 3·3 3·3 3·4 3·4 3·3 3·3 3·3 3·3 3·2 3·2 3·2 3·2 3·2 3·2 3·2 3·2 3·1 3·0 2·9 2·8 2·7 2·6 2·5 2·3 2·3 2·3 2·1 2·0 2·0 2·2 2·0	2·1 1·9 1·7 1·4 0·8 0·4 0·2 0·1	41

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Average lengths of successive leaf-sheaths. Varieties of the Saretha Group, 1917.

(Measurements in inches)

																																			Number of sheaths
Katha section																																			
Rakst ..	11·9	12·3	12·5	12·3	12·2	12·3	11·9	11·7	11·4	11·0	11·0	11·1	10·5	10·2	10·0	9·8	9·7	9·6	9·4	9·2	9·1						9·1	9·0	8·8	8·6	6·8	1·8	0·3	0·1	29
Katha ..	10·7	11·2	11·5	11·9	12·0	12·1	11·8	11·5	11·3	11·0	11·1	10·9	10·8	10·6	10·2	9·8	9·4	9·1	9·1	9·2	9·2	9·1	9·0				8·7	8·7	7·6	4·7	1·9	0·6	0·2	0·1	31
Ramui ..	9·2	10·4	10·8	10·9	10·9	11·0	11·1	11·0	11·0	10·7	10·7	10·9	10·7	11·0	10·9	10·7	10·6	10·4	10·2								10·0	9·6	8·6	8·4	7·4	3·4	0·5	0·2	27
Lalri ..	10·8	11·0	11·6	11·6	12·0	12·0	12·0	12·0	11·9	11·5	11·3	10·9	11·3	10·9	11·0	10·5	11·0	10·8	10·5	10·6							10·6	10·3	9·1	8·0	5·5	1·6	0·3	0·1	28
Chun ..	10·6	11·0	11·0	11·1	11·3	11·2	11·1	10·9	10·7	10·7	10·3	10·1	10·0	9·8	9·8	9·6	9·5	9·4	9·3	9·2	9·0	9·0	8·6	8·8	8·7	8·5	8·4	7·7	7·7	7·9	5·5	2·6	0·2	0·1	34
Chunnee ..	9·5	10·3	10·9	11·4	11·6	11·6	11·6	11·4	11·3	11·0	10·8	10·5	10·0	9·9	9·6	9·1	9·1	9·0	9·0	8·7	8·6	8·7	8·7	8·3	7·9		7·6	7·4	6·8	6·5	6·7	2·9	0·3	0·1	33
Barmukha ..	10·7	11·3	12·1	12·1	12·5	12·7	12·6	12·4	12·5	12·6	12·7	12·8	12·5	12·2	12·2	12·3	12·2	12·6	11·9	11·7							11·6	10·7	9·5	8·0	4·0	0·7	0·2	0·1	28
Kansar ..	11·1	11·9	12·5	12·7	12·9	13·0	12·6	12·5	12·3	12·3	12·4	12·1	11·6	11·3	11·3	11·4	11·3	11·4	11·2	11·1							11·2	10·4	9·8	8·6	4·3	1·0	0·2	0·1	28
Chynia ..	10·9	11·8	12·5	12·6	13·1	12·5	12·8	12·5	12·4	12·6	12·3	12·6	12·8	12·3	12·2	12·2	12·4	12·5	12·2	11·8							11·6	11·3	10·3	8·8	6·0	1·8	0·2	0·1	28
Burra Chunnee ..	12·7	13·0	13·1	13·3	13·4	13·6	13·4	13·2	13·1	13·2	13·2	13·2	12·8	12·7	12·6	12·6	12·6	13·0	12·9	12·5	12·5	12·7	12·7	12·3	12·2		12·1	10·9	9·9	8·6	4·2	0·7	0·2	0·1	33
Av. of section ..	10·8	11·4	11·8	11·9	12·2	12·2	12·1	11·9	11·8	11·7	11·6	11·5	11·3	11·1	11·0	10·8	10·8	10·7	10·6	10·4	10·2	10·1					10·1	9·6	8·8	7·8	5·2	1·7	0·3	0·1	30
Mesangan section																																			
Mesangan ..	12·1	13·3	14·4	14·8	15·1	15·4	14·9	14·6	13·9	13·7	14·2	14·3	13·8	13·1	12·7	12·1	12·2	12·3	12·4	12·3	12·0						11·6	11·2	9·9	8·7	4·1	0·5	0·3	0·1	29
Saretha ..	10·8	11·4	11·7	12·3	12·5	12·9	13·3	13·3	13·2	13·3	13·4	13·3	12·9	12·6	12·4	12·2	11·8	11·6	11·5	11·4	11·4	11·2	11·3	11·2	11·1		11·0	10·5	9·9	7·8	3·0	0·8	0·3	0·1	33
Jaganathia ..	11·2	11·0	12·3	13·0	13·3	13·5	13·7	13·0	13·4	13·4	13·2	12·8	13·0	13·0	13·2	13·1	12·8										12·6	11·6	11·7	11·5	6·8	0·9	0·2	0·1	25
Khari ..	11·7	12·3	12·5	12·6	12·7	12·9	12·9	13·2	13·3	13·0	12·9	12·6	12·5	12·5	12·5	12·4	12·2	12·2	12·4	12·2							12·0	12·0	11·3	9·8	4·8	0·7	0·2	0·1	28
Hullu Kabbu ..	10·8	11·3	11·6	12·3	12·7	13·2	13·2	13·3	13·7	13·5	13·5	13·0	13·4	12·8	13·1	12·4											12·7	12·2	11·0	9·1	4·8	0·9	0·2	0·1	24
Ganda Cheni ..	12·5	13·0	13·6	14·1	14·4	14·8	14·9	15·2	15·0	14·6	14·1	14·8	14·5	14·7	14·2	14·0	14·2	14·3									14·8	13·5	12·9	11·5	5·3	0·6	0·2	0·1	26
Av. of section ..	11·5	12·0	12·7	13·2	13·4	13·8	13·8	13·8	13·8	13·6	13·5	13·4	13·3	13·1	13·0	12·7	12·6	12·6	12·5	12·5							12·4	11·8	11·1	9·7	3·8	0·7	0·2	0·1	28
Av. of group ..	11·1	11·7	12·2	12·4	12·7	12·8	12·7	12·6	12·5	12·4	12·3	12·2	12·1	11·8	11·7	11·5	11·4	11·3	11·2	11·2	11·1	11·1					11·0	10·4	9·7	8·5	5·1	1·3	0·2	0·1	29

Teru
Ekar
Dhaulu
Rakhra
Kaghze
Ketari
Bansa
Bansi
Sunnabi
Putli Kl
Khadya
Naanal
Hotte C
Dhor
Mojorali
Av. of g

Average lengths of successive leaf-sheaths. Varieties of Sunnabile Group, 1917.

(In some cases too many leaf-sheaths were missing for reliable figures to be obtained.)
(Measurements in inches)

																																			Number of sheaths
Teru ..	10·3	10·8	11·1	11·1	11·2	10·8	10·9	11·0	11·2	11·3	11·3	11·1	10·4	9·9	9·8	9·7	9·4	9·0	8·9	8·4	8·5						8·5	7·9	7·1	5·7	2·2	0·5	0·2	0·1	29
Ekar ..	11·8	12·1	12·6	12·6	12·0	12·4	12·4	12·4	12·5	12·7	12·5	12·5	12·3	12·0	11·8	11·7	11·8	12·1	12·2	12·0	11·7	11·8	11·9				12·4	12·3	11·1	5·6	1·0	0·5	0·2	0·1	31
Dhaulu ..	11·3	11·7	12·0	12·4	12·4	12·8	12·9	12·5	12·4	12·3	12·2	12·4	12·6	12·4	12·0	11·5	11·4	11·4	11·7	11·5	11·4	11·0	11·4	10·9			10·6	10·4	9·5	6·7	2·3	0·5	0·3	0·1	32
Rakhra ..	11·3	12·4	13·1	13·2	13·2	13·1	13·0	13·0	13·1	13·2	13·3	13·3	13·0	12·8	12·7	12·6	12·4	12·6	12·2	12·4	12·5						12·3	12·1	11·2	7·2	1·5	0·4	0·2	0·1	29
Kaghzo ..	11·4	11·7	12·0	12·1	12·3	12·5	12·5	12·1	12·0	12·0	11·9	11·9	11·8	11·9	12·0	12·0	11·9	11·8	12·3	12·3	12·2	12·0					12·6	12·5	9·9	3·9	0·8	0·4	0·2	0·1	30
Ketari ..																																			
Bansa ..																																			
Bansi ..	10·0	10·6	11·3	11·4	10·9	11·1	11·2	11·1	11·2	11·3	11·5	11·3	11·3	11·2	11·4	11·0	11·3	11·4	11·5	11·4	11·1	10·8					10·2	9·8	8·8	5·5	1·8	0·5	0·3	0·1	30
Sunnabile ..	11·1	11·2	11·4	11·5	11·6	11·4	11·1	10·6	10·8	11·1	11·0	11·2	11·0	10·4	10·1	10·2	10·5	10·6	10·2	10·6	10·4	10·2	10·1	10·5			10·0	10·1	8·5	4·8	1·3	0·6	0·2	0·1	32
Puth Khajoo ..																																			
Khadya ..	11·3	11·3	11·3	11·3	11·5	11·5	11·6	11·5	11·5	11·3	11·2	11·2	11·0	11·2	11·2	11·2	11·2	11·0	10·8	10·7	10·7	10·8	10·8	10·5	10·3	10·1	9·9	9·7	9·7	8·2	3·5	0·7	0·3	0·1	34
Naanal	10·4	11·1	12·5	12·4	12·8	12·8	12·9	12·8	12·8	12·6	12·5	12·5	12·4	12·3	12·3	12·4	12·6	12·3	12·2	12·1	12·1	12·0	12·1	11·9	11·7	11·4	11·2	10·6	9·3	6·2	1·8	0·5	0·2	0·1	34
Hotte Cheni ..	12·9	12·9	13·0	13·2	13·2	13·1	12·6	12·4	12·2	12·3	12·4	12·6	12·6	12·5	12·5	12·2	12·0	11·6	11·9	12·3	12·1	12·0	11·9				11·8	11·4	10·2	7·1	2·5	0·8	0·3	0·1	31
Dhor ..	10·8	11·4	11·5	11·8	11·6	11·6	11·7	11·7	11·3	11·4	11·1	10·9	10·6	10·3	10·0	9·3											9·9	10·0	9·3	7·9	4·7	1·5	0·4	0·1	24
Mojorah ..	14·6	15·2	15·8	15·7	15·3	15·2	14·9	14·9	14·3	14·2	14·0	14·1	14·4	14·4	14·6	14·4	13·9	13·9	13·8	13·9							13·6	12·8	11·4	6·0	1·5	0·6	0·2	0·1	28
Av. of group ..	11·4	11·9	12·3	12·4	12·4	12·4	12·5	12·2	12·1	12·1	12·1	12·2	11·9	11·8	11·7	11·5	11·7	11·6	11·6	11·5	11·3	11·3					11·1	10·8	9·7	6·2	2·1	0·6	0·2	0·1	30

Note. There appears to be a tendency to periodicity in the first few varieties. A second maximum has been inserted by changing 12·1 to 12·2.

																Number of sheaths
Saret																
Buraukl								10·0	9·8	8·6	7·7	6·4	3·4	0·7	0·1	34
Ganda								13·4	12·8	11·3	9·4	4·6	0·6	0·2	0·1	32
Chin								8·9	9·1	8·8	8·3	5·9	1·4	0·4	0·1	39
Hullu K								11·4	11·6	11·7	9·7	5·2	0·7	0·2	0·1	32
Jaganat								11·6	11·6	11·4	10·1	7·2	1·5	0·2	0·1	34
Khari								11·0	10·4	9·5	8·2	3·2	0·5	0·2	0·1	31
Saretha	1·2	11·3	11·4	11·3	11·1			10·5	10·3	9·6	8·4	3·6	0·7	0·2	0·1	46
Av. of g								11·0	10·8	10·1	8·8	5·2	1·3	0·3	0·1	35
Sunna																
Bansa	1·8	11·7	11·4	11·2	11·0	10·8	10·6	10·3	9·9	9·4	7·8	3·2	0·7	0·2	0·1	48
Bansi	0·5	10·3	10·1	9·9	9·7			9·5	9·1	8·3	7·9	4·8	1·5	0·3	0·1	46
Dhor (H	1·8	11·6	11·3	11·0				10·7	10·1	9·5	8·0	3·0	0·5	0·2	0·1	45
Dhor (S	2·6	12·4	12·2	12·0				11·7	11·2	10·3	7·6	3·2	0·6	0·2	0·1	45
Kaghze	0·6	10·4						10·4	9·8	8·6	5·9	2·3	0·6	0·2	0·1	43
Ketari	8·7	8·9						9·1	9·1	8·5	6·8	3·5	1·3	0·3	0·1	43
Naanal	2·1	12·4	12·6	12·4	12·2	12·0		11·9	11·3	10·2	6·7	1·9	0·4	0·2	0·1	47
Putli K								12·6	12·1	11·8	10·4	4·2	0·6	0·2	0·1	40
Rakhra	0·4	10·5						10·0	9·9	9·1	6·3	0·9	0·4	0·2	0·1	43
Sunnab	0·9	11·1	11·1	11·2	11·2	10·8		10·6	10·6	10·4	9·2	5·2	1·3	0·3	0·1	47
Av. of g	0·9	10·7	10·8	10·9				10·7	10·3	9·6	7·7	3·3	0·8	0·2	0·1	45

Average lengths of successive leaf-sheaths, 1916.

(Measurements in inches)

Variety		Successive leaf-sheaths		Number of sheaths
Saretha group				
Buraukha	..	12·3 12·3 12·3 12·3 12·5 12·2 12·4 12·5 12·4 12·2 11·8 11·5 11·3 11·3 11·4 11·4 11·5 11·7 11·8 11·8 11·5 11·3 11·2 10·8 10·5 10·6	10·0 9·8 8·6 7·7 6·4 3·4 0·7 0·1	34
Ganda Cheni	..	13·0 14·0 14·5 14·9 15·2 13·5 15·3 15·3 14·8 14·5 14·5 14·5 14·4 14·6 14·7 14·9 14·7 14·8 14·6 14·3 14·2 13·9 14·0 13·8	13·4 12·8 11·3 9·4 4·6 0·6 0·2 0·1	32
Chin	..	9·0 10·1 10·2 10·6 10·8 11·0 10·3 10·9 10·7 10·5 10·2 10·0 9·9 9·6 9·5 9·3 9·1 9·2 9·3 9·3 9·2 9·2 9·1 9·0 9·1 9·1 9·2 9·3 9·3 9·3 9·4	8·9 9·1 8·8 8·3 5·9 1·4 0·4 0·1	39
Hullu Kabbu	..	15·2 14·6 14·4 14·6 14·6 14·4 14·4 14·4 14·4 14·1 14·0 14·0 13·9 13·7 13·7 13·9 13·6 13·4 13·5 13·3 12·9 12·8 12·3 12·3	11·4 11·6 11·7 9·7 5·2 0·7 0·2 0·1	32
Jaganathia	..	11·8 12·2 13·0 13·3 13·7 14·0 14·3 14·0 13·8 13·4 12·7 12·8 12·5 12·2 11·9 12·2 12·2 11·9 12·4 12·7 12·4 12·3 12·0 11·7 11·6 11·4	11·6 11·6 11·4 10·1 7·2 1·5 0·2 0·1	34
Khari	..	11·9 12·8 13·2 13·0 13·3 13·5 13·4 13·1 12·9 13·0 13·0 12·9 13·2 13·1 12·6 12·4 12·8 13·1 13·2 13·0 12·7 12·8 12·7	11·0 10·4 9·5 8·2 3·2 0·5 0·2 0·1	31
Saretha	..	12·0 12·0 12·4 12·2 12·2 12·6 12·4 12·5 12·8 12·8 12·4 12·8 12·5 12·3 12·3 12·1 11·7 11·5 11·2 11·4 11·3 11·3 11·5 12·0 12·1 12·2 12·2 12·1 12·1 11·9 11·7 11·3 11·2 11·2 11·3 11·4 11·3 11·1	10·5 10·3 9·6 8·4 3·6 0·7 0·2 0·1	46
Av. of group	..	12·2 12·6 12·9 13·0 13·2 13·3 13·2 13·2 13·1 12·9 12·7 12·6 12·5 12·4 12·3 12·3 12·2 12·2 12·3 12·3 12·0 11·9 11·8 11·6 11·5 11·4 11·2	11·0 10·8 10·1 8·8 5·2 1·3 0·3 0·1	35
Sunnabile group				
Bansa	..	12·0 12·1 12·0 12·1 12·3 12·3 12·4 12·4 12·7 12·7 12·4 12·5 12·3 12·3 12·3 12·1 11·9 11·6 11·8 12·1 12·3 12·4 12·2 12·4 12·3 12·1 11·9 11·8 11·7 11·6 11·2 11·2 11·5 11·8 11·7 11·4 11·2 11·0 10·8 10·6	10·3 9·9 9·4 7·8 3·2 0·7 0·2 0·1	48
Bansi	..	8·9 8·9 8·9 8·8 8·9 8·9 9·1 9·1 9·1 9·3 9·6 9·6 9·6 9·7 9·9 9·9 10·1 10·5 10·5 10·4 10·6 10·5 10·6 10·8 10·8 10·6 10·6 10·7 10·8 10·7 10·7 10·9 10·7 10·5 10·3 10·1 9·9 9·7	9·5 9·1 8·3 7·9 4·8 1·5 0·3 0·1	46
Dhor (Harrai)	..	10·5 10·8 11·0 10·8 11·1 11·1 11·4 11·5 11·5 11·3 11·0 11·1 11·3 11·2 11·3 11·1 11·2 11·4 11·7 11·7 11·6 11·7 11·7 11·6 11·4 11·3 11·4 11·4 11·4 11·6 11·6 11·8 11·7 11·8 11·6 11·3 11·0	10·7 10·1 9·5 8·0 3·0 0·5 0·2 0·1	45
Dhor (Sooni)	..	11·1 11·1 11·5 11·8 12·2 11·7 11·7 12·3 12·4 12·4 12·0 12·1 12·1 12·4 12·1 12·3 12·5 12·4 12·6 12·6 12·7 12·8 12·8 12·6 12·8 12·5 12·3 12·2 12·2 12·0 12·4 12·4 12·6 12·6 12·4 12·2 12·0	11·7 11·2 10·3 7·6 3·2 0·6 0·2 0·1	47
Kaghzo	..	12·2 12·1 12·5 12·4 12·7 12·6 12·9 13·1 13·1 13·1 13·0 13·1 13·0 13·0 12·5 12·5 12·5 12·5 12·5 12·6 12·5 12·3 12·3 12·3 12·1 12·1 12·2 12·1 11·8 11·5 11·2 10·9 10·8 10·6 10·4	10·4 9·8 8·6 5·9 2·3 0·6 0·2 0·1	43
Ketari	..	10·8 11·2 11·4 11·2 11·1 10·9 10·7 10·5 10·6 10·7 10·8 10·8 10·9 11·2 11·2 11·2 11·3 11·6 11·4 11·5 11·3 11·1 11·0 10·7 10·5 10·5 10·4 10·4 10·0 9·8 9·4 8·8 8·4 8·7 8·9	9·1 9·1 8·5 6·8 3·5 1·3 0·3 0·1	43
Naanal	..	12·1 12·5 13·0 13·3 13·3 12·9 13·2 13·4 13·5 13·6 13·4 13·3 13·3 13·1 13·1 12·8 12·8 12·9 12·9 12·8 12·9 12·7 12·6 12·6 12·6 12·5 12·4 12·2 11·9 11·6 11·4 11·4 11·8 12·1 12·4 12·6 12·4 12·2 12·0	11·9 11·3 10·2 6·7 1·9 0·4 0·2 0·1	47
Puth Khajee	.	12·9 13·0 13·4 13·6 13·7 14·1 14·0 14·2 13·9 14·1 13·8 13·5 13·3 13·1 13·1 12·7 13·4 13·0 14·1 14·5 14·4 14·3 14·1 13·8 13·9 13·7 13·6 13·6 13·3 13·0 12·6 13·0	12·6 12·1 11·8 10·4 4·2 0·6 0·2 0·1	40
Rakhra	..	10·4 10·8 10·8 11·0 11·4 11·3 11·4 11·2 11·3 11·4 11·3 11·3 11·3 11·1 11·1 11·2 11·6 11·5 11·2 11·4 11·5 11·3 11·5 11·5 11·4 11·4 11·2 11·0 10·9 10·6 10·4 10·2 10·2 10·4 10·5	10·0 9·9 9·1 6·3 0·9 0·4 0·2 0·1	43
Sunnabile	..	10·2 10·3 10·1 10·4 10·3 10·3 10·3 10·7 10·3 10·6 10·5 10·6 10·7 10·7 10·6 10·7 10·8 11·0 11·0 11·1 11·1 11·1 11·0 11·1 11·0 11·0 11·0 11·2 11·1 11·1 11·0 11·0 11·1 10·9 11·1 11·1 11·2 11·2 10·8	10·6 10·6 10·4 9·2 5·2 1·3 0·3 0·1	47
Av. of group	..	11·1 11·3 11·5 11·5 11·7 11·6 11·7 11·8 11·8 11·9 11·8 11·8 11·8 11·8 11·7 11·6 11·8 11·9 12·0 12·1 12·1 12·0 12·0 11·9 11·9 11·8 11·7 11·7 11·5 11·3 11·3 11·3 11·1 10·9 10·7 10·8 10·9	10·7 10·3 9·6 7·7 3·3 0·8 0·2 0·1	45

In considering the maxima it is evident that there is distinct periodicity in the growth here.

aminas, 1

nches)

3′ 11″	
4′ 0″	4′
4′ 9″	4′
4′ 6″	4′
4′ 7″	4′ (
4′ 1″	4′
3′ 5″	3′ (
4′ 3″	4′ :
4′ 9″	4′ 9
3′ 11″	4′ (
3′ 4″	3′ 3
4′ 0″	4′ 0
4′ 7″	4′ 7
3′ 10″	3′ 10
3′ 7″	3′ 7
4′ 0″	4′ 0

Average lengths of successive laminas, 1916.

(Measurements in feet and inches.)

Sarotha group

	Successive laminas		Number of laminas
Larokha..	2' [illegible] 3' 2" 3' 4" 3' 8" 3' 10" 4' 0" 4' 0" 4' 1" 4' 3" 4' 4" 4' 5" 4' 6" 4' 7" 4' 6" 4' 6" 4' 6" 4' 5" 4' 4" 4' 3" 4' 5" 4' 5" 4' 5" 4' 5" 4' 5" 4' 4" 4' 2" 4' 1" 3' 11"	3' 9" 3' 7" 3' 4" 3' 1" [illegible] 2' 1" [illegible]	35
Ganda Chotti ..	3' 1" 3' 8" 4' 1" 4' 4" 4' 9" 4' 11" 5' 1" 5' 2" 5' 2" 5' 2" 5' 2" 5' 2" 5' 1" 5' 2" 5' 3" 5' 4" 5' 5" 5' 6" 5' 6" 5' 6" 5' 6" 5' 7" 5' 6" [illegible]	5' 2" 4' 11" 4' [illegible] 4' 1" 2' [illegible]	[illegible]
Chin ..	3' 0" 2' 6" 2' 10" 3' 1" 3' 5" 3' 8" 3' 9" 3' 10" 4' 0" 4' 0" 4' 1" 4' 1" 4' 1" 4' 1" 4' 0" 4' 1" 4' 0" 4' 1" 4' 1" 4' 1" 4' 0" 4' 0" 4' 0" 4' 1" 4' 1" 4' 1" 4' 1" 4' [illegible] 4' 0" 4' 0" 4' 0" 4' [illegible]	3' 9" 3' 10" 3' [illegible] 2' 4" [illegible]	[illegible]
Hallu Kandu ..	3' 10" 3' 4" 3' 8" 3' 11" 4' 2" 4' 6" 4' 8" 4' 8" 4' 9" 4' 10" 4' 11" 5' 0" 5' 0" 4' 11" 5' 0" 5' 1" 5' 2" 5' 2" 5' 2" 5' 3" [illegible] 4' 9"	4' 9" 4' 7" 4' [illegible] 4' 1" [illegible] 2' 4" [illegible]	34
Jaganath ..	[illegible] 4' 0" 4' 3" 4' 7" 4' 8" 4' 9" 4' 9" 4' 10" 4' 10" 4' 11" 4' 9" 4' 9" 4' 9" 4' 9" 4' 9" 4' 8" 4' 9" 4' 9" 4' 10" 4' 10" 4' 10" 4' 11" 4' 10" 4' 9" 4' 9" 4' 8" 4' 7"	4' 6" 4' 5" 4' [illegible] 2' [illegible]	37
Khari ..	3' 8" 3' 11" 4' 2" 4' 4" 4' 7" 4' 9" 4' 10" 4' 10" 4' 11" 5' 0" 5' 0" 5' 0" 5' 0" 4' 11" 5' 0" 5' 1" 5' 0" [illegible] 5' 0" 5' 0" [illegible] 5' 1" 5' 01 [illegible] 2	4' 11" 4' 7" 4' 3" [illegible]	[illegible]
Sarotha ..	2' 6" 3' 0" 3' 2" 3' 5" 3' 6" 3' 7" 3' 8" 3' 9" 3' 11" 4' 0" 4' 1" 4' 3" 4' 2" 4' 2" 4' 3" 4' 3" 4' 3" 4' 3" 4' 3" 4' 3" 4' 1" 4' 1" 4' 1" 4' 1" 4' 1" 4' 2" 4' 4" 4' 6" 4' 5" 4' 5" 4' 6" 4' 5" [illegible] 4' 4" 4' 3" 4' 3" 4' 3" 4' 4" 4' 5"	3' 11" 3' 10" 3' 8" 3' 1" [illegible]	[illegible]
Av. of group	3' 1" 3' 3" 3' 6" 3' 9" 4' 0" 4' 3" 4' 4" 4' [illegible] 4' 6" 4' 7" 4' 8" 4' 7" 4' 8" 4' 8" 4' 8" 4' 9" 4' 9" 4' 9" 4' 9" 4' 8" 4' 9" 4' 9" 4' 9" 4' 9" 4' 8" 4' 7" 4' 7" 4' 6" 4' 6"	4' 5" 4' 3" 4' 6" [illegible] 2' 2" [illegible]	[illegible]

Sunnabile group

	Successive laminas		Number of laminas
Bansa ..	2' 10" 3' 0" 3' 2" 3' 5" 3' 8" 3' 9" 3' 10" 3' 11" 4' 0" 4' 1" 4' 2" 4' 1" 4' 2" 4' 4" 4' 4" 4' 1" 4' 1" 4' 0" 4' 0" 3' 11" 4' 0" 3' 11" 4' 0" 4' [illegible] 4' 2" 4' 1" 4' [illegible] 4' 1" 4' 1" 4' 1" 4' 1" 4' 0" 4' 0" 3' 11" 3' 1[illegible] 3' 11" 4' 0" 3' 10" 3' 10" 3' 10" 3' 10"	3' [illegible] 3' 3" 3' 1" 2' [illegible] 2' [illegible] 1' [illegible]	[illegible]
Bansi ..	2' 6" 2' 8" 2' 10" 2' 10" 2' 10" 2' 10" 3' 0" 2' 11" 3' 0" 3' 1" 3' 0" 3' 0" 3' 1" 3' 1" 3' 2" 3' 2" 3' 2" 3' 3" [illegible] 3' 4" 3' 1" [illegible] 3' 6" 3' 6" 3' 6" 3' [illegible] 3' 5" 3' 6" 3' 6" [illegible] 3' 6" 3' 6" 3' 7" 3' 6" 3' 8" 3' 8" 3' 7" 3' 7" 3' 6"	2' 11" 2' 8" 2' 6" 2' 4" 2' [illegible] 1' 8" 1' [illegible]	[illegible]
Dhor (Harrai) ..	2' 10" 3' 1" 3' 3" 3' 5" 3' 6" 3' 8" 3' 9" 3' 10" 3' 11" 4' 1" 4' 1" 4' 2" 4' 2" 4' 3" 4' 2" 4' 1" 4' 0" 4' 0" 4' 0" 4' 1" 4' 1" 4' 1" 4' 2" 4' 2" 4' 2" 4' 2" 4' 1" 4' 2" 4' 1" 4' [illegible] 4' 2" 4' 2" 4' 2" 4' [illegible] 4' 3" 4' 3" 4' 4" 4' 4" 4' 4" 4' 4" 4' 4"	3' 9" 3' 6" 3' 4" 3' 1" 2' 6" 1' 10" 1' [illegible]	[illegible]
Dhor (Seoni) ..	3' 1" 3' 3" 3' 6" 3' 9" 4' 0" 4' 2" 4' 3" 4' 5" 4' 5" 4' 6" 4' 6" 4' 7" 4' 8" 4' 7" 4' 7" 4' 6" 4' 7" 4' 7" 4' 6" 4' 7" 4' 7" 4' 7" 4' 8" 3' 7" 4' 8" 4' 8" 4' 8" 4' 8" 4' 8" 4' 9" 4' 9" 4' [illegible] 4' 9" 4' 8" 4' 7" 4' 6" 4' [illegible] 4' 5" 4' [illegible] 4' 6" 4' 6" 4' 7"	4' 2" 4' 0" 3' 8" 3' 4" 2' 10" 2' [illegible] 1' [illegible]	47
Kolta ..	2' 1" 2' 6" 2' 9" 3' 0" 3' 2" 3' 3" 3' 5" 3' 7" 3' 8" 3' 9" 3' 11" 4' 0" 4' 2" 4' 2" 4' 2" 4' 1" 4' 0" 3' 11" 4' 1" 4' 0" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 4' 0" 3' 11" 4' 1" [illegible] 3' 11" 3' 11" 3' 11"	3' 7" 3' 4" [illegible] 2' 1" 2' [illegible] 1' [illegible]	[illegible]
Kotari ..	2' 2" 2' 7" 2' 9" 2' 9" 2' 9" 3' 0" 3' 0" 3' 1" 3' 1" 3' 2" 3' 2" 3' 2" 3' 2" 3' 2" 3' 3" 3' 4" 3' 4" 3' 4" 3' 4" 3' 5" 3' 6" 3' 7" 3' 7" 3' 7" 3' 1" 3' [illegible] [illegible] 3' 4" 3' 4" 3' 3" 3' 3" 3' 4" 3' 4" 3' 2" 3' 1" 3' 0" 3' 0" 2' 11	2' 4" 2' 3" 2' [illegible] 2' 2" 1' [illegible] 1' [illegible]	[illegible]
Nimnal ..	2' 1" 2' 7" 2' 11" 3' 2" 3' 6" 3' 9" 3' 10" 3' 11" 4' 0" 4' 1" 4' 2" 4' 1" 4' 2" 4' 2" 4' 2" 4' 1" 4' 2" 4' 1" 4' 1" 4' 2" 4' 1" 4' 1" 4' 1" 4' 1" 4' 1" 4' 1" 4' 0" 4' 0" 4' 0" 4' 0" 4' 0" 3' 11" 4' 0" 4' 0" 4' 1" 4' 1" 3' 11" 3' 11" 3' 11" 3' [illegible] 3' 10"	3' 11" 3' 10" 3' 6" [illegible] 2' 7" 1' [illegible]	[illegible]
Puth Khajee ..	3' 5" 3' 7" 3' 11" 4' 0" 4' 2" 4' 4" 4' 5" 4' 6" 4' 8" 4' 8" 4' 7" 4' 7" 4' 6" 4' 6" 4' 6" 4' 5" 4' [illegible] 4' 5" 4' 4" 4' 4" 4' 5" 4' 5" 4' 6" 4' 7" 4' 9" 4' 9" 4' 8" 4' 8" 4' 7" 4' [illegible] 4' 7" 4' 6" 4' 6" 4' 6" 4' 5"	4' 6" 4' 3" 4' 0" 3' 9" 3' 0" 2' [illegible] 1' [illegible]	[illegible]
P[illegible] ..	2' 0" 2' 0" 2' 4" 2' 6" 2' 10" 3' 0" 3' 2" 3' 3" 3' 4" 3' 5" 3' 6" 3' 6" 3' 7" 3' 7" 3' 7" 3' 7" 3' 7" 3' 7" 3' 8" 3' 8" 3' 9" 3' 9" 3' 9" 3' 10" 3' 10" 3' 10" 3' [illegible] 3' 9" 3' 10" 3' 10" 3' 9" 3' 10" 3' 9" 3' 10" 3' 9" 3' [illegible] 3' 9" 3' 8" 3' 9" 3' 09 3' 08 3' 06	3' 3" 3' 2" 3' 0" 2' 9" 2' 1" [illegible]	[illegible]
Sunnabile ..	2' 3" 2' 7" 2' 10" 2' 11" 3' 0" 3' 2" 3' 1" 3' [illegible] 3' 4" 3' 5" 3' 5" 3' 5" 3' 6" 3' 7" 3' 7" 3' 8" 3' 7" 3' 8" 3' 8" 3' 7" 3' 7" 3' 8" 3' 8" 3' 8" 3' 8" 3' 8" 3' 8" 3' 8" 3' 8" 3' 7" 3' 7" 3' 6" 3' 7" 3' 6" 3' 6" 3' 6" 3' 6" 3' 5" 3' 5" 3' 5" 3' 5" 3' 5" 3' 4"	3' 3" 3' 1" 3' 0" 2' 10" 2' [illegible] 2' 0" 1' [illegible]	47
Av. of group ..	2' 6" 2' 9" 3' 0" 3' 2" 3' 4" 3' 6" 3' 7" 3' 8" 3' 9" 3' 10" 3' 10" 3' 10" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" 3' 11" [illegible] 4' 0" 4' 0" 4' 0" 4' [illegible] 4' 0" 4' 0" 4' 0" 4' [illegible] 3' [illegible] 4' [illegible] 3' 11" 3' 11" 3' 11" 3' 10" 3' 9" 3' 9" 3' 8" 3' 7"	3' 6" 3' 4" 3' 2" 2' 11" 2' 0" 1' 8" 1' [illegible]	[illegible]

											Number of laminas
Ka											
Raksi			3′ 7″	3′ 6″	3′ 6″	3′ 5″	3′ 4″	3′ 1″	2′ [illegible]	1′ [illegible]	29
Katha			3′ 6″	3′ 4″	3′ 3″	3′ 1″	2′ 9″	2′ 4″	1′ 9″	1′ 1″	31
Ramu			4′ 1″	4′ 1″	3′ 11″	3′ 8″	3′ 5″	3′ 1″	2′ 5″	1′ 11″	27
Lalri			4′ 2″	4′ 3″	4′ 2″	4′ 1″	3′ 10″	3′ 4″	2′ 6″	1′ 8″	28
Chin	3′ 7″	3′ 8″	3′ 8″	3′ 8″	3′ 6″	3′ 4″	3′ 1″	2′ 10″	2′ 3″	1′ 7″	34
Chun	3′ 4″		3′ 4″	3′ 4″	3′ 2″	3′ 0″	2′ 9″	2′ 7″	2′ 2″	1′ 7″	33
Barat			4′ 0″	3′ 11″	3′ 8″	3′ 4″	2′ 10″	2′ 5″	1′ 11″	1′ 6″	28
Kans			4′ 5″	4′ 5″	4′ 6″	4′ 4″	3′ 11″	3′ 3″	2′ 5″	1′ 6″	28
Chyn			4′ 3″	4′ 2″	4′ 0″	3′ 11″	3′ 7″	3′ 1″	2′ 6″	1′ 10″	28
Burra	4′ 9″		4′ 11″	5′ 0″	4′ 10″	4′ 6″	4′ 0″	3′ 4″	2′ 5″	1′ 7″	33
Saretl											
Av. o			4′ 0″	4′ 0″	3′ 10″	3′ 8″	3′ 4″	2′ 11″	2′ 3″	1′ 7″	30
Mes											
Mesa			3′ 11″	3′ 9″	3′ 8″	3′ 7″	3′ 3″	2′ 7″	2′ 1″	1′ 6″	29
Saret	3′ 10″		3′ 9″	3′ 7″	3′ 6″	3′ 4″	3′ 1″	2′ 8″	2′ 2″	1′ 8″	33
Jagar			4′ 11″	4′ 11″	4′ 11″	4′ 10″	4′ 7″	4′ 0″	3′ 1″	2′ 2″	25
Khar			5′ 0″	4′ 11″	4′ 11″	4′ 10″	4′ 3″	3′ 7″	3′ 0″	2′ 1″	28
Hullu			5′ 1″	5′ 0″	4′ 10″	4′ 7″	4′ 5″	3′ 9″	2′ 9″	2′ 2″	24
Gand			5′ 4″	5′ 2″	5′ 1″	5′ 1″	4′ 10″	4′ 2″	3′ 2″	2′ 4″	26
Kalky	4′ 1″	4′ 2″	4′ 3″	4′ 1″	3′ 11″	3′ 9″	3′ 5″	2′ 11″	2′ 4″	1′ 10″	34
Av. o			4′ 7″	4′ 7″	4′ 5″	4′ 3″	4′ 0″	3′ 5″	2′ 8″	2′ 0″	28
Av. o			4′ 3″	4′ 2″	4′ 1″	3′ 11″	3′ 7″	3′ 1″	2′ 5″	1′ 9″	29

Average lengths of successive laminas. Varieties of the Saretha Group 1917.

(Measurements in feet and inches)

			Number of laminas
K[illegible] section			
[illegible] ..	2' 6" 2' 9" 3' 1" 3' 4" 3' 6" 3' 8" 3' 9" 3' 9" 3' 11" 3' 11" 3' 11" 4' 2" 4' 0" 3' 11" 3' 10" 3' 10" 3' 9" 3' 9" 3' 9" 3' 8" 3' 7"	3' 7" 3' 6" 3' 6" 3' 5" 3' 4" 3' 1" 2' [illegible] 1' [illegible]	29
K[illegible] ..	2' 3" 2' 6" 3' 0" 3' 3" 3' 6" 3' 8" 3' 9" 3' 10" 3' 11" 3' 10" 3' 10" 3' 9" 3' 9" 3' 9" 3' 10" 3' 11" 3' 11" 3' 9" 3' 7" 3' 7" 3' 6" 3' 5" 3' 5"	3' 6" 3' 4" 3' 3" 3' 1" 2' 9" 2' 4" 1' 9" 1' 1"	31
[illegible] ..	2' 3" 2' 8" 3' 0" 3' 4" 3' 5" 3' 7" 3' 9" 3' 10" 3' 11" 4' 0" 4' 0" 4' 1" 4' 2" 4' 0" 4' 0" 4' 0" 3' 9" 3' 9" 4' 0"	4' 1" 4' 1" [illegible]	27
I[illegible] ..	2' 7" 2' 8" 3' 0" 3' 4" 3' 9" 4' 0" 4' 2" 4' 2" 4' 3" 4' 4" 4' 3" 4' 2" 4' 2" 4' 2" 4' 2" 4' 2" 4' 2" 4' 1" 4' 0" 4' 1"	4' 2" 4' 3" 4' 2" 4' 1" 3' 10" 3' 4" 2' 6" 1' 8"	28
[illegible] ..	2' 4" 2' 7" 2' 10" 3' 2" 3' 6" 3' 8" 3' 10" 3' 11" 3' 11" 3' 11" 4' 0" 4' 0" 4' 1" 4' 0" 3' 11" 3' 11" 3' 11" 3' 11" 3' 10" 3' 10" 3' 10" 3' 10" 3' 9" 3' 9" 3' 7" 3' 8"	3' 8" 3' 8" 3' 6" 3' 4" 3' 1" 2' 10" 2' 3" 1' 7"	34
Ch[illegible] ..	1' 11" 2' 1" 2' 5" 2' 10" 3' 2" 3' 6" 3' 8" 3' 10" 3' 9" 3' 10" 3' 11" 3' 10" 3' 10" 3' 10" 3' 10" 3' 10" 3' 9" 3' 9" 3' 8" 3' 7" 3' 7" 3' 7" 3' 6" 3' 6" 3' 4"	3' 4" 3' 4" 3' 2" 3' 0" 2' 9" 2' 7" 2' 2" 1' 7"	33
[illegible] ..	2' 2" 2' 8" 3' 1" 3' 5" 3' 8" 3' 10" 3' 11" 4' 2" 4' 3" 4' 3" 4' 4" 4' 3" 4' 3" 4' 3" 4' 2" 4' 2" 4' 2" 4' 2" 4' 2" 4' 1"	4' 0" 3' 11" 3' 8" 3' 4" 2' 10" 2' 5" 1' 11" 1' 6"	28
K[illegible] ..	2' 5" 2' 9" 3' 1" 3' 5" 3' 10" 4' 0" 4' 2" 4' 3" 4' 4" 4' 4" 4' 3" 4' [illegible] 4' 5" 4' 4" 4' 4" 4' 4" 4' 3" 4' 3" 4' 3" 4' 5"	4' 5" 4' [illegible] 4' 6" 4' 4" 3' 11" 3' 3" 2' 5" 1' 6"	28
[illegible] ..	2' 2" 2' 7" 3' 1" 3' 6" 3' 10" 4' 0" 4' 2" 4' 3" 4' 3" 4' 4" 4' 5" 4' 6" 4' 5" 4' 5" 4' 4" 4' 4" 4' 4" 4' 3" 4' 3" 4' 4"	4' 3" 4' 2" 4' 0" 3' 11" 3' 7" 3' 1" 2' 6" 1' 10"	28
B[illegible] Channee ..	2' 11" 3' 7" 3' 10" 4' 2" 4' 3" 4' 5" 4' 6" 4' 7" 4' 8" 4' 8" 4' 8" 4' 9" 4' 9" 4' 9" 4' 10" 4' 10" 4' 9" 4' 7" 4' 8" 4' 9" 4' 9" 4' 10" 4' 10" 4' 10" 4' 9"	4' 11" 5' 0" 4' 10" 4' 6" 4' 0" 3' 4" 2' 5" 1' 7"	33
Saretha			
Av. of Section ..	2' 4" 2' 8" 3' 0" 3' 4" 3' 8" 3' 10" 4' 0" 4' 1" 4' 1" 4' 2" 4' 2" 4' 2" 4' 2" 4' 2" 4' 1" 4' 2" 4' 1" 4' 0" 4' 0" 4' 0" 4' 0" 4' 0	4' 0" 4' 0" 3' 10" 3' 8" 3' 4" 2' 11" 2' 3" 1' 7"	30
Mesangan section			
Mesangan ..	2' 3" 2' 6" 2' 10" 3' 2" 3' 6" 3' 9" 3' 11" 4' 0" 4' 0" 4' 0" 4' 0" 4' 0" 4' 0" 4' 1" 4' 1" 4' 2" 4' 3" 4' 2" 4' 2" 4' 0" 4' 0"	3' 11" 3' 9" 3' 8" 3' 7" 3' 3" 2' 7" 2' 1" 1' 6"	29
Saretha ..	2' 4" 2' 6" 2' 10" 3' 2" 3' 5" 3' 7" 3' 10" 3' 11" 4' 1" 4' 1" 4' 1" 4' 2" 4' 1" 4' 1" 4' 1" 4' 0" 3' 11" 4' 0" 4' 0" 4' 0" 3' 11" 3' 11" 3' 11" 3' 11" 3' 10"	3' 10" 3' 7" 3' 6" 3' 4" 3' 1" 2' 8" 2' 2" 1' 8"	33
Teg[illegible] ..	2' 5" 2' 10" 3' 3" 3' 6" 4' 0" 4' 5" 4' 8" 4' 10" 4' 11" 5' 0" 5' 0" 5' 2" 5' 1" 5' 1" 5' 1" 5' 0" 5' 0"	4' 11" 4' 11" 4' 11" 4' 10" 4' 7" 4' 0" 3' 1" 2' 2"	25
Khar[illegible] ..	3' 10" 3' 11" 4' 0" 4' 2" 4' 4" 4' 8" 4' 8" 4' 10" 4' 9" 4' 10" 4' 10" 4' 11" 4' 10" 4' 10" 4' 9" 4' 9" 4' 10" 4' 10" 4' 10" 4' 11"	5' 0" 4' 11" 4' 11" 4' 10" 4' 3" 3' 7" 3' 0" 2' 1"	28
H[illegible] K[illegible] ..	2' [illegible] 3' 0" 3' 2" 3' 7" 3' 10" 4' 3" 4' 7" 4' 6" 4' 9" 4' 9" 4' 11" 4' 10" 5' 0" 4' 10" 5' 0" 4' 11"	[illegible] 1" [illegible] 4' 10" 4' 7" 4' [illegible] 3' [illegible] 2' 9" 2' [illegible]	24
G[illegible] Cheena ..	2' 6" 2' 10" 3' 3" 3' 8" 4' 0" 4' 4" 4' 9" 5' 0" 5' 1" 5' 3" 5' 3" 5' 3" 5' 4" 5' 3" 5' 3" 5' 2" 5' 2" 5' 2"	5' 4" 5' 2" 5' 1" 5' 1" 4' 10" 4' 2" 3' 2" 2' 4"	26
K[illegible] ..	2' 2" 2' 8" 3' 1" 3' 5" 3' 8" 3' 11" 4' 0" 4' 1" 4' 2" 4' 3" 4' 4" 4' 3" 4' 4" 4' 5" 4' 3" 4' 3" 4' 3" 4' 3" 4' 3" 4' 2" 4' 2" 4' 2" 4' 1" 4' 1" 4' 1" 4' 2"	4' 3" 4' 1" 3' 11" 3' 9" 3' 5" 2' 11" 2' 4" 1' 10"	34
Av. of Section ..	2' 7" 2' 11" 3' 2" 3' 6" 3' 10" 4' 2" 4' 4" 4' 6" 4' 6" 4' 7" 4' 8" 4' 8" 4' 8" 4' 8" 4' 8" 4' 7" 4' 7" 4' 5" 4' 4" 4' 5"	4' 7" 4' 7" 4' 5" 4' 3" 4' 0" 3' 5" 2' 8" 2' 0"	28
Av. of Group ..	2' 5" 2' 9" 3' 1" 3' 5" 3' 9" 4' 0" 4' 1" 4' 3" 4' 3" 4' 4" 4' 4" 4' 5" 4' 5" 4' 4" 4' 4" 4' 4" 4' 3" 4' 2" 4' 1" 4' 1" 4' 2"	4' 3" 4' 2" 4' 1" 3' 11" 3' 7" 3' 1" 2' 5" 1' 9"	29

											Number of laminas
Teru .			3′ 1″	2′ 11″	2′ 9″	2′ 8″	2′ 6″	2′ 1″	1′ 7″	1″ 0″	29
Rakhra .			4′ 3″	4′ 4″	4′ 3″	4′ 2″	3′ 11″	3′ 2″	2′ 3″	1′ 6″	28
Ekar .			4′ 2″	4′ 2″	4′ 4″	4′ 5″	4′ 0″	3′ 1″	2′ 2″	1′ 5″	31
Dhaulu .			3′ 4″	3′ 4″	3′ 4″	3′ 2″	2′ 11″	2′ 5″	1′ 10″	1′ 3″	32
Kaghze .			4′ 2″	4′ 4″	4′ 7″	4′ 6″	3′ 11″	3′ 1″	2′ 4″	1′ 7″	30
Ketari .											
Bansa .											
Bansi .			3′ 10″	3′ 8″	3′ 6″	3′ 2″	2′ 11″	2′ 6″	2′ 1″	1′ 8″	30
Sunnabile .			3′ 3″	3′ 0″	3′ 1″	3′ 0″	2′ 8″	2′ 3″	1′ 10″	1′ 3″	32
Putli Khajee .											
Khadya .	3′ 9″	3′ 8″	3′ 7″	3′ 5″	3′ 3″	3′ 0″	2′ 10″	2′ 6″	1′ 11″	1′ 6″	34
Naanal .	4′ 0″	3′ 11″	3′ 11″	3′ 8″	3′ 7″	3′ 5″	3′ 0″	2′ 7″	2′ 2″	1′ 10″	34
Hotte Cheni .	3′ 6″		3′ 8″	3′ 8″	3′ 7″	3′ 7″	3′ 4″	2′ 9″	2′ 3″	1′ 10″	33
Dhor .			3′ 6″	3′ 4″	3′ 5″	3′ 5″	3′ 1″	2′ 9″	2′ 2″	1′ 5″	24
Mojorah .			4′ 3″	4′ 0″	3′ 11″	3′ 10″	3′ 7″	2′ 11″	2′ 4″	1′ 7″	28
Av. of group .			3′ 9″	3′ 8″	3′ 8″	3′ 6″	3′ 3″	2′ 8″	2′ 1″	1′ 6″	30

Average lengths of successive laminas. Varieties of the Sannabile Group, 1917.

(In some cases too many laminas were missing for relative figures to be obtained.)

	Average lengths of successive laminas	Number of laminas
Lerii	[illegible] 2' 8" 3' 1" 3' 2 [illegible] 3 6" 3 8 3 9" 3' 8" 3 7 3 7 3' 6" 3' 7" 3' 7" 3' 6" 3 6" 3' 5" 3 5" 3' 4" 3 4" 3 4" … [illegible] 2 9" 2 8" 2 6 2 1 1" 1 [illegible]	29
Bakhre	2 4" 2 6" 3 1 3 4 3' 8 3 9" 4 0" 4 2" 4' 3" 4' 4' 4' 5" 4 6 4 [illegible] 4 [illegible] 4 4 4 5 4 2 4 [illegible] 4 2 4 2 … 4 4 4 4 3" 4 2 [illegible] 2 2 1 [illegible]	28
Ekir	2 8" 2 9" 2' 8" 3 3" 3 6" 3 8 [illegible] 9" 4 0" 4' 1" 4' 4' 4' 2" 4' 3 4 3" 4 2" 4 1 4 1 4 [illegible] 3 11 3 11 3 11 4 1 4 1 4 1 … 1 2 4' 2 4 4 4 4 0 [illegible] 1 [illegible]	31
Jamun	2 [illegible] 2 9 [illegible] 1" 3 [illegible] 3 [illegible] 3 8" 3 8 [illegible] 3" 3 5" 3 8" 3 8 3 7 3 7 [illegible] 8 3 7 3 [illegible] 3 7 3 6 … [illegible] 4 [illegible] 2" 2 [illegible] 2 1 1 [illegible]	32
Kaghe	2 7 2 11" 3 1" 3 [illegible] 3 [illegible] 6" 3 7 3 9" 3' 11 4 0 3 11" 3 10 3 10 3 9 3 10" [illegible] 4 0 3 1[illegible] 4 4 [illegible] 4 1 … 4 2 4 4' 4 7 4 [illegible] 3 1[illegible] [illegible] 4" 1" [illegible]	36
Ketari		
Jessi		
Bus	[illegible]	[illegible]
	[illegible]	32
Pita Kreye		
Khadvo	[illegible]	34
Nanal	[illegible]	31
Hotte [illegible]	[illegible]	33
Dhor	[illegible]	24
M[illegible]rah	[illegible]	[illegible]
Av. of group	[illegible]	30

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BY

W. McRAE, M.A., B.Sc., F.L.S

Government Mycologist, Madras

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BY

W. McRAE, M.A., B.Sc., F.L.S.,

Government Mycologist, Madras.

(Received for publication on 2nd April, 1918.)

Introduction.

Hevea brasiliensis in India is grown chiefly in the south-western region of the peninsula along the outer fringe of the Western Ghats from the southern part of Travancore through Cochin State to the northern part of the district of Malabar, as well as in a few more inland localities in the Anamalai, Nilgiri, and Shevaroy Hills, in Coorg and in North Mysore where it is grown at higher elevation in a climate not usually considered favourable. The estates occupy the flat land in the upper parts of the valleys and the lower slopes of the foot-hills, and individual estates or groups of estates are separated from one another by vast stretches of forest and jungle. During recent years *Hevea* has been planted rapidly, and now there are about 60,000 acres of which about half is in full tapping. Leaving out of account two small groups of trees planted experimentally by the Forest Department about 1879 and 1886, the first *Hevea* was planted under estate conditions in 1903, and broadly speaking there were two main periods of activity in planting *Hevea* in South India, 1906 to 1908 and 1910 to 1912, so that there are considerable blocks of all ages up to 13 years from planting. The following table for which I am indebted to Mr. Anstead, Deputy Director of Agriculture, Planting Districts,[1] shows the distribution (in acres) in the various districts.

[1] Anstead, R. D. "The Planting Districts of South India." *Agric. Journ., India*, XII, p. 416, 1917.

Year	South Travancore	Central Travancore	Mundakayam District	Cochin	Malabar	Anamalais	Nilgiris	Shevaroy	Wynaad	Coorg	North Mysore	Acres
1903	12·74	...	...	...	...	...	...	...	...	...	...	12·74
1904	220·06	...	225·71	454·00	...	...	...	...	...	...	...	899·77
1905	993·34	...	797·40	106·50	...	...	...	...	...	...	...	1897·24
1906	1904·16	...	2225·42	1345·33	136·20	187	...	...	...	...	...	5798·11
1907	1394·69	71	2424·41	743·42	530·80	392	...	...	...	87	...	5643·32
1908	1412·88	100	1822·75	174·14	1951·20	448	20	...	...	123	...	6051·97
1909	621·26	302	366·35	255·48	699·17	...	...	...	61	...	...	2305·26
1910	1262·01	178	1186·78	1532·69	1821·82	...	7	...	...	108	...	6096·30
1911	1404·70	100	1591·96	1249·00	3390·16	50	100	...	...	655	...	8540·82
1912	721·49	160	783·32	1508·04	685·64	100	...	...	...	392	...	4290·49
1913	631·22	...	186·51	...	829·30	...	263	800	...	...	115	2825·03
1914	193·17	70	7·00	465·00	375·09	...	...	...	...	...	...	1110·26
1915	10·00	...	6·50	100·00	12·00	...	...	...	...	...	...	128·50
1916	15·17	...	...	74·08	24·83	...	...	...	...	...	...	114·08
TOTAL	10796·89	921	11624·11	8007·68	10456·21	1177	390	800	61	1365	115	45,713·89

To this total has to be added a small number, not above 200 acres, to allow for a slight amount of rounding off of fields, and also about 2,000 acres for small patches of *Hevea* here and there that do not come into the figures representing estates, besides which about 10,000 acres are owned by Indians. Thus the total area of *Hevea* in South India is very nearly 60,000 acres.

Rainfall. The annual rainfall is always high, being about 120 to 140 inches on most estates while reaching as much as 240 inches on some, and about two-thirds of this comes in the four months from June to September. The South-West Monsoon bursts early in June after which it rains more or less continuously for the next three months, sometimes uninterruptedly for 20 or 30 days at a time, while the amount of rain in the fourth month may or may not be great. "It may rain any day and it sometimes rains every day." During October and November a fair amount of rain falls under the influence of the returning North-East Monsoon, the precipitation occurring as heavy showers that continue at most a few days at a time. From December to March very little rain falls and the weather is dry and hot. During April and May there are occasional showers which are connected with cyclonic disturbances. On the whole the climate is warm and moist with the exception of a spell of hot weather when the humidity is comparatively low. The monthly rainfall for 3 estates in the north, middle, and south of the main rubber-growing area is given below, as well as the daily rainfall for estate B during the South-West Monsoon (June to September) to show the character of the rainfall during that period; the temperature record for one estate is also shown.

(1) *Monthly rainfall on three estates*

Estate	Year		January	February	March	April	May	June	July	August	September	October	November	December	Total
A	1915	Rainfall in inches	2·30	0·65	2·71	6·48	10·41	28·68	40·80	18·29	20·29	20·70	13·29	...	164·60
		No. of days on which rain fell	2	2	9	12	12	26	26	24	27	15	18	...	173
	1916	Rainfall	...	...	1·64	3·70	13·69	40·68	40·63	27·52	14·35	20·96	4·05	0·31	167·53
		No. of days	...	...	6	9	25	26	25	28	23	27	13	2	184
B	1915	Rainfall	2·15	5·55	8·95	12·65	15·40	47·17	51·03	22·20	30·07	16·03	27·53	...	238·73
		No. of days	3	4	10	13	19	25	26	22	23	12	18	...	175
	1916	Rainfall	...	1·49	3·09	4·13	12·76	67·50	35·63	28·27	26·08	18·21	5·85	...	203·01
		No. of days	...	3	6	9	17	27	26	29	24	26	10	...	177
C	1915	Rainfall	4·68	7·37	2·22	8·85	13·92	57·23	48·53	18·66	46·86	11·18	19·48	0·50	239·48
		No. of days	4	6	6	11	15	19	30	21	24	13	23	2	174
	1916	Rainfall	...	1·25	1·00	10·93	7·79	39·79	30·07	18·72	20·25	17·75	15·67	0·12	163·34
		No. of days	...	2	4	10	14	28	27	23	25	21	14	1	169

(2) Daily rainfall on estate B for the monsoon months.

Date	1915				1916			
	June	July	August	September	June	July	August	September
1	0·00	0·82	1·55	0·00	5·75	0·00	3·41	1·40
2	0·12	0·00	1·41	0·00	2·85	0·00	1·31	3·71
3	0·35	0·00	0·20	1·04	10·35	1·42	1·63	0·57
4	0·60	0·52	1·38	0·55	10·35	0·13	0·40	1·65
5	0·50	1·62	1·82	0·00	3·05	0·59	0·28	0·04
6	0·30	0·20	1·73	0·00	3·68	2·41	0·52	1·74
7	0·15	0·50	0·00	0·38	3·98	0·75	3·53	0·09
8	0·00	0·92	0·66	1·60	0·25	0·72	0·00	0·12
9	0·12	0·05	0·60	1·75	3·04	1·38	0·15	0·96
10	0·00	1·05	0·45	0·65	3·34	0·00	0·23	3·75
11	0·00	0·09	0·00	0·55	4·78	0·16	0·24	3·16
12	0·00	0·00	0·00	1·60	0·96	1·60	1·48	0·50
13	0·17	0·00	0·00	0·00	0·00	0·72	0·62	0·12
14	2·67	3·20	0·00	0·00	1·12	0·00	0·96	0·42
15	4·15	2·14	0·00	0·00	1·96	0·00	0·94	0·62
16	0·28	2·08	0·00	1·32	0·83	0·81	1·52	0·37
17	1·11	0·00	0·00	1·92	2·70	0·50	0·84	0·15
18	0·65	6·12	0·24	2·30	1·00	6·05	0·10	3·47
19	2·15	9·57	0·00	0·80	1·38	0·37	0·40	0·67
20	1·17	3·54	0·48	0·20	1·00	0·67	1·12	0·00
21	0·72	2·70	2·65	0·80	0·69	5·73	0·42	0·00
22	1·82	4·62	0·58	0·52	0·31	0·56	0·06	0·70
23	9·17	0·72	0·85	1·74	2·08	0·44	0·26	0·67
24	2·19	0·73	0·94	2·18	1·25	0·13	1·54	1·00
25	1·85	0·33	1·00	1·95	0·09	1·79	0·62	0·00
26	4·80	2·58	2·00	2·00	0·13	0·58	0·60	0·15
27	4·33	1·20	0·70	1·53	0·40	1·39	1·37	0·00
28	4·50	0·83	0·39	0·84	0·18	4·23	1·76	0·00
29	1·25	2·20	0·62	2·85	0·00	0·41	1·52	1·05
30	2·05	1·99	0·73	1·00	0·00	1·00	0·18	0·00
31	0·00	0·80	1·22	0·00	0·00	1·09	0·26	0·00
	47·17	51·03	22·20	30·07	67·50	35·63	28·27	26·08

In 1915 the monsoon burst on the 14th of June and in 1916 on the 1st of June. The former is the more usual time.

(3) *Record of temperature on one estate.*

		January	February	March	April	May	June	July	August	September	October	November	December	
1915	Fahr. ...	88–72	92–75	95–76	94–76	91–77	84–74	81–73	82–72	82–73	83–73	83–72	83–71	Mean Max. and Min.
	Fahr.	91–69	94–72	99–73	98–72	95–74	93–72	89–70	89–71	87–72	87–71	86–70	88–68	Extreme ,, ,,
1916	Fahr. ...	86–70	90–73	94–77	93–78	88–75	...	81–72	81–72	82–72	79–73	81–72	85–71	Mean Max. and Min.
	Fahr. ...	88–68	94–70	96–74	98–72	94–72	...	87–70	85–70	86–70	86–70	86–70	87–69	Extreme ,, ,,

These figures give an idea of the extent of cultivation, of the conditions in which *Hevea* grows, of the range of age of the trees, and, seeing that the disease is present in most of the area, of the amount of each age affected.

Early notice of the disease. During the increased activity of planting in 1909-1910 there was a large demand for seed, and this was partly met from the existing seed on the older estates. In this way the attention of planters was directed to the fact that fruits were becoming attacked by a disease by which they rotted on the trees. Then, too, it was noticed on these estates that there was a considerable shedding of leaves during the monsoon in addition to the normal leaf-fall in the dry weather, but when the demand for seed subsided, less attention was paid to these phenomena. About 1913, however, when efforts were being made to utilize the seeds of *Hevea* for purposes other than planting, attention was again directed to the fruit-rot. Still it was not thought of much consequence, as the demand for seed for planting had become small, compared to the available supply, and the utilization of seed for other purposes had not yet become a commercial proposition, or at least it had not been undertaken to any extent. About the same time it was noticed on the oldest estates that the leaves fell in increasing numbers during the heavy weather of the monsoon, and this was thought to be a result of the exceedingly moist monsoon conditions and to be a partial explanation of the somewhat disappointing latex yields which were lower than had been anticipated. This led later on to an investigation, an account of which is published in this paper.

Hevea sheds its leaves periodically in December-January, and all or nearly all the leaves fall then. Up to about the fourth or fifth year from planting, however, young *Hevea* trees do not show this phenomenon to any marked extent, and during these two months young plantations are evergreen. Sometimes the leaves are shed before the new flush appears and the trees are comparatively or quite bare, but some trees retain a considerable part of their foliage till the new flush of leaves is well expanded. Thus the "picture of repose" on an estate during the season of leaf-fall is by no means uniform. The leaves assume various tints of yellow, brown, and red, and the whole phenomenon is comparable to the wintering of deciduous trees in temperate regions. A description of the second leaf-fall that occurs in the monsoon (June to August) is to be found on page 227.

During 1915 a considerable amount of information was gained about the disease, and it seemed that the fruit-rot, the abnormal leaf-fall during the monsoon, and a rot of the tapped surface that occurred in the latter half of the monsoon were in some way related: a species of *Phytophthora* was found on the infected parts, and subsequently was shown to be the causative factor. The abnormal second leaf-fall, fruit-rot, and bark-rot were found to be general in the older estates which happened to be in the southern part of the area in which *Hevea* is grown, and they had gradually appeared in estates in the more northern part of the area as the trees began to produce their fruits.

Field characters.

There are five well defined symptoms caused by the presence of *Phytophthora* in *Hevea brasiliensis*: wilting of the leaves, fruit-rot, leaf-fall, bark-rot, and partial die-back of the branches. From about the middle to the end of June, or, in other words, about a fortnight to three weeks after the monsoon bursts, the fruits on infected trees begin to show dull ashy-grey portions on their surfaces. The discoloured part is slightly wrinkled and sunk a little below the surface level of the healthy part of the fruit. It frequently appears at the proximal or stalk-end of the fruit, and gradually extends downwards and laterally till the whole fruit is covered. Sometimes, however, it appears first on the side of the fruit, or at its distal end. Several discoloured spots may appear and run together. Drops of latex ooze out here and there on the discoloured surface and gradually turn black. The outer covering of the fruit becomes dark and sodden and infected by a soft-rot. It splits along the sutures, exposing the hard endocarp within and remains attached to it. The endocarp most frequently does not split. The seeds often have a pale dirty yellow colour, or have the brown markings only faintly developed, and may not occupy the whole of the loculus, while the endosperm within is rotten and contracts to a thin parchment lying along the inner wall of the testa. The decayed fruit hangs on the tree for a considerable time, then falls off leaving the stalk attached to the branch, but it or the stalk alone may hang on the tree even till the fruiting season of the next year. A few days after the dull ashy-grey colour appears, especially during a break in the monsoon when there is little or no rain for a day or two, the infected surface becomes covered with a thin incrustation which is white when dry. This consists of mycelium of a *Phytophthora* with a most copious formation of sporangia. The number of rotten fruits on a tree or on an estate varies greatly. In badly infected areas every fruit on a tree may be rotten, and over considerable areas (hundreds of acres) an exceedingly small percentage of fruits comes to maturity and ripens properly, the rest being all attacked by the fruit-rot. On the other hand in places with a lighter rainfall the fruits have not been nearly so badly attacked.

(2) Towards the end of June when the monsoon has set in steadily and soon after the fruit-rot has appeared, infected trees begin to shed their leaves, a few at first, then in gradually increasing numbers, and this goes on for about a month or even six weeks. It is usually most noticeable from the middle of July to the middle of August, after which time the trees cease to shed their leaves to any appreciable extent. Some trees lose all their leaves and stand quite bare with the rotting fruits or the fruit-stalks showing conspicuously; but most lose only a portion of their leaves. Many, however, do not shed their leaves to any appreciable extent, and these are invariably trees that have few or no fruits. By August the foliage on the trees looks decidedly thin, and the ground is covered with a thick coating of fallen leaves. Usually the leaf falls as a whole, but one or more leaflets may come off separately, and the leaf-stalk may remain for a few days attached to the shoot. On the green leaf-surface there are often dull grey spots which are somewhat circular in outline, or several run together forming an irregular patch varying in size up to 3 or 4 centimetres. Minute drops of coagulated latex are often present towards the interior of the spot, and near the edge a faint glistening appearance may be seen. The stalk of the leaf or of a leaflet frequently has a discoloured brownish spot which in well marked cases is shrunk slightly below the general level of the surface, and has droplets of coagulated latex. Leaves sometimes assume shades of yellow and red before they fall, as they do in the normal season of leaf-fall in December-January. Quite a considerable number, however, may be quite green when they fall, with no discoloration on the leaf-surface or on the stalk. After this second leaf-fall a certain amount of new flush is produced, but when trees are badly attacked, they may stand bare till the natural periodic renewal of leaves in January.

(3) After the leaves have fallen off, the current year's branches die back. This may extend along a small branch to the junction with its parent branch, or through a series of branches up to the one springing from the parent stem. The rate of dying-back depends on the nature of the shoot. Long shoots that have grown quickly die back more rapidly than shorter shoots that have grown but a few inches in the same period. Cases have been met with in which a shoot has died back two feet in three months and others in which the die-back has continued during two seasons.

(4) From the living proximal regions of such branches fresh shoots are produced about the middle of February, and begin to wilt about the middle of March. Tiny droplets of latex may appear on the leaves and leaf-stalks. The leaflets shrivel, dry up, and fall off, leaving the leaf-stalk attached to the twig

for some time, or the leaf may come off as a whole. The lowest two or three centimetres of a shoot become discoloured, and it ultimately dies back to its parent branch.

(5) During the heaviest part of the monsoon when trunks of trees are continually wet, a slight rot appears on or near the tapping cut. Dark spots appear here and there, and extend upwards for an inch or two in dark streaks on the recently tapped surface, the underlying tissue being soft and sodden, and exudations of latex appear on the surface and in cracks in the tissue, sometimes forming pads of coagulated latex between the bark and the wood. If the rain is long continued, the bark splits vertically along the streaks exposing the wood, and, if tapping is persisted in, the bark also splits laterally, and the wood becomes exposed throughout the length of the tapping cut. The rotting of the tapped bark gradually extends upwards, more quickly along the cracks and more slowly in the intervening places, till it is stopped by the advent of dry weather. The disease extends downwards more slowly into the untapped bark. Areas of wood 17 inches in length and from 1 to 3 or 4 inches in height may be exposed, the lower edge bounded by the line of the tapping cut, the upper edge ragged and irregular. If, however, there are spells of drier weather, or if the attack comes late in the season, the bark-rot penetrates only a short distance into the cortex, and may not expose the wood or may expose it only very slightly, so that it is healed over quickly after the monsoon rains have ceased.

Second leaf-fall usually occurs first on *Hevea* trees when they come into the fruiting stage, which, in South India, is usually about the 5th year. Then however, it is the fruit-rot that is most in evidence, while in succeeding years the second leaf-fall becomes more noticeable. Younger *Hevea* does not have this second leaf-fall, though it has been seen occasionally on individual trees and groups of trees before they reach the fruiting stage. In one instance it occurred on a few trees that had been planted only two years ; they were in a very small field surrounded by much older trees that had both fruit-rot and second leaf-fall rather severely, and in another case it was observed on supplies about 10 feet high 9 months from planting among 10-year old trees which were also badly affected by fruit-rot and second leaf-fall.

Bark-rot generally appears well on in the monsoon, and may occur in the first season in which the fruit-rot appears or in a subsequent season, but it has not been found on trees that have not had fruit-rot. To take a particular example, fruit-rot and second leaf-fall were noticed first in 1914 during the latter part of the monsoon in a small valley at one end of an estate. Next monsoon the trees in this valley were badly infected, and both fruit-rot and second leaf-fall were found on trees throughout the estate of about 1,000 acres, though the attack was irregularly distributed and, on the whole, light. Towards the end of the monsoon bark-rot appeared for the first time. This is fairly typical of what occurs in the younger estates, that are being more carefully observed in the light of better present knowledge. Some estates seem to be particularly subject to bark-rot especially in part of the district where the rainfall is high, and during the monsoon precipitation is almost continuous for weeks at a time. Here blocks of one hundred acres could be selected in which about 50 per cent. of the trees are or have been affected by bark-rot. Taking the rubber-growing districts as a whole, however, bark-rot cannot be said to be a serious disease, though it must be classed as a dangerous one.

The disease caused by this species of *Phytophthora* extends from the southern limit of the area in which *Hevea* is grown to some distance north of Calicut. Within this area every district is affected to a greater or less extent. Further north the estates are not extensive, the rainfall is much lower, and, though the fungus has been found there, as far as I know the phenomena described above occur only to a limited extent.

Microscopic characters in the tissues of the plant.

Sections of the dull greyish spots on the leaf show hyphæ in the mesophyll passing into and through the cells as well as lying close alongside them in the intercellular spaces. They also occur in the epidermal cells of both surfaces. They pass outwards through these cells, through the stomata, and through ruptures in the epidermis, and form on the surface a thin felt of mycelium bearing sporangia. When the spot has become just visible on the leaf-surface, the protoplasm of the penetrated cells is still colourless. The tissue as a whole, however, contracts slightly in diameter as the section through the edge of the spot shows. The chlorophyll-granules lose colour, and ultimately the cell-walls become yellow, and the cell-contents also become yellow or even brown, and collapse so that the cells come apart easily. Minute lesions appear into which latex exudes, and it escapes to the surface in minute drops. Hyphæ do sometimes penetrate the latex tubes, but this has been observed seldom. Whether the latex escapes from the laticiferous tubes at the points where they are penetrated by the hyphæ, or whether the walls of the tubes are disintegrated by the agency of the fungus or otherwise, has not yet been determined. Young leaves bursting from the bud become flaccid, and all of them may be infected right down to the growing point, their entire laminæ and the embryonic tissue of the stem being penetrated by the hyphæ.

In the majority of leaves that fall during the monsoon, the dull discoloured spot on the petiole is more or less clearly visible, and it may occur on any part of the petiole. It is usually from 1 to 4 centimetres long, and may be on one side of or right round the petiole. Similar spots may be present on the petiolules of the leaflets. Sections reveal the presence of the hyphæ in the tissues, and they occur in a way very like those in the young stem. Hyphæ are not usually present on the surface of the spot when the leaf falls, but, when a petiole is kept for one or two days in a moist chamber, they come to the surface readily. Before the leaves fall, an absciss layer is formed at their point of junction with the shoot.

Among my notes is a record of having found *Phytophthora* on the inflorescence in a previous year, but the material has been mislaid. During the last two flowering seasons, a search was made for it on several estates, but with negative results, even though fruit-rot and leaf-fall were heavy during both the monsoons, particularly so in 1917. By inoculation the flowers and their stalks become infected readily by *Phytophthora*, but to decide whether this occurs in nature needs further observation.

Beneath the dull ashy-grey spot on the fruit, hyphæ are found passing along the intercellular spaces and sometimes into and through the cells as well. The chlorophyll-grains become yellow, then also the protoplasm and cell-walls. The cells lose their turgidity and come apart, and the intercellular spaces become filled with water. This is the beginning of the soft-rot. In fruits that have small spots, and in inoculated fruits, after two days this can be quite clearly seen, but soon bacteria and hyphæ of other fungi, especially *Fusarium*, *Coprinus*, *Nectria*, and *Botryodiplodia*, appear in the tissues. The soft-rot is begun by the *Phytophthora*, and is helped on by the bacteria and other fungi. All of these fungi are found commonly on the pericarp of healthy fruits both before and after the endocarp has split and liberated the seeds, and especially after the empty fruits have fallen to the ground. Seeds from such fruits invariably germinate and grow into healthy seedlings. These fungi do not enter into the present problem, and work on them was stopped after the *Phytophthora* was discovered. The mesocarp splits along 6 lines of suture, and contracts at the edges away from the endocarp to a much greater extent than in healthy fruits. The hyphæ pass into the axis of the fruit either downwards from the insertion of the fruit-stalk or inwards through the 3 slits between the three carpels, and thence through the hilum into the seed. The endosperm and embryo are rapidly permeated. Soft and watery by nature, the endosperm forms an excellent pabulum on which the fungus increases rapidly. It gradually shrinks till it becomes a thin remnant adhering to part of the inner wall of the testa. The remaining space is sometimes partially occupied by a copious growth of hyphæ as is also not infrequently the loculus between the endocarp and the testa. Hyphæ are found in the hard endocarp where they pass from cell to cell chiefly through the pits on the cell-wall. Their diameter being usually greater than that of the pits, they contract as they pass through. The endocarp, however, remains hard, and only a thin layer of the outside surface disintegrates and softens, and here sometimes oogonia are produced. In a similar way the hyphæ penetrate the tissue of the testa, but it, too, remains hard and brittle. From the axis of the fruit, hyphæ pass through the tissues of the fruit-stalk in the same way as they do through a branch.

Hyphæ of *Phytophthora* occur in all the tissues of the branch, and are found both in the cells and between them. They are specially abundant in the medullary rays, and sometimes give them the appearance of white streaks in the wood. In the cortex they pass through the cell-wall at any point, but in tissues that have thick-walled cells, they, as a rule, pass through the cell-wall at a pit becoming narrower in diameter as they pass through. They have not, however, been found in the thick-walled stone cells of the cortex. Usually they are from 3 to 6μ in diameter, but in the pith they are sometimes up to 10μ with branches of considerably smaller diameter arising from them. On the discoloured areas of bark on the recently tapped surface of the stem, the cell-walls become yellow and the cell-contents brown. The cells collapse and become irregular in outline, thus leading to the contraction and rupture of the tissue as a whole. Hyphæ of *Phytophthora* are found between and in the cells of the inner part of the living bark. They are, however, fewer and more difficult to find in this position than in any other part of the tree. The fungus gets into the branch in three ways, through the fruit-stalk, through the leaf-bud, and through the green twigs. Hyphæ pass directly from the tissues of the stalk of an infected fruit into the connected tissues of the branch from which it sprang. Six weeks after the fruit-rot had been first observed on a tree, the stalk of an infected fruit had become discoloured to within half a centimetre of its insertion on the branch. Hyphæ were found throughout the stalk in cortex, vascular tissue, and pith. They had penetrated into the cortex, wood, and pith of the parent branch, and in a lacuna of the cortex, the mycelium was richly developed. Hyphæ were not found in the branch beyond 1 centimetre from the point of insertion of the fruit-stalk. When a leaf-bud is infected, the hyphæ pass inwards from the young infected leaves, kill the growing point, and continue downwards into the young branch. They pass more quickly along the branch in this case than they do from a fruit-stalk, possibly because the tissues behind the growing point of a leaf-branch are more succulent and less differentiated than, and the cell-contents have a different reaction from, those from which the fruit-stalks arise. Green branches may become directly infected by hyphæ that penetrate their epidermis. Occasionally a young green branch has been found with a single isolated discoloured patch on an internode, and sections have shown the presence of the *Phytophthora*.

During the dry weather the fungus is not active anywhere on the outside of the tree. Experimental work with it on the tree in the field during that period was brought to a stand-still ; it was found impossible by ordinary means to infect leaves or branches, and only when they were placed under bell-jars in moist chambers was it possible to continue. The only two places where the living fungus has been found at this season are as mycelium near the junction of dead and living tissues in a branch that had partially died back, and at the insertion of the stalk of a fruit that had been infected during the previous monsoon, and it no doubt also exists as oospores in the dried up fruits. From these places it can begin its activity in the new season when the early rains come, and conditions are sufficiently moist to enable it to develop. The germination of oospores has not yet been observed ; they have been found in nature on the fruits alone, and that but seldom and in small numbers. The development of the fungus from a small crack at the point of insertion of an old fruit-stalk was observed in April. Non-septate hyphæ from 4 to 5μ in diameter were present in the fruit-stalk and in the branch below the point of insertion as far as the pith. They had grown into a small depression on the exterior, and formed sporangia measuring $32{\cdot}4—51{\cdot}2 \times 19{\cdot}2—26{\cdot}8\mu$ (only 6 were measured), some of which discharged their zoospores when kept in water on a glass-slide. There was no appearance of the fungus on any other part of this twig, nor on those immediately surrounding it ; the leaves were not affected, and the flowers and very young fruits were healthy. There seemed no possibility of outside infection at that time, nor immediately before. It is reasonable to suppose that the mycelium that had entered the fruit-stalk and the branch from the previous year's infection, had remained alive within the branch and was developing in the moist conditions when the rain came.

Zoospores discharged in such conditions at the beginning of the new season would form the starting point for infection of other parts of the tree. The fungus also develops from within branches that have partially died back. On splitting a branch in the vicinity of the place to which the die-back has extended, there appears a clear line of demarkation between dead and living tissues; it is 0·5 to 1 millimetre broad and is dark-brown. The dead wood is dry and brittle, brownish in colour, and the vasa are easily visible to the naked eye, while the living wood is moist and tough, yellowish in colour, and the vasa are not so clearly seen. Sections show thick non-septate or sparingly septate hyphæ of a *Phytophthora* in the dead tissues as well as in the living tissues adjacent for a distance of a centimetre. Hyphæ are found in the cortex, phloem, xylem, medullary rays and pith. Some are inter-cellular, but others pass into and through the cells of these tissues. From the distal portions of the living part of a branch that has partially died back, fresh shoots are produced in the early part of the growing season, and a few weeks later they wilt. During the investigation of this point in 1916, shoots that were produced about the middle of February showed signs of wilting about a month later. The lowest 2 or 3 centimetres of the shoots became discoloured

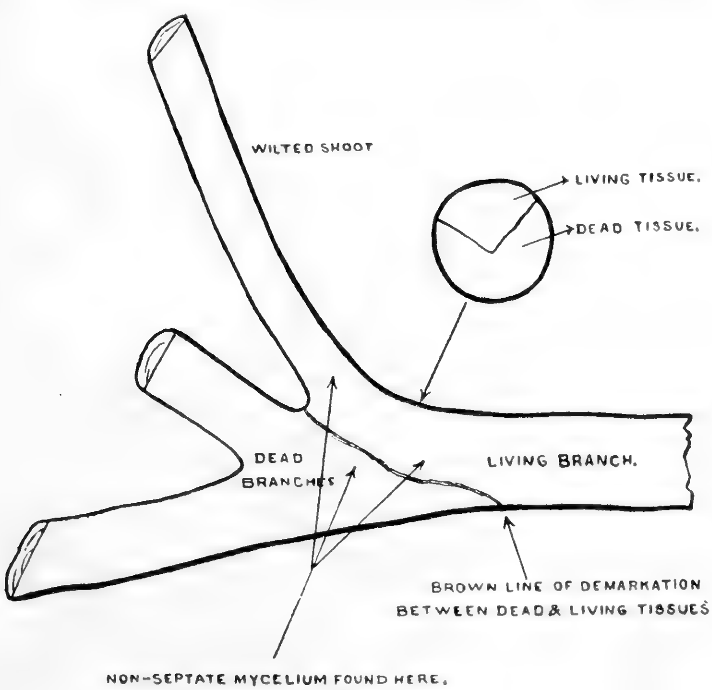


Fig. 1.

on the outside and the leaflets shrivelled and fell off. By the time the leaves are wilting and falling, the hyphæ have extended to a point from 3 to 4 centimetres beyond the attachment to the parent branch. These leaves that fall off are not invaded by the fungus, as is proved by sectioning and by incubation. Two examples which were examined in the month of April may be taken. Figure 1 shows a section of a branch that had partially died back,

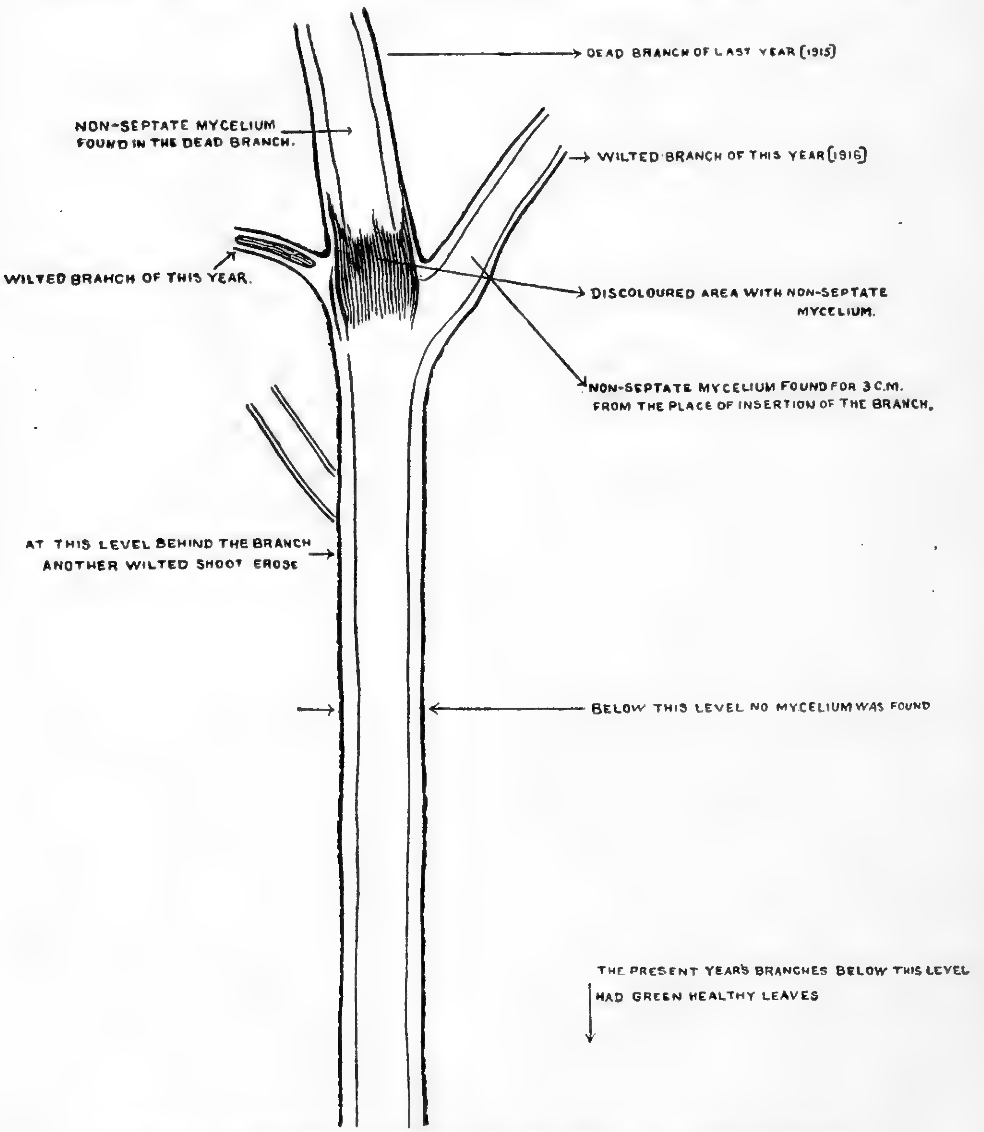


Fig. 2. Diagram showing place where the fungus passes over the dry weather.

and from the living part of which a new shoot had developed in the early part of the growing season. The leaves of the living shoot were wilting and falling off. Hyphæ of *Phytophthora* were found in the living tissue of the parent branch, and in the new shoot at the places indicated. They were not found in the shoot beyond these places, neither were they in or on the leaves. Figure 2 is a similar case, but three shoots had developed and become wilted. The hyphæ were found as in the former example, but had extended backwards in the main axis to a distance of 7 centimetres. The search for hyphæ was carried farther back than in the former case, and none were found in the branch system nearer the main stem. Except for this one end-branch that had died back and the three wilted shoots, all the subsidiary branches springing from the one that left the main branch were free from the fungus. Parts of the infected areas just beyond the limit of the partial die-back when incubated produced sporangia of *Phytophthora* in both examples. Such cases are found when the young leaves have flushed and the wilting shoots are easily seen. Marked infected shoots have not been seen to do this in the ensuing season, as in every case noted another fungus, usually *Botryodiplodia theobromæ* Pat., has infected the dead branch and carried on a die-back beyond the limits of the *Phytophthora.* This happens in nature in a great many, probably the majority of cases in which *Phytophthora* has begun the die-back, and it seems that only a comparatively small number of partially died-back branches can actually reproduce the disease in the succeeding season. The fungus has not actually been found in this portion to come out to the surface and produce sporangia in nature, but there is little doubt that it does so when the air becomes very moist at the beginning of the monsoon. A similar instance of perennial mycelium has been given by Butler and Kulkarni[1] where the mycelium of *P. colocasiæ* may survive the dry weather and start renewed growth in the succeeding wet season. Melhus[2] has given a list of species of *Peronosporaceæ* that have been reported to have perennial mycelium, and among them, besides the one just mentioned, are two species of *Phytophthora, P. infestans* and *P. cactorum.* During the monsoon a similar thing happens, but, instead of wilting, the leaves fall off. Figure 3 is a diagrammatic representation of a branch system that was examined in the middle of July. The lowest side-branch which was a new one had its terminal bud infected in April, and was now dead almost

[1] Butler, E. J., and Kulkarni, G. S. "Studies in *Peronosporaceæ,*" *Mem. Dept. Agric., India, Bot. Series,* V, pp. 233—261, 1913.

[2] Melhus, I. E. "Perennial Mycelium in species of *Peronosporaceæ* related to *Phytophthora infestans.*" *Journ. Agric. Res.,* V, p. 67, 1915.

to the main branch shown ; the one above it was green but leafless (eight leaf-scars showing that eight leaves had fallen), while all the others had green leaves and looked quite normal. The other leaf-scars mentioned in the diagram are

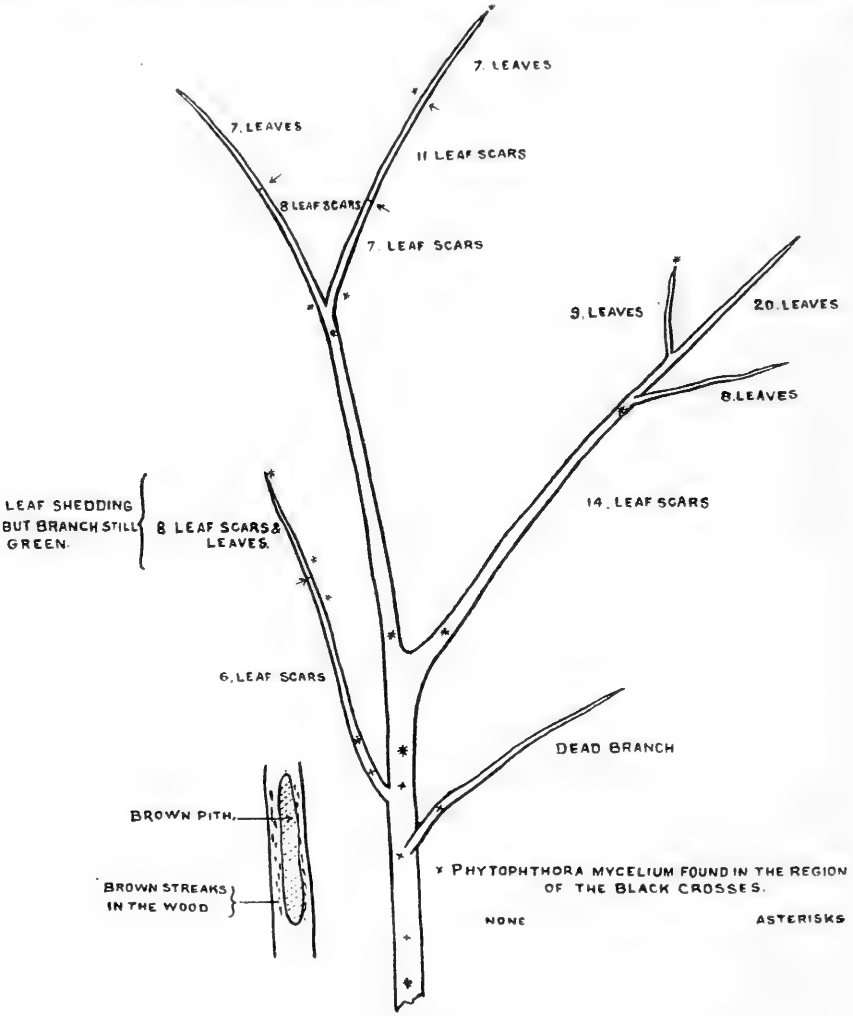


Fig. 3.

those of the previous season's leaves. The main branch was discoloured on one side about the place of insertion of the lowest side-branch. The lowest part of the lowest side-branch was discoloured, but some of the cells of the cortex were still green so that this part of the branch was not quite dead. Within the main branch the pith was brown for a distance of 4 centimetres above and below the insertion of the lowest side-branch. The xylem was streaked with small irregular brown markings and the cortex was slightly brown. This discoloration extended a little beyond the point of insertion of the leafless side-branch whose tissues for 2 centimetres were slightly discoloured. Hyphæ of *Phytophthora* were found in the discoloured tissues and copiously in the medullary rays and in some of the larger vessels. The fungus was not found on the surface of any of the branches. The shaded part and the crosses show the limits within which hyphæ were found, while the asterisks indicate the regions where sections were taken in the search for hyphæ ; none, however, were found there. The character and measurements of the hyphæ proved that this was the fungus that is being investigated. On incubating pieces of the discoloured tissue sporangia of *Phytophthora* were developed. One or two of the leaves on the single branch that was shedding its leaves were secured. They came off easily when the specimen was being cut showing that an absciss layer had already been formed cutting off each from the branch. No discoloration was found on the petioles or leaflets of these leaves, nor on any of the leaves on the other branches. In this case the infection of the branch and the falling of the leaves took place in the same season in a way very similar to that of the former two cases in which the infection from one season caused the wilting of the leaves at the beginning of the succeeding season. This is another example of the fungus within a branch giving a stimulus that causes the branch to shed its leaves.

Thus when the lower part of a twig is invaded by the fungus, two things may happen : —(1) In the early part of the season the leaves on the twig wilt and fall off, and (2) in the monsoon they fall off being quite green or having previously turned yellow, and this even though they are not themselves invaded by the fungus. The presence of the fungus and of tyloses in the vessels suggests that the upward flow of the sap is being checked, but they do not seem to be present in sufficient quantity to fill the vasa to such an extent as to clog them and directly retard the passage of the sap sufficiently to cause the leaves to wilt and to fall. It seems more likely that the copious development of hyphæ in the medullary rays causes the cells of these rays to lose their pumping function, and that accordingly the sap does not pass or passes in much diminished quantity beyond the region of the stem infected by the fungus. As already pointed out, most of the leaves that fall in the second leaf-fall during the monsoon are directly infected, but a proportion that are not infected fall for the cause just stated, and in the early part of the growing season before the monsoon comes this also happens to a very limited extent.

Cultures.

The first culture of the *Phytophthora* was got by slightly scraping the mycelium and sporangia from the surface of an infected leaf, shaking the scraping in a little sterile water, and plating the material in French-bean-agar. A sporangium that had germinated as a conidium was removed on the second day and placed in a French-bean-agar sloped tube. Subsequently cultures were made in a similar manner from other leaves and from fruits in the growing seasons of different years. They were also made from shavings from the living tissue close to the line of division between dead and living tissues of a branch that had died back and from a spot of bark-rot. The tissue was placed in a moist chamber and from the mycelium and sporangia developed on it cultures were made as before. Thus all the cultures started from single sporangia. Transfers were made as a rule by transferring mycelium from tube to tube. Though the fungus grows somewhat better on other media still French-bean-agar was invariably used throughout, as it was the first medium found on which the fungus grew readily.

Growth in culture media. Six tubes of each medium freshly prepared were inoculated at the same time and kept under the same conditions. One of each was used for examination during the period of observation. In agar-agar there was very slight submerged growth after two days and it very slowly increased, and at the end of a month there was a little growth on the surface. In glucose-agar the growth was similar to that in agar-agar, but it advanced along irregular lines and the submerged hyphæ were richly branched and irregularly swollen. In carrot-agar the growth was mostly submerged with sparse hyphæ projecting slightly above the surface. On the 5th day it had advanced about 1 centimetre, and by the 9th day the aërial hyphæ began to show more copiously and gradually increased till at the end of a month there was a fair amount of mycelium all over the surface. In potato-agar the growth was like that in carrot-agar but advanced at first a little more rapidly. The aërial hyphæ, however, did not appear to such an extent and at the end of the month were still scanty. On *Hevea*-leaf-agar the growth at first was slight and submerged, but from the ninth day it increased more rapidly and hyphæ appeared on the surface. By the fourteenth day the whole surface was scantily covered with mycelium. At the end of a month the mycelium was a dull felted mass on the surface. On French-bean-agar the growth of aërial hyphæ was good, reaching 1 centimetre on the second day, 5 centimetres on the ninth, and 9 centimetres on the fourteenth day, covering the whole surface of the medium in the sloped tube and advancing up the sides. The mycelium was white and fairly luxuriant. On Quaker-oats-agar the growth progressed as fast as that in French-bean-agar, but was more dense. On maize-agar and cowpea-agar the growth was very good extending to 2 centimetres on the second, 6 centimetres on the ninth, covering the whole surface by the fourteenth day, and filling up the space between the agar and the other side of the tube. The mycelium was dense, white, and flocculent. The luxuriance of growth of the mycelium in the culture media increases according to the order in which they have been described. On carrot and potato slabs hyphæ appeared on the second day and gradually spread all over the surface by the fourteenth day, becoming more dense by the end of a month. Sporangia appeared in the tubes from the third to the eighth day except in the agar-agar and glucose-agar tubes where they were present between the seventeenth and twenty-ninth days and in the potato-agar and *Hevea*-agar tubes where they were not present after two months. The main difference lay in the fact that in some media the growth was almost entirely submerged, in others though at first submerged was later scantily aërial, and in others aërial and copious from the first and also in the varying intervals at which sporangia were produced. Though examined a year afterwards, none of the tubes contained oogonia.

Inoculation experiments.

The plants used for inoculation at Coimbatore were all grown in the plant-house from seed and were from one to two years old. It was found impossible to establish stumps as the young trees could not withstand the dry winds in the hot weather even when protected as much as possible by other plants. In Kallar at the foot of the Nilgiris a small Government garden of *Hevea* trees up to 13 years old was at my disposal, and here neither fruit-rot nor leaf-fall occur and *Phytophthora* has not been found. The plants used for experiment were thus never exposed to infection from *Phytophthora* before being used. The infective material used was taken from pure cultures in French-bean-agar and consisted of minute pieces of mycelium with mature sporangia actively discharging zoospores in sterile distilled water or of the water containing zoospores just discharged.

(1) *On leaflets of the plant.* The leaflet was bent slightly and held in position by a split stick or a piece of thread in order that the drop of water might remain in one place, or two adjacent leaflets were held together lightly and the drop of water placed between them. The plants when small were placed under large bell-jars or in glass cages and the leaf was placed in an Erlenmeyer flask suitably supported when a large plant was used.

The first sign of discoloration was noticed on the 3rd or 4th day after inoculation. The discoloured area became pale, flaccid, and wrinkled, and extended till it involved the whole leaflet which became slightly twisted. Infection took place both from the lower and the upper surface. When the air was very moist hyphæ and sporangia were found copiously on the surface, but when air was allowed access to the jars so that the air in the jars was fairly dry, few hyphæ were found on the surface. When an infected leaflet was made to touch another that other became infected, and when drops of water were allowed to pass from a leaflet that had ripe sporangia the leaflets on which the drops fell became infected. Infected leaflets fell from the 9th to the 16th day after inoculation. In some cases an infected leaflet fell and the plant remained healthy. When the discoloration passed down the petiole the other leaflets also fell and sometimes also the petiole but it sometimes remained on the stem for several days—sufficiently long to allow of other natural factors coming into play to cause its fall. In section the germ-tubes of three zoospores were seen passing through the cells of the upper epidermis into the palisade parenchyma and the germ-tubes of two passing into a stoma on the under surface. The appearance of the leaf-spot in section was like that in nature, and the characters and measurements of the hyphæ and sporangia of the fungus within the leaflets agreed with those of the *Phytophthora* in culture. Re-cultures made from sporangia from these leaves were used subsequently with success to infect fruits.

(2) *On the leaf-buds.* On young bursting leaf-buds discoloration appeared on the 3rd to the 5th day; the small pale leaves became flaccid and collapsed or fell off and the bud shrank. Copious mycelium and sporangia were usually produced. In a few cases the bud dried up and fell off leaving the plant healthy for some weeks, and sections at the place of abscission failed to show the presence of hyphæ. In other cases the discoloration gradually passed down the stem or the branch, each leaf falling off in succession. When dry air conditions were induced the progress of the discoloration stopped, but when the plant was kept in moist-air conditions all the time the discoloration continued till the plant was killed. The control plants remained healthy throughout. After an artificial infection of a bud and the subsequent dying-back of the branch the *Phytophthora* has not yet been observed to begin again in the new season, but this negative result is due to accident and insufficient work on this point of the subject. From a naturally infected bud, however, this has been traced as noted on page 236.

(3) *On the petiole.* The leaflets were pushed through a glass tube so that it surrounded the petiole. The ends were plugged loosely with cotton-wool and the tube suitably supported so that there was no strain on the petiole.

In other cases where the plants were kept under cover no tubes were used. On the petiole the discoloration appeared on the 2nd to the 6th day and the leaf fell on the 8th to the 11th day. Sectioning and incubating the discoloured part showed that the fungus was like that in culture. The controls were unaffected.

(4) *On the green branch* a small cup of plasticine or of soft paraffin-wax was moulded, and this held a small quantity of water into which the infective material was put. Discoloration appeared on the 2nd to the 5th day. In growing shoots, a week or two old, of young plants the part above the point of inoculation bent over and hung down, while those a little older remained erect and gradually died in from 5 days to 2 weeks. This depends on the amount of supporting tissue developed in the shoot. Discoloration sometimes passed downwards below the cup, the leaves were shed one by one, and young plants died down to the base. Sections showed the presence of hyphæ of *Phytophthora* in all the discoloured tissues, and on incubation for a day sporangia were produced like those in culture. Green shoots of trees shed their leaves immediately above the point of inoculation, and then the whole upper part died; yet in some cases, though a part of the stem became discoloured round the point of inoculation, the discoloration did not extend and the branch remained quite healthy. Later on one of the latter was examined, and though there were hyphæ within the tissues they could not be definitely assigned to *Phytophthora* and on incubation moulds were produced. The controls remained unaffected.

(5) *On the tapped surface.* A small cup of plasticine was moulded against a part of the tapped surface on a tree that had been tapped the same day. Mycelium from a pure culture was kept for 24 hours in a watch-glass with a little water. Before inoculation more water was added, and when the sporangia were discharging freely a small piece of the mycelium with sporangia and zoospores was transferred to the water in the cup. During the monsoon a small flap of waxed cloth was tacked on the tree above the cup and hung down over it about an inch. This was meant to prevent rain-water streaming down the trunk from entering the cup too freely and washing out the infective material. When the inoculations were done in less rainy weather this was dispensed with. Tapping was stopped on all trees after they were inoculated.

(*a*) 15 were inoculated and 8 showed the discoloration of the bark on the 7th day. The other 7 showed no sign and were re-inoculated as before on the 7th day. After 47 days 9 had bark-rot and 6 had not. The controls had no rot. (*b*) At the end of the monsoon 10 were inoculated and 7 showed discoloration and softening of the bark on the 12th day and 3 did not. The cups were then removed. The spots gradually dried up and extension stopped. Six weeks afterwards the spots were quite dried up and the bark below was healthy. The controls did not show any rotting. (*c*) During the monsoon 5 were inoculated but no flap of waxed cloth was used. None of them developed rot. This may have been due to the fact that a very heavy downpour of rain about an hour after inoculation may have washed out the infective material. (*d*) A small piece of the dead bark of the tapped surface was peeled off exposing the green layer and a plasticine cup moulded round and below it. The inoculation was done exactly as before. Of 14 inoculated 10 showed discoloration on the 7th day and 4 did not. The latter were re-inoculated as before on the 7th day. After 47 days 13 had bark-rot and one had not. In all cases the controls showed no sign of rotting. The spots varied in size up to 5×5 centimetres and extended chiefly on the tapped surface, but sometimes downwards slightly into the untapped bark. The tissue was soft and rotten, in some cases as deep as the cambium. It contained hyphæ of *Phytophthora* which produced sporangia. Longitudinal cracks appeared in some of the spots. Some months afterwards the trees were examined; then all the spots had healed and during the succeeding monsoon none of them renewed their growth.

(6) *On the inflorescence.* For each experiment a part of the branch with an inflorescence was kept in water under a bell-jar. Six each were used for the inoculation of the rachis, the peduncle, and the flower, and six were kept as controls. Within 6 days the region round the inoculated place on the rachis became discoloured and sections showed the presence of hyphæ of *Phytophthora* within the tissues. The flowers fell from the inoculated peduncles which shrank slightly and turned black and contained hyphæ within their tissues. The inoculated flowers withered, became dark-coloured and fell off. Carefully teased out flowers showed the presence of hyphæ of *Phytophthora* within the tissue of the perianth and ovary, and sporangia were present on some in considerable numbers. Control inflorescences remained healthy and did not become discoloured.

(7) *On the fruit.* Clean-skinned fruits, about full size but with the skin green and unsplit, were washed well in sterile water with sterile cloths, dried with sterile cloths and placed in potato-dishes. Great care has to be exercised in getting them clean, else moulds appear and vitiate the cultures.

(*a*) In each of 5 potato-dishes four fruits were placed. In one the fruits were inoculated at the stalk-ends, in another at the flower-ends, and in a third on the sides, while the fruits in the other two dishes were kept as checks. On the 3rd day distinct discoloration began to show on most of the inoculated fruits and next day was present in all. On the 5th day the spots had extended (on one of them to $1\frac{1}{2}$ centimetres), and hyphæ were present on the surface. One of the fruits inoculated at the stalk-end had a spot of *Penicillium* and was removed. On the 7th day the discoloration had extended well round the fruit on most and entirely round on some. They were all sectioned and hyphæ of *Phytophthora* were found in the mesocarp and endosperm, and the sporangia on the outside were exactly like those of the *Phytophthora* in culture. The control fruits were not discoloured.

(*b*) The same experiment was repeated except that in this case the potato-dishes were made into moist chambers by sealing the two dishes with a water layer. By the evening of the day following the inoculation discoloration appeared on a few and next day was distinct on all. On the 3rd day it had extended from 1 to 2 centimetres and hyphæ appeared on the surface. On the 4th day discoloration had reached half way round the fruit in most cases and copious mycelium was present. On the 5th day 8 fruits were entirely discoloured and 4 were almost so. In 5 of the fruits the mesocarp split along the sutures and contracted slightly. Seven of the 8 control fruits were healthy and one had a small spot of *Fusarium*. The inoculated fruits were sectioned and hyphæ of *Phytophthora* were found within the mesocarp which was soft and sodden as in the fruits in nature. Hyphæ were also found within the endosperm and in the axis of the fruit-stalk. The sporangia corresponded in characters with those of the culture. The control fruits did not become rotten.

(*c*) In another experiment four fruits in a moist chamber were inoculated by placing a drop of water, containing zoospores only, in the depression at the stalk-end filled with water. Four other fruits were kept as controls. The zoospores were got by allowing the sporangia on a piece of mycelium on a slide to discharge freely, then carefully running off the water on to a cover-slip and transferring it to the water on the fruit. Three of these became well infected by the 5th day and were examined when hyphæ were found in the mesocarp as well as hyphæ and sporangia on the surface. The other was uninfected, and the 4 control fruits remained healthy. The fungus can thus infect the fruit at any part of its surface. Seeing that the infection of fruits was used to test the infective capability of cultures made from various parts of the plant, it was found in many trials that infection was more often successful at the stalk-end as the depression round the insertion of the stalk holds water so readily. Similar results have been got in different years on fruits both from the West Coast and from an estate on the Nilgiri District where the fruit-rot does not occur. Younger fruits from the size of peas upwards have been infected in exactly the same way.

Inoculation on to other plants. In nature this *Phytophthora* has been found only on *Hevea brasiliensis.* Artificial infections have been induced, however, on *Manihot Glaziovii* and *Ricinus communis.* The inoculative material was mycelium with discharging sporangia from a culture on French-bean-agar except in two plants of *Ricinus* where it was from a Quaker-oats-agar culture. The plants were grown at Coimbatore from seed and were not exposed to outside infection before the experiment. The 8 inoculated *Ricinus* leaf-buds became infected while the 4 controls remained healthy, and the 4 inoculated leaf-buds of *Manihot* became infected, while the 3 controls remained healthy. The leaf-bud and three or four leaves on the branch behind it were inoculated in each case. The infected leaves show a discoloured spot on the 2nd or 3rd day, and the spot gradually extends till about the 7th or 8th day part or all of the leaf is flaccid and limp and aërial hyphæ and sporangia are found under moist conditions. They behave very much as do the *Hevea* leaves. When young plants are used the fungus may pass down the stem and kill them as it does in *Hevea* seedlings. Twenty-three fruits of *Hevea* and 27 fruits of *Manihot* were washed in 0·1 per cent. corrosive sublimate, then in distilled water, wiped dry with sterile cloths and placed in moist chambers. Of the 16 *Hevea* fruits inoculated 13 became infected by the 6th day and 3 did not, while of the 7 controls 6 were healthy and one was mouldy. Of the 21 *Manihot* fruits inoculated 12 became infected by the 6th day and 9 did not, while of the 6 controls 5 were healthy and one had a spot of mould on the last day. The infected fruits of *Manihot Glaziovii* become discoloured and rot in the same way as do those of *Hevea*, but they do not decay so quickly.

The fungus.

The hyphæ are hyaline, and vary much in diameter; they usually measure from 2·5 to 6μ across, but may be up to 10μ, especially in the pith and in vigorously growing cultures where the branching is irregular and profuse. Transverse walls are sparsely formed; they occur to cut off the reproductive organs and to cut off an empty part of a hypha from the part containing protoplasm, and this may happen very early in the life of an individual fungus. Cross walls are sometimes irregularly thickened. Differentiated haustoria as such have not been seen. A branch that has entered a cell may be found, but as a rule though it is sometimes irregularly swollen, it does not differ from one that has passed through a cell.

The reproductive organs of this *Phytophthora* are of two types, sporangia and oogonia. The former are found on the hyphæ that protrude above the surface of the plant and the culture medium, while the latter are embedded in the tissues of the plant and within the culture medium.

Sporangia are borne both terminally and laterally on aërial hyphæ both in culture and in nature, and on hyphæ lying along the surface in culture, and are formed abundantly in suitable conditions. When aërial hyphæ from a vigorously growing culture or from the surface of a plant are placed in water—either distilled, rain, or well-water—they form sporangia which become fully formed and discharge zoospores in from twelve to twenty-four hours. As an example a slightly infected fruit was placed in a moist chamber at 5 P.M. Next morning at 8 A.M. a few aërial hyphæ were removed and placed in sterile rain-water under a cover-slip. A drawing of one branchlet having young sporangia was made and measurements were taken by 8·30 A.M. (Plt. II, figs. 22—25). Six young sporangia (Nos. 1 to 6) were measured; one (No. 7) was a minute swelling at the end of its hypha; another (No. 8) was seen as a small swelling 10μ in diameter at 9·30 A.M. The succeeding measurements are given in the table below. The slide was several times irrigated during the day. Between 3 and 4 P.M. five sporangia discharged, and one had produced a germ-tube 57μ long. Two failed to discharge by 5 P.M. when the hypha was washed away and lost.

No.	8·30 A.M.	10·30 A.M.	2·30 P.M.	3-4 P.M.
1	28μ	41μ	41μ	Discharged.
2	25	41	41	Discharged.
3	11	25	30	......
4	20	40	40	Discharged.
5	22	39	39	Discharged.
6	16	38	35	Discharged.
7	0	25	27	Germinated as a conidium.
8	{9·30 A.M.} 10	27	32	......

Similar results are got when a minute culture on the underside of a cover-slip on a Ward's tube is placed in a drop of water on a slide. In a moist atmosphere or in a small quantity of still water mature sporangia remain ready to discharge for a considerable time, but when irrigated or placed in a large drop of water they discharge in from 10 minutes to half an hour. In culture they discharge in the moisture of condensation on the surface of the medium and on the sides of the tube. They have never been seen to discharge zoospores when they are not in contact with water though many attempts have been made to induce them to do so. When they germinate at all in these conditions they do so as conidia. Sporangia are mostly pear-shaped with the sporophore attached at or near the middle of the blunt end. In such water-cultures they vary from 17 to 44μ × 15 to 29μ, the average being 32 × 23μ. At the narrow end is a protuberant, blunt papilla which consists of a hyaline thickening of the wall. The apex of the papilla and the thickening below it dissolve when the zoospores are on the point of emerging, and an opening is thus provided through which they pass. Sometimes a sporangium has two apexes and only one or both of them may be concerned in the discharge of the zoospores. In water-cultures from vigorously growing hyphæ that have been taken from a young culture or from the mycelium that has just emerged on the surface of the plant in nature, sporangia are fairly uniform and symmetrical, while especially in older well-infected fruits and in old nutrient-agar cultures the variation is considerable. On fruits and on old French-bean-agar cultures they may be broadly or narrowly pear-shaped or elliptical and occasionally come near being spherical. They may be bent (Pl. II, fig. 6) or even hour-glass-shaped (Pl. II, fig. 4) or very occasionally lobed (Pl. II, fig. 5.) On fruits the sporangia vary from 33 to 67μ × 14 to 28μ, the average being 48 × 21μ, while in French-bean-agar cultures they vary from 33 to 72μ × 20 to 41μ, the average being 48 × 30μ. Thus both in nature and in culture the sporangia are considerably larger than those developed in water-culture. This, however, is due to the different conditions in which they grow. When they develop submerged in sufficient water they come to maturity and discharge more rapidly than they do in the " drier " conditions in which they develop in nature and in culture tubes.

A typical sporangium is attached at the blunt end symmetrically to its sporophore; but the latter is placed in many cases more or less to one side, *e.g.*, Pl. II, figs. 1, 3, 4, 5, and in extreme cases may come comparatively near the apex, *e.g.*, Pl. II, figs. 6 and 13. Sporophores vary considerably in length. In water-cultures they are usually long varying from 10 to 200μ and they may be as long as 960μ. In nature and on inoculated fruits and leaves they are often quite short, and very occasionally the sporangium is sessile. When they are short the branching of the sporangiophores can be made out, but when they are long it is, as a rule, impossible to trace them far enough in the weft of hyphæ in which they lie. The branching is sparse, usually from 5 to 10 sporangia occurring on a branchlet. The sporangiophores are not distinguishable from ordinary hyphæ except by the presence of sporangia. Their diameter varies considerably especially in nutrient-agar cultures. It is usually from 4 to 6μ, but varies from 3 to 10μ. At the place of insertion the wall may be thickened considerably and often quite irregularly inside both the sporangium and the sporangiophore, *e.g.*, Pl. II, figs. 6, 8 and 9. The sporangiophore may be inflated at various points along its length into large or small swellings, *e.g.*, Pl. II, fig. 11, is a simple example. Usually, however, in vigorously growing cultures, and especially in water-cultures the sporangiophores are regular and uniform as in Pl. II, fig. 2, and it is in old cultures that the greatest variations are found.

The method of formation of zoospores within the sporangium is typical of the genus. The central vacuole is large, its diameter being from 0·2 to 0·4 that of the transverse diameter of the sporangium. When the sporangium is ripe it germinates rapidly in the presence of water. Usually the apex of the papilla dissolves and the protoplasm, which has already segmented into zoospores, escapes through the opening, when the individual zoospores become free from one another and swim away. Usually from 14 to 22 zoospores emerge from a sporangium but sometimes down to 10 and up to 30 and 40 have been counted. In secondary sporangia produced for example on a germ-tube the number is usually small. Though the protoplasm within the sporangium has segregated into zoospores before the opening forms, they as a rule emerge one after another so fast as to appear like a stream of protoplasm, and they congregate just outside the mouth moving slowly for a few seconds. Then one or two break away and the rest suddenly become active and swim away faster than they can be counted. At other times they come out one at a time very slowly and may even take 10 seconds each to pass through the opening. In the morning when the temperature is lower they are not so active as they are in the higher temperature of the afternoon. As each passes out through the narrow opening it contracts considerably assuming a long dumb-bell shape, but rounds again immediately it passes the opening. When part of the protoplasm has escaped, the part that is still within the sporangium often separates into its individual zoospores which move about within the sporangium, but ultimately escape. Occasionally some of the zoospores do not escape, but remain within the sporangium and germinate there, and the germ-tube usually passes through the apical opening though sometimes through the sporangial wall. In one case the apex of the papilla swelled up into a thin vesicle into which the protoplasm passed from the sporangium, each zoospore becoming separated as it emerged into the vesicle. After a very short interval the vesicle burst and the zoospores swam away. This method of discharge was seen by the writer once only, and has not been confirmed though he and his assistants have observed the germination of sporangia many times from material got from cultures and from nature. When water is not present in sufficient volume the sporangium does not discharge zoospores, but germinates as a conidium by putting forth one or more germ-tubes, usually through the apical opening but occasionally through the wall. This is seen to some small extent even in water-cultures; it can be made to occur in a culture where care is taken to withdraw the water of condensation from the culture medium, and it occurs to a very large extent when rain does not fall on infected fruits for a day or so after they have begun to form sporangia on the surface in large numbers as they often do. The zoospores usually swim away individually, but not infrequently two or more remain attached or they may have their cilia entangled and gyrate round one another as they move along. The zoospores are kidney-shaped and vary from 7 to 10·5μ having an average measurement of 8·7μ. Each has a nucleus and sometimes a vacuole. They have two cilia. Sometimes a zoospore has only one cilium, but whether this is due to its having lost one which may have been entang'ed with that of another zoospore and become detached while they struggle together, or whether a second cilium did not develop I do not know as I have been unable to trace the origin and development of the cilia. The fact that cilia have been found lying loose in the preparation suggests the former possibility. The cilia are inserted at or near the hilum. Sometimes they appear to be attached near the two ends of the zoospore, but this appearance I feel sure is due to slight overstaining and the difficulty of tracing the delicate cilia to their points of origin. In some preparations the cilia, though becoming clear of the zoospore at its ends, can be traced distinctly across the zoospore to its hilum. The cilia vary in length from 16 to 23·6μ, the average being 19μ, and the pairs are of slightly unequal length. When the zoospores come to rest as they do within half an hour they become spherical, surround themselves with a thin cell-wall, and germinate in from 10 minutes to an hour by sending forth one or more germ-tubes. Sometimes the tube immediately forms another sporangium which may discharge zoospores in the ordinary way or may germinate as a conidium; usually however it forms a hypha of considerable length with several branches. Germ-tubes have been observed to extend from 40 to 80μ in 24 hours, while the extreme growth in length in that time was 236μ of which a length of 28μ from the tip was filled with protoplasm. In a recent culture, however, from an infected fruit lengths of 40 to 270μ were measured in 4 hours. Though as a rule no transverse wall is formed behind the retreating protoplasm, yet occasionally the part with protoplasmic contents is cut off from the remaining empty part by a cell-wall even at this early stage.

Oogonia are found in the tissues and submerged in the medium. They are as a rule found singly each at the end of a hypha, but in a few cases two originated very close together on very short branches from one hypha. The oogonium is roughly a sphere whose lower part tapers towards the septum which cuts it off from the hypha. Its wall is hyaline or very slightly tinged with yellow, but it may become slightly brown when the oospore is mature. It is thin, seldom exceeding 1μ in thickness but it may be sometimes up to nearly 5μ in thickness. The septum dividing the oogonium from the hypha is sometimes a little thicker than the oogonial wall, and the wall of the lower tapering part of the oogonium is sometimes also slightly thickened. At first the oogonial wall is smooth and even, but after the oospore is mature it becomes irregularly undulated and crinkled and roughened. Oogonia and antheridia are borne on separate branches. The antheridium is colourless, and thin-walled, its walls being about the same in thickness as the oogonial wall. It lies at the base of the oogonium completely surrounding its lower tapering part as well as part of its stalk so that the cross septum cutting off the oogonium is usually seen through the antheridium. It remains attached even after the oospore is mature. It has thus exactly the same relative position with regard to the oogonium as Pethybridge found to occur in *P. erythroseptica* and Dastur in *P. parasitica*. Here, too, the branch that becomes the oogonium grows through the antheridium. The actual process of fertilization has not been observed. When mature the oospore is spherical with a smooth surface and a thick wall which is not always of uniform thickness. The contents are deep yellow and granular, sometimes with fairly large oil-drops. Before maturity it is thin-walled and hyaline, and completely fills the oogonium or almost so, but when it is dark-yellow and thick-walled it occupies only a part of the oogonial cavity. Usually the diameter of the oospore is about 0·8 that of the oogonium, while in the one with the greatest difference it was 0·52. The wall of a mature oospore is from 2 to 4μ in thickness. The oospore has not been observed to germinate.

Oogonia and oospores were first seen on a French-bean-agar culture on 4th February, 1916. The original culture was made from sporangia developed on a discoloured spot on a leaf placed in a Petri dish on 5th August, 1915. Next morning some sporangia were plated out on carrot-agar, and on 13th August, 1915, a sporangium germinating as a conidium was removed to a French-bean-agar tube. The resulting pure culture was sub-cultured several times on French-bean-agar, and one made on 7th December, 1915, was examined on 4th February, 1916, when oogonia were seen. Another sub-culture of the same series made on 9th January, 1916, was examined on 16th February, 1916, and oogonia were found. A third of this series sub-cultured on 1st February, 1916, contained oogonia when examined on 17th February, 1916. In these three cultures the interval between date of sub-culturing and that of observing oogonia was 59, 38 and 17 days respectively. On 7th December, 1915, several sub-cultures were made on Quaker-oats-agar at the same time and from the same material as those just described. In one of these oogonia were found on 4th February, 1916. For a long time, though we put sub-cultures in what we thought were exactly the same conditions, no more oogonia were found. On 30th June, 1917, a *Hevea* fruit with a slight discoloration on its surface was kept overnight in a moist chamber. Next morning sporangia growing out of it were plated out in glucose-agar, and on 4th July one germinating as a conidium was placed in each of 4 Quaker-oats-agar tubes and in each of 4 French-bean-agar tubes. On 17th August one Quaker-oats-agar tube and one French-bean-agar tube were examined, but no oogonia were present. On 7th September other two tubes were examined with negative results, and on 25th September these two tubes were again examined with negative results. On 18th October a third set of two tubes was examined with negative results. On 10th November the fourth set of two tubes was examined, and oogonia were found in the Quaker-oats-agar tube only. In these five tubes alone have oogonia developed, yet we have examined over 100 cultures specially grown for this purpose on various kinds of media at different times during 1916 and 1917. Thus the oogonia in the first four instances were got from the same strain, and this is a similar experience of other investigators of this genus.

The first tube that produced oogonia sown on 7th December, 1915, and examined on 4th February, 1916, contained 30 of them all of which were mature, maturity being decided by the oospores having a distinct coloration and a thickened wall. In this tube were 6 oogonia whose length was greater than 40μ, and only one oogonium of this size (it being $44 \times 38\mu$) has been seen in subsequent cultures. The average measurement of these 6 oogonia was $45 \times 41\mu$—the largest being $49 \times 45\mu$, and the smallest $42 \times 35\mu$. The oospores they contained, however, were very little larger than the general average, their average being $26 \times 25\mu$, the largest $28 \times 26\mu$, and the smallest $24 \times 22\mu$. Indeed larger oospores have been found in other cultures though the latter were contained in oogonia that did not measure above 38μ.

From the tube sown on 9th January, 1916, and examined on 16th February, 1916, 30 oogonia were obtained. They were much more uniform in size than those from any other culture. This does not seem to be because they were immature, for the average of the measurements of oogonia is about the same as that of those in other cultures, and the oospores are slightly larger. The other cultures call for no special mention.

Oogonia were found first in nature on three rotten and dried up fruits gathered from the ground under *Hevea* trees on 6th September, 1916, and examined next day. During the succeeding week about 300 fruits were examined both on the trees and on the ground under them from the same block and other blocks on the same estate, but no more oogonia were found. On 20th June, 1917, twenty fruits picked from several trees on another estate were found with oogonia. The pericarp of these fruits was soft and rotten, but it had not then split along the six sutures. Forty other fruits collected at the same time were devoid of oogonia. On 10th August, 1917, on a third estate in another district oogonia were found on about 10 rotting fruits in a stage similar to the last. On the fruits examined on 7th September, 1916, nineteen mature oogonia with oospores were found immersed in the tissue of the mesocarp. Round twelve of them the oogonial-walls were still present, three had remnants of the oogonial-walls, and four had none. The epicarp of the fruits was soft and rotten, consequently it was difficult to make microscopic preparations, so I think that the oogonial-walls of these seven had been broken away either partially or completely in the manipulation of the material, or they may have disintegrated within the tissue of the epicarp. There is the possibility, too, that the last four never had oogonial-walls and were not oospores. This supposition, however, is discounted by the facts that in cultures no thick-walled spores have been found that are not oospores developed within oogonial-walls, and that they agree in size, colouring and thickness of wall with the oospores found on these fruits. The smallest oogonium with its oospore measured $24{\cdot}6 \times 22{\cdot}5\mu$ and $20{\cdot}5 + 20{\cdot}5\mu$ respectively; the largest oogonium with its oospore measured $30{\cdot}4 \times 28\mu$ and $28 \times 26\mu$ respectively. The averages of the twelve were: oogonia—$25{\cdot}5 \times 24{\cdot}9\mu$, and oospores—$23{\cdot}9 \times 23{\cdot}3\mu$. If the three oospores with incomplete oogonial-walls are taken into account, the average of the oospores is $23{\cdot}5 \times 23\mu$. The average of the 4 spores without oogonial-walls is $23{\cdot}8 \times 23\mu$; thus they agree very closely in size with the oospores.

On the fruits collected on the 20th June, 1917, 45 oogonia with oospores were found in the mesocarp. The oogonia varied from 20 to $26\mu \times 20$ to 27μ, the average being $23{\cdot}7 \times 23{\cdot}5\mu$, while the oospores varied from 18 to $23\mu \times 18$ to 22μ, and the average was $20{\cdot}3 \times 20\mu$. Both oogonia and oospores are slightly smaller than those found on fruits in the previous year. It is likely that they were not fully mature, as the colour was paler, and they were found unexpectedly early in the season. As moulds develop rapidly on stored rotting fruits, all except those searched for oogonia were put in pickle, so the chance of examining them at a later stage of development was lost. On the fruits collected on 10th August, 1917, twenty-two oogonia with oospores were found, eleven from the soft mesocarp and eleven from the outside of the endocarp. The oospores of those found in the mesocarp were of a lighter tint, and were probably not mature, and this is borne out by the fact that both oogonia and oospores were on the whole smaller than any others found on fruits. The oogonia and oospores from the endocarp were the largest found on fruits, being a little larger than those seen in September, 1916, and they come nearer those that developed in culture. Some of those oospores were more deeply tinted than any hitherto seen, being almost brown and difficult to see through. As in the case of the four spores without an oogonial covering seen on the fruits examined on 7th September, 1916, so here too a few spores were found that had no surrounding oogonial-wall. On the last occasion twenty-two of them were measured, and they varied from 20 to $29\mu \times 19$ to 28μ, their average being $24{\cdot}5 \times 24\mu$. Their limits are within those of the oospores found on the same fruits, though their average is a little higher. They were found on the outside of the endocarp, the tissue surrounding them having to be teased out on the slide in order to make a microscopic preparation. They have exactly the appearance of oospores in colour, thickness of wall and appearance of the contents, and I think that they are oospores from which the oogonial-wall had decayed, or had been removed mechanically in making the preparation. Such spores have not been observed in culture, where the same difficulty of manipulation in making a microscopic preparation does not exist.

The variation in size of 136 oogonia and oospores found in culture on French-bean-agar is for oogonia 22 to $49\mu \times 20$ to 45μ, and for oospores 16·4 to $32\mu \times 15$ to 32μ, while that of 79 found on fruits in nature is for oogonia 20 to $48\mu \times 20$ to 40μ, and for oospores 16 to $32\mu \times 16$ to 32μ, so that the limits of variation in the two cases are close. The average, however, for those in culture is higher than that for those in nature, the average in the former case being for oogonia $33 \times 31\mu$, and for oospores $25{\cdot}5 \times 25\mu$, and in the latter case for oogonia $25 \times 24{\cdot}6\mu$ and oospores $21 \times 20{\cdot}5\mu$. On the last occasion, however, on which oogonia and oospores were found on the endocarp of the fruit, the average of the eleven seen was for oogonia $30{\cdot}5 \times 29{\cdot}7\mu$, and for oospores $23{\cdot}6 \times 23{\cdot}5\mu$, and this average approaches much nearer that in culture. Seeing that so few were found on the fruits, every one distinctly seen was measured, and it may be that some of them were not fully mature. As the case stands at present, it appears that oogonia and oospores in culture in French-bean-agar are somewhat larger than those in fruits.

SUMMARY OF THE MEASUREMENTS OF OOGONIA AND OOSPORES.

In culture.

Oogonia			Oospores		
No.	Variation	Average	No.	Variation	Average
30	31·5—49 × 28—45·5	36·6 × 34·5	30	21 —28 × 21 —26·2	25·2 × 24·5
30	28 —35 × 28—31	31·2 × 29	30	22·7—28 × 22·7—28	26·8 × 26
39	25·2—44 × 24—39·2	33·2 × 30·5	39	20 —32·8 × 20 —32·8	25·3 × 25
37	22 —39·6 × 20—39·2	32·7 × 30·6	37	16·4—32·8 × 15·2—32·8	25 × 25
Summary	22 —49 × 20—45	33·4 × 31·1	136	16·4—32·8 × 15·2—32·8	25·5 × 25

On fruits.

12	24·6—30·4 × 21·3—28	25·5 × 25	12	20·5—28 × 20 —26	23·9 × 23·3
45	20·4—26 × 20 —27·2	23·7 × 23·5	45	18 —22·8 × 18 —22	20·3 × 20
11	22 —26 × 22 —25·6	24·6 × 24	11	16 —21 × 16 —20	18·8 × 18·2
11	24 —48 × 23 —40	30·5 × 29·7	11	16 —32 × 18 —32	23·6 × 23·5
Summary	20·4—48 × 20 —40	25·1 × 24·6	79	16 —32 × 16 —32	21 × 20·5

The position of the antheridium puts this *Phytophthora* into the *infestans* group as constituted by Pethybridge, the members of which now are *P. erythroseptica* Pethyb., *P. infestans* deBary, *P. Phaseoli* Thaxt., *P. parasitica* Dast., *P. Colocasiæ* Racib., *P. Allii* K. Sawada, *P. Melongenæ* K. Sawada, and probably also *P. arecæ* (Colem.) Pethyb., and *P. Thalictri* Wilson and Davis. It differs from *P. erythroseptica* in the larger size of the sporangia, in the presence of an apical papilla on the sporangium, and in the readiness with which it discharges zoospores. The oogonium and oospore are more variable, the oospore-wall is thicker and the colour is more marked. It differs from *P. infestans* in the larger and more elongated sporangia, in the smaller antheridia, in the slightly smaller oogonia and oospores, and in the fact that the oogonial-wall is not brittle, pressure on the cover slip not causing the oospore to be expelled. It differs from *P. Phaseoli* in that the conidiophores are not tapering, and do not have swollen nodes, and in the larger sporangia and oogonia. It differs from *P. parasitica* in the more elongated sporangia, larger oogonia, and oospores, and in the absence of chlamydospores. It differs from *P. Colocasiæ* in that no part of the conidiophore adheres to the sporangium after its separation, in the smaller zoospores, and in the absence of chlamydospores. It differs from *P. Allii* and *P. Melongenæ* in the larger oogonia and oospores, and in the greater thickness of the oospore-wall, and also from the latter in the larger sporangia and in the absence of chlamydospores. It differs from *P. arecæ* in the more elongated sporangia, and in the smaller oospores. From *P. Thalictri*, a possible member of this group, it differs in the larger sporangia and oogonia, and in the slightly larger oospores.

As this fungus cannot be included in any of the above species, the name *P. Meadii* was proposed for it, and the description published first in the *Journal of the Bombay Natural History Society*, Vol. 25, page 760, is as follows:—*Phytophthora Meadii* nov. spec. mycelio ramoso ex hyphis primo continuis tandem septatis, 3—6μ usque ad 10μ crassis, inter et intracellularibus; sporangiophoris ramosis 10—200μ longis sed aliquanto brevibus; sporangiis inversipyriformibus sed variis, terminalibus vel lateralibus, in fructibus 33—67 × 14—28μ, in aqua submersis 20—44 × 16—29μ; zoosporis ovatis vel ellipsoideis, biciliatis, ciliis 16—26μ longis, sporis globosis 7—10μ; oogoniis pyriformis, hyalinis, levibus vel rugosis, in fructibus 20—48 × 20—40μ in cultibus 22—49 × 20—45 μ; antheridiis persistentibus, hyalinis, rotundis vel ovoideis, levibus 8—16 × 10—16μ, et oogonii basem et oogoniophori partem circumclaudentibus; oosporis sphæricis, in fructibus 18—28 × 18—26μ in cultibus 16—32 × 15—32μ membrana 2—4μ crassa, mellea aut fulva, levi.

Hab. in foliis, fructibus, ramis, cortice *Heveæ brasiliensis.*

Travancore, Cochin, Malabar, Indiæ orient.

Seeing that it has been stated that *P. Faberi* is the cause of fruit-rot and leaf-fall of *Hevea* in Ceylon, parallel cultures of the South Indian fungus and *P. Faberi* were grown, and inoculations made of both on *Hevea* and cacao fruits, Mr. Petch, the Government Botanist and Mycologist, Royal Botanic Gardens, Peradeniya, very kindly sent me excellent specimens of cacao fruits attacked by *P. Faberi*, and the study of the fungus was made, and the inoculative material was derived from these specimens. The comparison is given in some detail. The difference between the sporangia of the two fungi is small, and this led me at first to think that the fungus on *Hevea* in South India was *P. Faberi.*[1] The limits of the measurements of sporangia on fruits are fairly close. While in

[1] McRae, W., and Sundararaman, S. "Leaf-fall of *Hevea*." *The Planters' Chronicle*, X, pp. 452—454, 1915. Also "Proceedings of the Annual Meeting of the United Planters' Association of Southern India," pp. 69—76, 1916.

water-cultures those of *P. Meadii* are smaller than those of *P. Faberi*, the limits of *P. Faberi* grown on *Hevea* fruits come fairly close to those of *P. Meadii* in water-culture.

P. Faberi sporangia ..	34 — 70 × 16 — 36μ	on cacao fruits.
	32 — 66 × 25 — 32μ	in water-culture.
	32 — 44 × 20 — 32μ	on *Hevea* fruits.
P. Meadii sporangia ..	33 — 67 × 14 — 28μ	on *Hevea* fruits.
	20 — 44 × 16 — 29μ	in water-culture.

The sporangium of *P. Faberi* is usually slightly nearer the spherical shape than that of *P. Meadii.* The papilla of *P. Faberi* is, as a rule, more protuberant than that of *P. Meadii*, and the base of the sporangium of the former has a cellulose plug much more frequently than has the latter. The zoospores are very nearly alike. Those of *P. Faberi* measure from 8—12·8μ on cacao fruits, while they measure 8—10μ on inoculated *Hevea* fruits, those of *P. Meadii* measure 7—10·5μ. The number of zoospores is nearly alike, in *P. Faberi* being 16—24 and in *P. Meadii* 14—22 under similar conditions. Though in a few instances numbers up to 40 have been counted in *P. Meadii* this difference is rather discounted perhaps by the fact that a larger number of those of *P. Meadii* have been counted and under more varied conditions. Besides Rorer[1] records the number as 15 to 30. In my material and cultures of *P. Faberi* I found resting conidia only, and they were produced in abundance on cacao fruits, inoculated *Hevea* fruits and in culture. They were light yellow in colour with a smooth wall about 2μ in thickness and varied from 28—46 × 26—43μ. Coleman,[2] however, found oogonia and oospores, and figs. 4—6 in Plate XVIII of his paper show the "oogonial wall for the most part closely applied to that of the oospore." He remarks, "In some examples, from the mode of attachment of the oogonial stalk, it appears as if the oogonial wall had become directly the wall of the oospore by a process of thickening. This was in all probability not the case, as the oospore almost always fills the oogonial cavity so completely that the oogonial wall can be made out only with difficulty." Coleman seems to have had genuine oogonia in some at least of his preparations. Rorer[1] also figures an oogonium in Plate XVII, fig. 14 of his paper, and in it the oospore occupies the great part of the oogonium. In *P. Meadii* on the other hand, the wall of the oogonium is easily distinguishable from that of the oospore and when mature the oospore

[1] Rorer, J. B. "Pod-Rot, Canker, and Chupon-Wilt of Cacao caused by *Phytophthora* sp." *Bull. Dept. of Agric., Trinidad*, IX, No. 65, pp. 79—120, 1910.

[2] Coleman, L. C. "Diseases of the Areca Palm." *Dept. of Agric., Mysore State, Mycological Series, Bull.* 2, 1910, also *Ann. Myc.*, VIII, pp. 591—626, 1910.

lies loose within the oogonium, its diameter being from 0·5 to 0·8 that of the latter. The measurements of the oogonia of the two fungi are fairly close, but the oospores of *P. Meadii* are much smaller. Von Faber[1] gives the measurements of *P. Faberi* as 22—45μ, Rorer as 33—40μ, and Coleman as 22·4—41·2μ, while those of *P. Meadii* are for oogonia on fruits 22—48μ, and for oospores 16—32μ. In *P. Faberi* no antheridia have been seen, unless perhaps by Rorer,[2] who in Plate XVII, fig. 14, of his paper, figures an "oospore showing oogonium wall and antheridial branch," and if this be a true antheridium, then it is of quite a different type to that of *P. Meadii* in which, besides, an antheridium is invariably present. The main differences then between the two fungi are that the oospore of *P. Faberi* almost completely fills the oogonial wall, and that no antheridium is present, while in *P. Meadii* the oospore lies loose within the oogonial wall, and a persistent antheridium is invariably present. The differences are so distinct that the two cannot be regarded as of the same species.

Cross inoculations were made with *P. Meadii* and *P. Faberi* on the fruits of cacao and *Hevea*. Fruits of both were washed in distilled water and rubbed well with soft cloths. They were again washed individually in sterile distilled water and wiped with sterile cloths. Each cacao fruit was placed on a glass stand in a potato-dish, into which a little water was placed to form a moist chamber, while four *Hevea* fruits at a time were placed similarly in potato-dishes. The glass dishes and the water were sterilized before being used. All the fruits were well grown, but not quite mature; they were all collected on the same afternoon from a small isolated Government garden, where neither *P. Meadii* nor *P. Faberi* has ever been found. They were treated in precisely the same manner, kept under the same conditions, and inoculated from the same culture of *P. Meadii* and of *P. Faberi*. The bruising of some of the fruits was done by making a few criss-cross lines by means of a sterile knife-point on an area of about half a square centimetre. Each of the two cultures was immersed in distilled water, and when the discharge of zoospores became active, a minute piece of the mycelium was placed in a large drop of water on each of the respective fruits. Several times pieces of the mycelium taken were placed on a slide instead of on the fruit, and examined to see that they contained bursting sporangia which they did. The table indicates how long after the date of inoculation hyphæ, sporangia and discoloration of the surface of the fruits were observed to be present.

[1] von Faber, F. C. "Die Krankheiten und Parasiten des Kakao-Baumes. Arbeiten a.d. Kais." *Biol. Anst. für Land-und Forstwirtschaft*, VII, pp. 193—210, 1910.

[2] Rorer, J. B. "Pod-Rot, Canker, and Chupon-Wilt of Cacao caused by *Phytophthora* sp." *Bull. Dept. of Agric., Trinidad*, IX, No. 65, pp. 79—120, 1910.

Cross inoculation of fruits of Hevea.

No. of days after inoculation		1st	2nd	3rd	4th	5th
P. Meadii on Hevea	4 fruits	—	D +	+	+	
			H —	—	+	
			S —	—	+	
P. Faberi on Hevea	4 ,,	—	D —	—	+	+
			H —	+	+	+
			S —	—	—	+
P. Meadii on Hevea, bruised	4 ,,	—	D +	+	+	
			H —	—	+	
			S —	—	+	
P. Faberi on Hevea, bruised	4 ,,	—	D —	+	+	+
			H —	+	+	+
			S —	—	—	+
Control Hevea	4 ,,	—	—	—	—	** —
Control Hevea, bruised	4 ,,	—	—	—	—	—

D, discoloration on surface. H, hyphæ on surface. S, sporangia produced.

On *Hevea* fruits the discoloration caused by *P. Meadii* rapidly became dark dull green and then a dirty, greyish green, while that caused by *P. Faberi* progressed more slowly to the same result. When the former had assumed an ashy grey appearance, the latter had still their natural green, and it took about two days longer to discolour them thoroughly. The mycelium of *P. Faberi* grew along the surface of the *Hevea* fruits for a distance of about two centimetres, while that of *P. Meadii* did not. Hyphæ of *P. Meadii* emerged on the discoloured surface a day before those of *P. Faberi*, and were much more copious afterwards. Resting conidia of *P. Faberi* were always associated with sporangia in about equal numbers. On the 5th day a small spot of mycelium of a *Fusarium* appeared on two *Hevea* fruits in the check-dish, and on the next two days on each of other two fruits, while the bruised check-fruits remained unchanged till the 8th day, when a small spot of *Fusarium* appeared on one. The surface became discoloured in a way somewhat similar to that when *Phytophthora* was present, but it progressed much more slowly. That the two *Phytophthoras* caused the discoloration, the test showed clearly however. Both *P. Meadii* and *P. Faberi* infected all the *Hevea* fruits.

Unbruised cacao fruits did not become infected with *P. Meadii* after 20 days. The inoculative material was tested by removing it from the fruits on the 14th, 17th and 20th days respectively, and placing it in distilled water and in culture media. In each case the fungus was alive, and readily produced sporangia and discharged zoospores. The tissue of the fruit was not

Cross inoculation of fruits of cacao.

No. of days after inoculation		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	
P. Meadii on cacao	3 fruits	—			—	—	—	—	—	—	—	— on 14th day — on 17th day — on 20th day
P. Faberi on cacao	2 ,,	—	D + — H — — S — —	+ — — — — —	+ + — — — —	+ + + + + +						
P. Meadii on cacao, bruised	1 fruit	—	D — H — S —	— — —	+ — —	+ — —	+ + —	+ + —	+ + —	+ + —	+ + —	+ + — on 20th day
P. Faberi on cacao ,,	1 ,,	—	D + H — S —	+ — —	+ — —	+ — —	+ + —	+ + —	+ + +			
Control cacao	2 fruits	—	—	—	—	—	—	—	—	—	—	— on 20th day
Control cacao, bruised	1 fruit	—	—	—	—	—	—	—	—	—	—	— on 20th day
P. Meadii on cacao	6 fruits	5— 1—	— —	— —	— D + H — S —	— + + —	— + + —	— + + —	— + + —	— + + —	— + + —	— on 20th day + + + on 12th day
Control cacao	,,	—	—	—	—	—	—	—	—	—	—	— on 20th day

D, discoloration on surface. H, hyphæ on surface. S, sporangia produced.

penetrated. *P. Faberi* infected unbruised cacao fruits in two or three days producing copious sporangia and resting conidia on the 5th day and gradually blackening the surface till by the 7th or 8th day the whole fruit was black. The bruised cacao fruit showed infection of *P. Meadii* on the 4th day, and of *P. Faberi* the 2nd day. The hyphæ produced from the 4th to the 20th day on the surface of the former did not form sporangia *in situ*, yet several times during the interval they produced them in two days after being placed in water and in culture media. The two unbruised and the bruised control cacao fruits were still fresh and healthy on the 20th day. Immediately afterwards twelve more cacao fruits were put up as before and not bruised. Six were inoculated from a culture of *P. Meadii* by placing pieces of the French-bean-agar containing mycelium with actively discharging sporangia in a drop of water on a groove on the side of each fruit. One showed discoloration on the 4th day. Next day the discoloration was marked and hyphæ were present. On the 9th day the discoloration had passed all round the fruit but not quite to the ends, and hyphæ were present in little masses all over. The hyphæ were close to the surface, much branched and irregularly swollen. Till the 12th day no sporangia were produced *in situ*, though as before when the mycelium was placed in water, sporangia were produced. The other five fruits were healthy after 20 days. The inoculative material when placed in water continued growing, and sporangia discharged, so that it was alive all the time it was on the fruits, and the surface of the fruits was always sufficiently moist to allow of the growth of the fungus. Five of the control fruits were healthy after 20 days; the sixth became mouldy with *Eurotium* and *Aspergillus* on the 12th day, owing doubtless to the fact that the water in the potato-dish dried up and allowed access to the open air during my temporary absence from the laboratory on other work. Thus under exactly similar conditions *Hevea* fruits were infected readily both by *P. Faberi* and *P. Meadii*, while cacao fruits were infected readily by the former and with difficulty by the latter.

Cacao is not grown in the rubber districts of South India, and there are no plants on estates. There may be one or two plants grown in gardens in places like Trivandrum and Calicut, and there are a few in a small Government garden at Kallar at the foot of the Nilgiris, but all these places are far away from the estates. In the latter case the cacao plants are not attacked by *P. Faberi*, and the few acres of *Hevea* in the garden are not attacked by *P. Meadii*. Thus it seems impossible that *Hevea* could be infected from cacao in South India. No other trees or plants have been observed to have a similar fruit-rot or leaf-fall. True, I have comparatively few opportunities of observing trees in the jungle; still, since I made the suggestion at a planters' meeting in 1916, I have had no positive case reported. That rather discounts the possibility of the fungus having passed to *Hevea* from trees in the country. Another possibility is that the disease was introduced along with plants and seed (possibly fruits) that were imported in considerable numbers from Ceylon. It is quite possible that *P. Meadii* occurs in Ceylon, for the only definite report is that of Petch in 1910 who successfully inoculated 6 *Hevea* stems out of 13 by means of spores of *Phytophthora* obtained from diseased cacao fruits and of pieces of diseased cacao pods, and concluded from this experiment that the canker and fruit-disease of *Hevea* are caused by *P. Faberi* which is the cause of canker and pod-disease of cacao. No detailed description of the *Phytophthora* on *Hevea* fruits in Ceylon has been published. Seeing that both *P. Meadii* and *P. Faberi* infect *Hevea* fruits readily, and that cacao is grown as an estate crop in Ceylon, it is quite likely that it is *P. Faberi* that is attacking *Hevea* there, though this does not preclude the possibility of *P. Meadii* being present also.

Dissemination of the fungus.

The fungus appears to start its activity after the dry season at comparat ively few points, but when the monsoon has once burst, it spreads rapidly on fruits and then to leaves. Sporangia are produced on the surface of the fruits in very large numbers indeed, and the zoospores in correspondingly greater numbers. The rapid dissemination from the first few infected fruits can be explained by rain-drops that fall on these infected fruits splashing the spores considerable distances to other fruits. Faulwetter[1] in an illuminating and suggestive paper showed by experiment that water is splashed by a falling drop only when it falls upon a film of water, and it is the water of the film which composes the splash-drops. A drop ·02 c.c. in volume falling 16 feet on to a horizontal glass slide covered with a film of water splashed drops to 24 inches, on a plate inclined at 45° to 28 inches and on a plate inclined at 30° to 46 inches. When the plate was at 7 feet above the surface of the counter, the distances were in the 1st and 3rd cases 42 and 66 inches respectively. He also found that in wind driven by an electric-fan and travelling at 10 miles an hour at the point of splash which was 3 feet above the floor, a drop falling 16 feet splashed drops to an extreme distance of 18 feet. The size of the drops is comparable to that of rain-drops, and winds of 10 miles an hour and much more during the early part of the monsoon are often

1 Faulwetter, R. C. "Wind-blown Rain, a factor in Disease Dissemination." *Journ. Agric. Res.*, X, pp. 639—648, 1917.

experienced on the rubber estates. With the almost continuous rain the opportunity of continuous distribution by splashing is given, and even though frequent collisions between splash-drops and rain-drops will occur, thus preventing many of the former from reaching their extreme distance, still some of them will be carried off, and be again splashed farther distances. This explanation would seem to be sufficient to account for the rapid spread of the fungus from fruit to fruit and to leaves on an estate, and the great numbers produced on infected fruits provide many opportunities of their being washed down on the tapping surface.

Loss.

Hevea has been attacked by this fungus in South India before planting has been well established, so that there is no very extensive series of figures showing the yield of latex for any length of time on the estates of healthy trees. Estates have been in bearing for only a few years, 8 or 10 at the most, and that on a comparatively small acreage which has gradually become affected by abnormal leaf-fall. It is thus difficult to estimate the latex yields that might normally be expected. That so far they have not come up to the expectation current at the time of planting is fairly generally conceded, and part of the shortage is undoubtedly due to the effects on the trees of *Phytophthora*. The loss due to the rotting of fruits is a minor factor, as the utilization of fruits for purposes other than planting, for the present at any rate, hardly comes into the estimate. From discussions with most of the planters who have had much to do with the disease, I have come to the conclusion that 30 to 40 lbs. of made rubber per acre per annum is about the average loss, and it may be as high as 70 or 80 on badly infected blocks of trees. This transposed into money value, with the rubber, say, at 2/9 per pound and the cost of production, say, at 9 pence a pound, gives a loss of from £3 to £4 per acre per annum which multiplied by the yielding infected area of about 30,000 acres represents a total loss to the industry of about £100,000 sterling and a possible future loss over the area of 60,000 acres of a very large sum of money indeed. The loss involved is so large that it is practicable to spend a large sum of money on remedial or preventive measures on every estate.

Preventive measures.

It is only recently that the life-history of the fungus has been worked out in comparative detail so that the discussion of combative measures against it is more a suggestion of lines of work than a statement of definite means of prevention. In this connection the main facts to be borne in mind are (1) that the mycelium passes the dry-weather inside branches that have partially died back, (2) that oospores, which are resting-spores, are found in the fruit, and (3) that the fruits are the main propagating centres for multiplying the fungus. This suggests that the branches that have died back, and the fruits, should be dealt with. In the one case the aim is to stop the fungus from beginning its activity in the new season, and in the other to stop its rapid propagation after it has once begun. If all branches that this fungus has caused to die back were removed, say, a foot beyond the junction of living and dead tissues, many of the centres of infection that begin the new attack of the fungus each year, would be destroyed. Now all branches that die back on *Hevea* do not do so because of this fungus. There are other factors that produce die-back, *e.g.*, shade causes the lower branches to die, and other fungi, *e.g.*, *Botryodiplodia theobromæ* Pat. and *Glœosporium alborubrum* Petch, also do so. There is no simple field method of distinguishing between these various causes, so that, if die-back branches are to be removed, then all will have to be removed irrespective of the causative agent. Many of the branches that have died back are mere twigs, while others are larger. There are many such on each tree —far more than is realized till the necessity comes to remove them—and they are scattered over the tree indiscriminately. To remove them to a very large extent is possible, but to do it thoroughly will certainly be costly. The cost, however, would be greatest in the first year, and would rapidly decrease in succeeding years, presuming that this method is found efficacious and is continued.

It has also been shown that the fungus may invade a branch along the fruit-stalk, and that the fruit-stalks of rotted fruits may remain on the tree through the dry weather till the beginning of the monsoon. This is a real difficulty in the way of preventive measures, for it is impossible to remove every possible centre of infection of this kind. Even if all these old fruit-stalks were removed when the trees are bare in December-January, there is the fact that the mycelium of the fungus invades the branches from which the fruit-stalks spring at their point of insertion. Removing die-back branches would not destroy this source of re-infection entirely.

Removal of the fruits before the break of the monsoon, or at the latest during the first fortnight of the monsoon, though this is cutting it rather fine for safety, would stop the rapid propagation of the fungus that begins about 15 days after the monsoon has set in. This would also for future infection get over the difficulty mentioned in the last paragraph with regard to infection by fruit-stalks. If the fruits are not there to become infected, the fruit-stalks would not carry the mycelium of the fungus into the branches. To remove fruits from a rubber tree is not an easy matter, as they are scattered over young twigs towards the ends of the branches. So far as my observations go, the fruits seem to be more plentiful on the intermediate rather than on the higher branches ; but of course I have not seen old rubber (*i.e.*, more than 15 years old), and do not know whether this holds good generally. At any rate it is substantially true for rubber in South India at the present time. Removal of the fruits is not an impossible task, though to do it thoroughly will be expensive.

There is another possibility, *i.e.*, the destruction of the flowers in order to prevent the formation of fruit. This might be done by mechanically removing the flowers, or by spraying them with a chemical that would kill them. The stalk of the inflorescence is easily cut until it begins to become strengthened in order to bear the weight of the developing fruit. The inflorescences, however, borne as they are on the numerous twigs on the outer ends of the branches, are not easily reached even with a knife on the end of a long pole such as a shepherd uses to get down leaves of trees for his flocks. The manipulation of such a weapon at best is clumsy, and it has been found that, unless the knife has a keener edge than a coolie can be expected to keep, the stalks bend before it instead of being cut by it. Again, most of the inflorescences spring from the axils of leaves that are still on the twig, and they cannot be removed without removing the leaves as well, thus causing a considerable amount of defoliation ; but this we particularly wish to avoid seeing that the new season's tapping is about to begin. Besides every inflorescence does not produce fruit, so that removing all of them entails a great deal of unnecessary labour. In several estates in April and May twigs were examined on the inflorescences of which all the flowers had faded, and the presence or absence of young fruits was noted. They were taken from the lower and middle branches of the trees, as these were more easily accessible. On 63 twigs there were 651 inflorescences, of which 230 had one or more fruits, *i.e.*, only 35 per cent. of the inflorescences bore fruit. On a considerable number of the twigs there were inflorescence-scars showing that some inflorescences had fallen off, but they were not taken into account as they do not affect our purpose. Thus the difficulty of cutting the inflorescence because its stalk bends so readily before the knife, the unavoidable removal of leaves in doing it, and the low percentage of inflorescences that bear fruit, render the removal of flowers by mechanical means impracticable.

Spraying the inflorescence with a chemical, such as a solution of copper sulphate that would kill them, is not under present conditions practicable.

The trees are 20 to 40 feet high, so that power sprayers would have to be used, and in order to get at each flower so much of the solution would be used that it would practically amount to spraying the tree. Besides it would be exceedingly difficult to spray the upper parts of trees from the ground, as the side branches of trees on most well grown estates touch and sometimes overreach one another. The same applies in an increased degree to spraying the fruits, as the stand of foliage is greater during the fruiting season. Spraying the fruits of the areca-palm, *Areca catechu*, with Bordeaux Mixture as a preventive against the attack of *Phytophthora arecæ* (Colem.) Pethyb., has been a marked success. There, however, the fruits are aggregated in from 1 to 3 bunches on the single stem just under the crown of leaves, and are comparatively easily accessible for spraying. Bordeaux Mixture would protect the fruits of *Hevea* against *Phytophthora* just as effectively, but their scattered position on the tree precludes its use at present for reasons of economy, while there is the additional reason against its use in that even traces of a salt of copper in latex cause the rubber to deteriorate, and it is almost certain that traces of copper would be washed by rain into latex from sprayed trees. The action of any other protective fungicide on rubber would have to be investigated before it could be recommended as a spray. Besides in any extensive spraying operations the difficulty of getting enough water to spray in the dry weather would be great, and the cost of treating the higher portions of an estate would be very high.

The question whether it is not possible to prevent trees from flowering, or to reduce the amount of flowering by some cultural means, has also been considered. The Government Economic Botanist has discussed this with me on estates, but it does not seem feasible. Horticultural endeavour has been rather in the direction of increasing the flowering capacity of plants, and so far as we know, there are no cultural methods of preventing a tree from flowering, or reducing the number of flowers it produces that are applicable in estate conditions.

It seems to me that the only feasible methods of directly dealing with the fungus are removing the dead branches and the fruits, and in 1917 four blocks of considerable size, 100 acres in two cases, in widely separated parts of the rubber-growing area were set apart for experiment which consisted in destroying all old fruits and debris, in removing and destroying, shortly after the season of periodic leaf-fall (practically in March and April), all branches that had died back, and in removing and destroying all fruits before the 1st of June. This will be repeated in 1918, and will give data as to the cost and the effectiveness of the measures undertaken in stopping or reducing the disease.

There still remains to be discussed what measures meantime may be taken to check and prevent bark-rot. In untreated cases, where the rot has sunk as deep as to the cambium, the piece should be cleanly excised and the wound carefully painted with tar and tallow. The excised portions must be burnt, and knives sterilized by dipping in an antiseptic solution, *e.g.*, 1 per cent. formalin. In certain areas of the district, practically those in which rainfall is not excessive, and where bark-rot is not a pressing menace, it has been found sufficient to tap less deeply when bark-rot begins to appear, and if that is not enough, to stop tapping for a few weeks. This is usually quite sufficient and no further trouble occurs. The underlying cortex cuts off the infected piece of bark which ultimately scales off. In other parts of the district this is not enough, and recourse is had to smearing the tapped surface with a mixture of tar and tallow. This is done as a preventive on blocks where experience has shown that bark-rot occurs, and its use has proved successful. Enough tallow is melted with tar, so that when cold, the mixture is a paste and not a liquid. It can be carried round in any suitable vessel by the coolie, who puts a thin smear on the renewing bark just above the tapped surface with his thumb or with a piece of gunny, and the consistency of the paste makes it easy to handle, and prevents it running down over the tapping cut. A very little tar in cultural media inhibits the growth of the fungus. Concentrations of 0·5 per cent. or more of tar in a Quaker-oats-agar medium on which the fungus grows well completely prevent growth, while lower concentrations as far as 0·1 per cent. do not prevent growth in every case.

Quaker-oats-agar		6 tubes	Good growth. In 14 days the sloped surface of the medium was covered by the mycelium.
Ditto	5% tar	6 ,,	No growth.
Ditto	1% ,,	6 ,,	,,
Ditto	0·5% ,,	6 ,,	,,
Ditto	0·25% ,,	6 ,,	No growth in 5 tubes; slight growth in 1 tube.
Ditto	0·1% ,,	6 ,,	No growth in 4 tubes; slight growth in 2 tubes.

This particular experiment was carried on for a month, and the fungus made a copious mycelial growth in the Quaker-oats-agar medium to which no tar had been added, and in no case where the fungus grew in low concentrations of tar in the same medium was the growth anything like as good. I think it is both the water-proofing and the fungicidal qualities of the mixture that come into play in preventing the fungus from infecting the tree. With izal, one of the coal-tar products, a similar series of experiments was carried out.

(*a*) Different concentrations of izal in French-bean-agar tubes were made up and autoclaved.

(*b*) Different concentrations of izal made with sterile water were added to liquid French-bean-agar tubes that had been autoclaved in order to make definite concentrations of izal in the French-bean-agar.

Concentration	(a)		(b)	
French-bean-agar	14 tubes.	Good growth in all tubes.	6 tubes.	Good growth in all tubes
5% izal in French-bean-agar	8 ,,	No growth.	7 ,,	No growth
1% ,, ,, ,, ,,	8 ,,	ditto	7 ,,	,,
0·5% ,, ,, ,, ,,	8 ,,	ditto	8 ,,	,,
0·1% ,, ,, ,, ,,	8 ,,	ditto	7 ,,	,,
0·01% ,, ,, ,, ,,	...	......	8 ,,	Growth in 2 tubes.
0·001% ,, ,, ,, ,,	...	... ..	8 ,,	Growth in 3 tubes.

Different concentrations of izal in water were made, and in no case of 0·1 per cent. or above did the mycelium grow or sporangia discharge. Izal is thus a powerful fungicide so far as this fungus is concerned, and can be used in dilute solutions. As, however, it is to be applied in the monsoon, a considerably more concentrated solution is required, and 5 per cent. is the usual strength used on estates. The ordinary conical kitchen lamp makes a good receptacle, and the slightly projecting wick drawn along the tapping cut leaves a thin film of the izal solution. Other investigators have tried izal and other similar substances, and recommended as preventives 10 per cent. izal, 20 per cent. carbolineum, 20 per cent. brunolinum or 50 per cent. Jodelite to be applied as frequently as tapping is done. I have also found that the distillate from coconut-shells charred in a closed chamber (earthenware pot) even in solutions of 0·1 per cent. prevents the growth of the fungus in culture ; but its effect in the field has not been tested yet. This is of some interest at the present time, when the other substances are expensive and not easy to get.

I have seen folded strips of gunny tied round the trunks of trees in a slanting direction with good results. The rain-water streaming down the trunk was guided along the gunny, and caused to run down the side of the tree away from the cut. The bark below the gunny in the region of the tapping surface remained comparatively dry as long as the gunny remained tight. This was being tried from the point of view of preventing flooding of the cups during heavy rain, and it is a sound idea and well worth developing from the point of view of bark-rot. Something cheap and just good enough to last for the rainy months, and then not worth the trouble of keeping till the next season, would probably be the most suitable form. It must not be so tight round the tree that translocation through the bark is retarded, and it must be tight enough above the tapping cut to prevent water percolating between it and the bark on to the tapped surface. The latter is the more difficult condition to satisfy, but if the bark is smoothed and very slightly grooved, it has been found possible to tie the "collar" on tight enough and seal the intervening space with tar. The difficulties are obvious, and make-shifts will have to be made to get over them till more normal mes, when timanufacturers can turn their minds to the production of some suitable device.

General measures with regard to estate ventilation will also indirectly help to reduce the amount of damage caused by this and other bark-diseases, and this, of course, is the immediate and main concern of preventive work. Most estates in South India were closely planted, and the trees are now being thinned out to between 80 to 100 per acre. Lower branches, especially those that hang downwards, should also be cut off, and this will give a larger, freer air space, and allow more light to get around the stems, and so ensure that the bark grows and renews in more healthy conditions. Sooner or later, however, the crowns of the trees will develop till they come close together, and form a more or less continuous canopy of leaves, so that, after thinning, preventive measures applied to the bark are still as necessary. That gangs of specially trained coolies are necessary on estates for efficiently carrying out measures against diseases is generally recognized, and in South India we have gone a step further by providing at the Agricultural College, Coimbatore, for writers who are to supervise those "pest gangs," a simple course in plant-diseases with special reference to diseases of *Hevea*, and one day I hope to attract young planters to the College for short courses on diseases of planters' crops.

Occurrence of fruit-rot, leaf-fall and bark-rot in other countries.

In 1908 Petch[1] described a fruit disease of *Hevea*, and in 1910[2] gave a further description and stated that it was determined to be due to *Phytophthora* in 1905, in which year it occurred on an epidemic scale. He also records the fact that after the fruits have rotted, the green branches may also die back, and suggests that *Phytophthora* is the cause. He describes the claret-coloured canker, and gives the result of inoculations with *P. Faberi* from cacao pods on to

[1] Petch, T. "Die Pilze von *Hevea brasiliensis*." *Zeitschr. für Pflanzenkr.*, XVIII, pp. 90—91, 1908.

[2] ,, "Cacao and *Hevea* Canker." *Circ. and Agric. Journ. of the R. B. G., Ceylon*, V, pp. 143—180, 1910.

Hevea stems. Three out of the ten inoculations with spores suspended in water produced canker, and three inoculations with pieces of diseased cacao pods also produced canker. He accordingly concluded that the canker and pod-disease of *Hevea* are both caused by *Phytophthora*, and that the species is the same as that which causes pod-disease and canker in cacao, *viz.*, *P. Faberi* Maub. He also described a bark-rot that occurred during the prolonged rains of 1909-1910, and thought that it did not appear to be due to canker. Thus in 1910 in Ceylon fruit-rot, a die-back of the fruiting branches, claret-coloured canker, and bark-rot were reported on *Hevea*, and the cause of the first three was attributed to *P. Faberi*, while the last was thought to be due to physiological causes correlated with excessive rainfall. In his book he gives the various symptoms in detail. In 1912-13 Petch[1] says that it has been found that the leaf-fall which often follows the fruit-disease, and is characterised by the appearance of a dark-brown ring on the leaf-stalk, is caused by the canker fungus (*P. Faberi*), and in 1914 he[2] states that canker was first recorded in Ceylon in 1903, so that the causative fungus *P. Faberi* has been found to attack every part of the tree except the leaves, though it attacks the leaf-stalks, and causes defoliation. In 1916 he[3] associates the fruit disease and the consequent leaf-fall as caused by the same fungus. He also states that it has been shown that the fungus produces resting-spores in the diseased pods, and remains dormant in branches partly killed back. In various subsequent references he reiterates the above statements. Thus in Ceylon the disease attacks fruits, leaf-stalks, green-branches and fruiting-stalks (causing a partial die-back), bark and renewing bark, and causes a general leaf-fall in the monsoon, and all the symptoms are attributed to the action of *P. Faberi*. In South India I have never seen claret-coloured canker, but the other symptoms are exactly as they are found here, though the causative fungus is a different species of *Phytophthora* ; and taking into account the discussion on a previous page, it seems possible that the causative fungi in Ceylon and South India are different. Still as Dastur suggests from a consideration of the literature, it may be that *P. Faberi* in Ceylon causes claret-coloured canker only, and that the species causing the other symptoms has not yet been definitely determined, especially if in 1916 Petch means that resting-spores have been found in diseased fruits in Ceylon, and the resting-spores are oospores. As the resting conidia of *P. Faberi* were so readily produced by the fungus on inoculated *Hevea* fruits as well as on cacao pods, and as there is nothing to show that they are oogonia

[1] Petch, T. "Administration Report of the Dept. of Agric., Ceylon," p. 7, 1912-13; p. 6, 1916.
[2] ,, "International Rubber Congress met Tentoonstellig, Batavia," pp. 12—14, 1914.
[3] ,, "Diseases of *Hevea*". *Trop. Agric.*, XLVII, pp. 279—281, 1916.

containing oospores, it would seem that something other than resting conidia was meant. In 1918 Petch[1] describes a bark disease new to Ceylon, the cause of which has not been determined. It is quite different from canker and bark-rot. His description fits exactly with a disease of stems I saw in one of the rubber-growing districts of South India in 1917. I was unable to find the cause. In only two cases did I get a fungus within the diseased bark, and it was *Corticium javanicum*; but I do not suggest that it was the cause, and considering the circumstances on the estate I believe it was not. My inability to find a fungus within the bark was also Petch's experience. It is very likely the same as the brown-bast recorded from Malay as Petch thinks possible. Peters[2] in 1912 described a fruit-rot of *Hevea* in the Cameroons that was destroying about two-thirds of the fruits, associating it with the extraordinary rainfall of that year, and the description fits that of the fruit-rot of South India. His paper is confined to fruit-rot, and no mention is made of any other symptoms on the tree. A *Phytophthora* was found and brought into culture, but no inoculation experiments are recorded. He compared his cultures with cultures of *P. Faberi*, and decided that the identity of the two fungi was not really settled. Peters did not see an oogonial membrane, and saw antheridia in only two cases. The sporangia come within the limits of those of *P. Meadii*, but the oospores are considerably larger. The measurements of only a few spores, 10—30 in each case, do not give enough data to enable one to say with certainty whether it is the same as *P. Meadii*, and Dastur makes the same remark with regard to the identity of this and his Burma *Phytophthora*, and he considers as resting-spores what Peters calls oospores. Rutgers[3] states that *Hevea* canker occurs in Java, Sumatra and Borneo, and describes the symptoms in four forms, one of which corresponds to bark-rot; the second to claret-coloured canker; the third is described thus: In a great number of cases the red canker spots are of small size, but near them in the inner bark, close to the cambium or sometimes in the place of the cambium, is a colouration which is less striking but more widely spread. The colouration shows itself in a section chiefly as yellow, brown, or grey stripes and flecks sometimes also as a brown stripe on the place of the cambium. A typical characteristic of the third form of canker is the complete drying up of the section in the region

[1] Petch, T. "*Hevea* Bark Disease." *Trop. Agric.*, L., pp. 14—17, 1918.

[2] Peters. "Uber eine Fruchtfäule von *Hevea brasiliensis* in Kamerun." *Ber. über d. Tatigkeit d. Kais. Biol. Anst. im Jahre* 1911 (*Mit. K. B. Anst. für Land und Forst-wirtschaft.* No. 12, 1912).

[3] Rutgers, A. A. L. "Inter-Rubber Congress met Tentoonstellig, Batavia," pp. 4—9, 1914; also Rutgers, A. A. L. and Dammerman, K. W. "Ziekten en Beschadigingen van *Hevea brasiliensis* op Java." *Mededeelingen van het Laboratorium voor Pflantenzickten*, No. 10, pp. 27—31, 1914.

of the discoloration (*Translation*). The fourth is the formation of burrs when the third form is not dealt with. He states that the black-stripe has only been found in estates strongly attacked by canker, and also all stages between it and the typical red spots have been found. The cause of all these appearances he attributes to *P. Faberi*, which also causes the canker of cacao and the fruit-rot of cacao and *Hevea*; but the hyphæ of *Phytophthora* have not been found in the third form, though it is always associated with the second. It is not clear whether all the infective material he used for inoculating *Hevea* was derived from *P. Faberi* from cacao, or partly from cacao and partly from *Hevea*. His latest paper I have not seen. Dastur [1] in 1916 reported from Burma the presence of fruit-rot and black-thread, which is very like the bark-rot of South India, and said by Bryce to be the same as the one occurring in Ceylon, and suggested the possibility of the *Phytophthora* he found to be the cause being the same as that in South India. The differences, however, between the two fungi are somewhat striking. His measurements of sporangia on fruits and stems, *viz.*, $20{\cdot}7—35{\cdot}7\mu \times 15{\cdot}0—25{\cdot}5\mu$ sometimes reaching $44{\cdot}2\mu$ in length and $29{\cdot}0\mu$ in breadth, the average being $28{\cdot}5 \times 20{\cdot}4\mu$, come fairly near those of *P. Meadii* in water-cultures, *viz.*, $20—44\mu \times 16—29\mu$, the average being $32 \times 23\mu$, but they are considerably smaller than those on fruits, *viz.*, $32—67\mu \times 14—28\mu$, the average being $48 \times 21\mu$. The zoospores in a sporangium number 3 to 10, while in *P. Meadii* they number 14 to 23 and very occasionally up to 30 and 40. Then resting conidia are present in the Burma *Phytophthora*, but they have not been seen in *P. Meadii*. Antheridia, oogonia and oospores are absent from the Burma *Phytophthora*, while they are present in *P. Meadii* both in culture and on fruits. We exchanged cultures of the two fungi and grew parallel cultures; but the Burma *Phytophthora* did not produce oospores in my laboratory, while the South Indian one did in Pusa. Different climatic conditions might well account for these differences, but till oospores are found in the Burma *Phytophthora*, we cannot be quite certain of their identity. Pratt [2] reported "black thread" or stripe canker or cambium rot from Sumatra, and gave details of remedial measures. Belgrave and Norris[3] reported it from Malay in the same year, and attributed it to a species of *Phytophthora* isolated from the diseased wood, and got 100 per cent.

[1] Dastur, J. F. "*Phytophthora* sp. on *Hevea brasiliensis*." *Mem. Dept. Agric., India, Bot. Series*, VIII, pp. 217—232, 1916.

[2] Pratt, H. C. "Preventive measures against Black Thread." *Trop. Agric.*, XLVIII, pp. 304—306, 1917.

[3] Belgrave, W. N. C. and Norris, F. de la M. "Notes on Bark Cankers and their Treatment." *Agric. Bull., F. M. States*, VI, pp. 2—7, 1917.

successful inoculations. They state that the penetration of the wood is usual, deep, and rapid, and both vertical and horizontal spread of the fungus is much more rapid in the wood than in the bark. They have not seen a fruit-rot and presumably not a leaf-fall as they do not mention it. They also report the presence of claret-coloured canker, but the description differs considerably from that of Ceylon, and from a note on water-logged bark there seems to be some confusion in Malay both in the names and in the descriptions of diseases of the bark. Richards [1, 2] reported a bark disease, which has the same symptoms as bark-rot, from it isolated a species of *Phytophthora*, and states that from evidence collected it appears that the fungus is not *P. Faberi*, but another species of the same genus, and is the same as that described by Dastur. He also records the presence of canker. In Malay it seems that bark-rot and perhaps claret-coloured canker are present, but not fruit-rot nor any of the other symptoms noted in South India. There is also another disease, brown-bast, which appears to be similar to that described by Petch from Ceylon and seen by me in one part of South India. In Richards' paper is an extract from Aher's " Rubber Industry in Brazil and the Orient ", in which is mentioned the fact that a cambium-rot occurs in Brazil. No description, however, is given, so it is not known whether it has any relationship to the bark-rot of the East. In the *Tropical Agriculturist* for 1914, Vol. XLII, p. 268, there is a reference to an abnormal leaf-fall in Surinam : the fact is simply stated that *Hevea* drops its leaves twice a year there. Wester [3] writing on rubber culture in the Philippines mentions stem-canker, bark-rot, abnormal leaf-fall and diseased pods of *Hevea* among the more serious diseases that have appeared in other rubber-growing countries in the Far East, so they have not been recorded from those islands. There is in the literature some indefiniteness, and very little description of the fungus in the various aspects of the disease caused by *Phytophthora*, and it would appear that more than one species of *Phytophthora* is responsible for them.

Since this paper was written it was brought to my notice that a culture of *P. Meadii* sent to Pusa produced resting conidia there soon after its arrival, and has continued to do so in subsequent sub-cultures. They have appeared in French-bean-agar and oat-juice-agar, though never so copiously as in cultures of the Burma *Phytophthora* on *Hevea*. Dastur kindly sent me sub-cultures in

[1] Richards, R. M. " Brown Bast and Black Thread." *Malay Penin. Agric. Assocn. Cir.*, No. 1, pp. 4—5, 1917.

[2] ,, " Diseases of the Leaves and Stem of *Hevea brasiliensis* in the Malay Peninsula." *Agric. Bull., F. M. S.*, V, pp. 312—316, 1917.

[3] Wester, P. J. " Rubber Culture in the Philippines." *Phil. Agric. Review*, X, p. 219, 1917

French-bean-agar, in which are numerous resting conidia. I have searched my cultures of various dates but have found no resting conidia in them, and during the three years the fungus has been under observation in culture in Coimbatore, it has not produced resting conidia, and they have not been found in nature in South India. It may be that climatic differences account for the difference of behaviour of the fungus in Coimbatore and Pusa, for in the former place the annual range of temperature is from about 60° to 101°F., while in the latter it is from about 32° to 112°F.

While studying *Pythium palmivorum* Butl., the fungus that causes bud-rot of palmyra palms, *Borassus flabelliformis*, in the Godavari and Kistna districts, Butler[1] found that resting conidia could not always be found, but that sometimes they could be and then were present in very large numbers. They were either absent or rare at certain seasons and in some years. The same experience has been found with this fungus on coco-palms, *Cocos nucifera*, in South India. Resting conidia are seldom seen, but early this year they were found in very large numbers indeed on large discoloured areas on young expanding leaves. It appears that a similar experience is presented by *P. Meadii* in culture in South India and Pusa.

The fact that *P. Meadii* can produce resting conidia rather confirms the identity of the *Phytophthoras* from Burma and from South India. I have made measurements of the resting conidia from the culture of the Burma *Phytophthora* and from that of the South Indian *Phytophthora* returned to me by Dastur, and the measurements come very close together. My measurements of the former, however, are larger than those given by Dastur in his paper. The measurements of 100 resting conidia of the Burma *Phytophthora* in French-bean-agar measured in Coimbatore were 18—47 × 18—46μ, the average being 34·3 × 33·8μ while those in Dastur's paper are 17—34μ. The measurements of 100 resting conidia of *P. Meadii* from a sub-culture in French-bean-agar returned from Pusa were 16—47 × 16—47μ, the average being 34·8 — 34μ.

These resting conidia also come fairly close to those of *P. Faberi* in size. Rorer gives the variation as 30—50μ. My measurements were on cacao fruits 26—46 × 23—43μ, the average being 35·3 × 35μ, on French-bean-agar 24—51 × 22—49μ, the average being 38 × 37μ, and on inoculated *Hevea* fruits 20—39 × 18—39μ, the average being 34·5 × 34μ.

[1] Butler, E. J. "The Bud-rot of Palmyra Palms." *Mem. Dept. Agric., India, Bot. Series,* III, pp. 255—257, 1910.

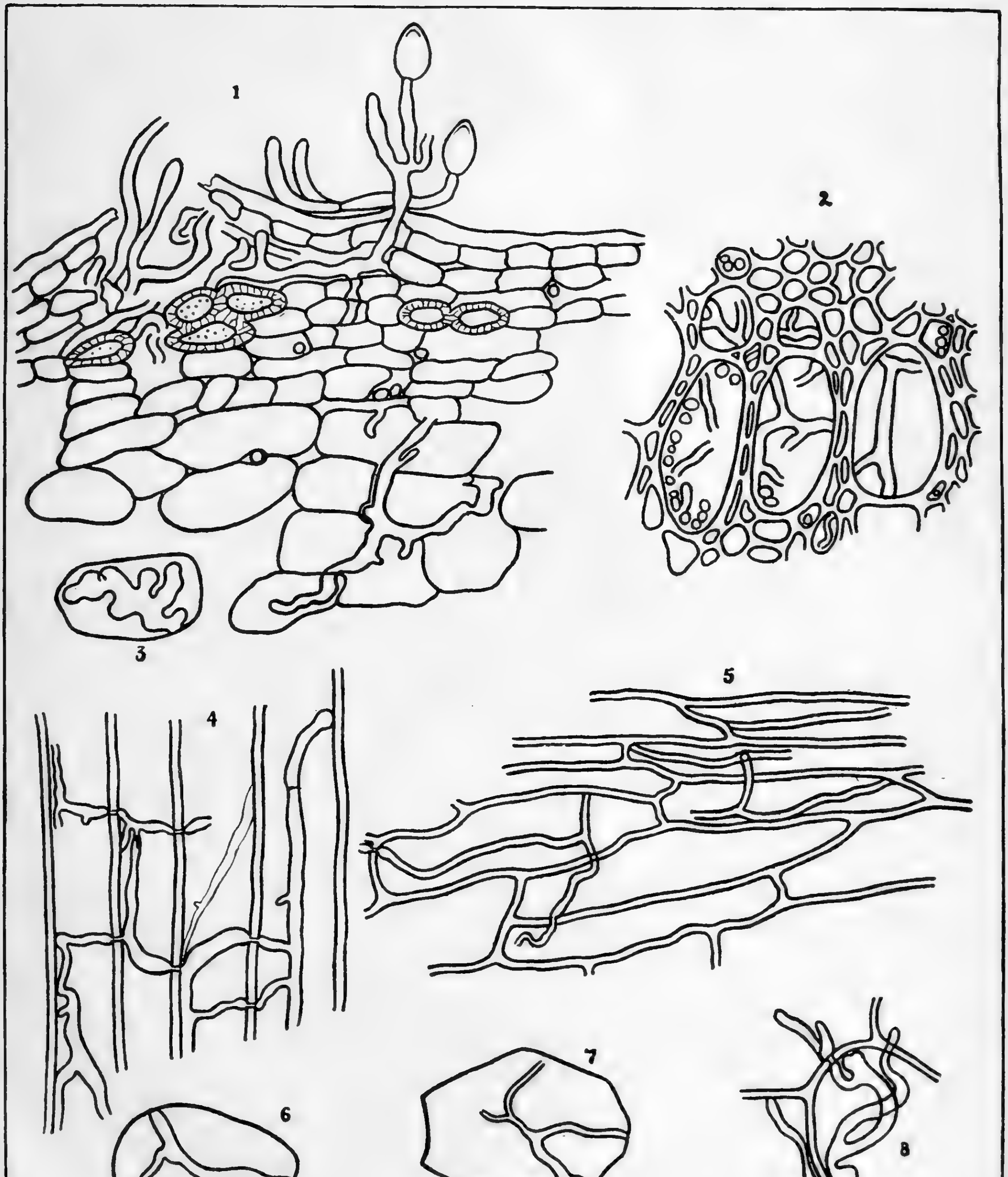
The presence of resting conidia on *P. Meadii* required that the relationship of this fungus to other members of the genus should be reconsidered. I do not think, however, that this fact enables it to be placed under any of these species.

Explanation of Plate I.

Phytophthora Meadii n. sp. *on Hevea brasiliensis.*

Fig. 1. Section of outside of fruit, × 300.
,, 2. T. s. of petiole, × 500.
,, 3. Cell from mesocarp of fruit, × 500.
,, 4. Section through the endocarp of the fruit, × 240.
,, 5. ,, ,, ,, seed-coat, × 240.
,, 6. Cell from pith, × 460.
,, 7. ,, ,, mesocarp of fruit, × 460.
,, 8. ,, ,, pith, × 500.

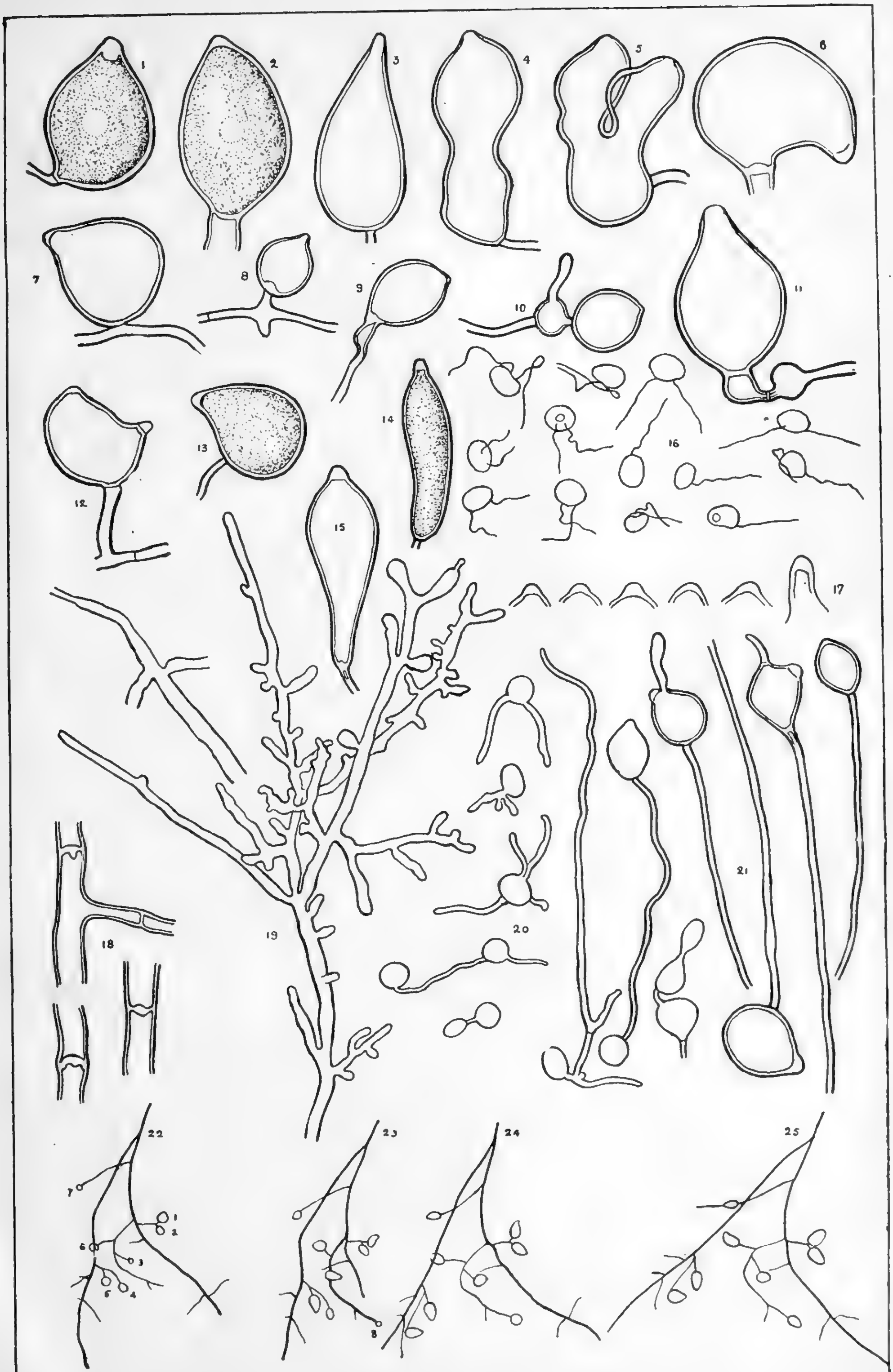
PLATE I.



Explanation of Plate II.

Phytophthora Meadii n. sp. *on Hevea brasiliensis.*

Figs. 1—15. Sporangia, × 500.
Fig. 16. Zoospores, × 500.
" 17. Papillæ of sporangia, × 500.
" 18. Hyphæ with irregularly thickened transverse walls, × 1,000.
" 19. Mycelium, × 240.
" 20. Germinating zoospores, × 500.
" 21. Sporangia with long conidiophores, × 250.
Figs. 22—25. Developing sporangia, × 66.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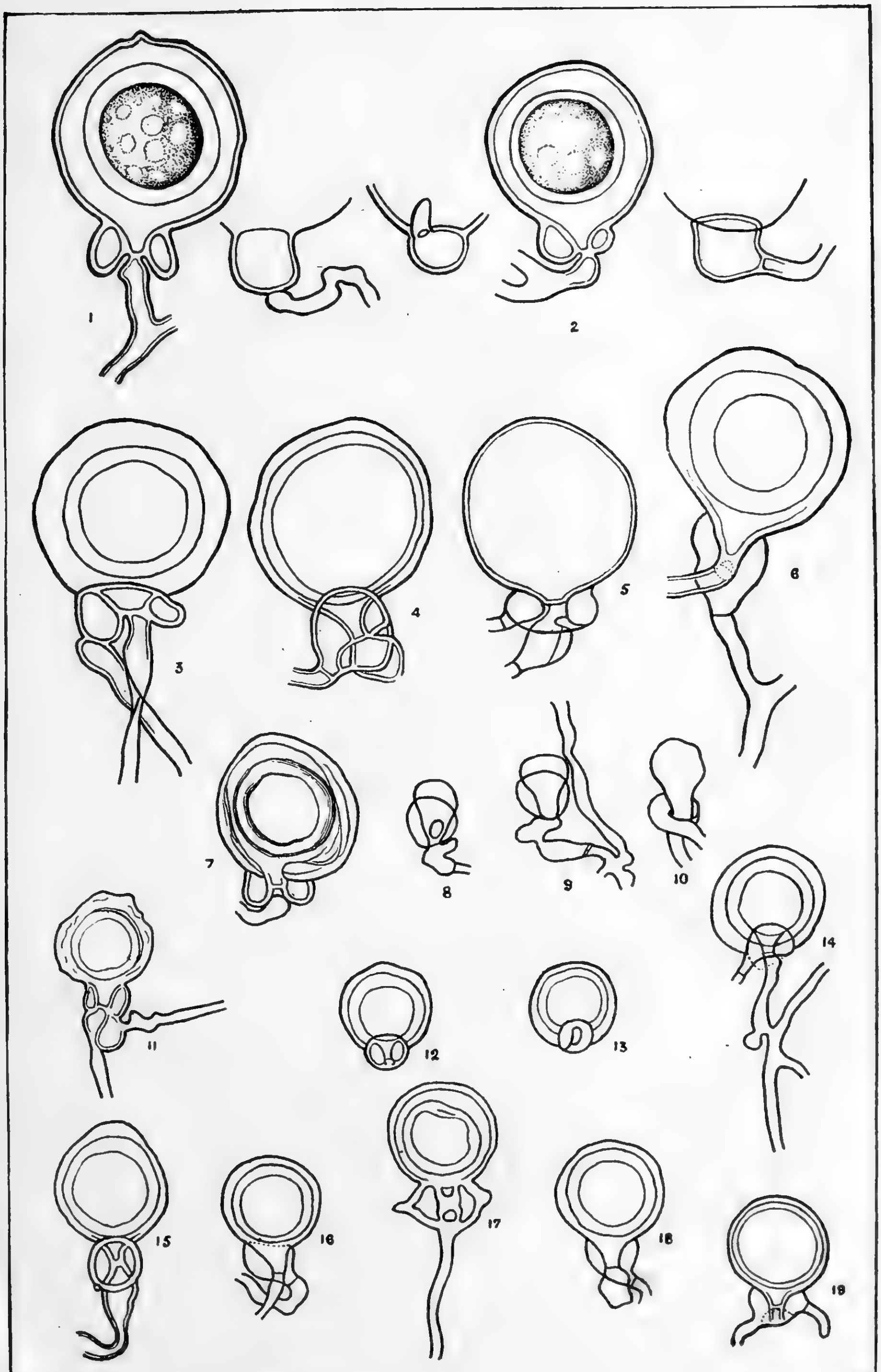
Explanation of Plate III.

Phytophthora Meadii n. sp. *on Hevea brasiliensis.*

Figs.	1— 6.	Antheridia, oogonia and oospores,	+ 1,000.
Fig.	7.	Oogonia with oogonial wall folded,	+ 660.
,,	8	Young oogonia and antheridia	+ 750.
,,	9.	Young oogonia and antheridia	× 500.
,,	10.	Young oogonia and antheridia	× 750.
Figs.	11—19.	Oogonia antheridia, × 600.	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