POTASH AND PAYING CROPS

GERMAN KALI WORKS

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FURNISHED GRATUITOUSLY
TO THE
NEW YORK AGRICULTURAL EXPERIMENT STATION
FOR DISTRIBUTION AS THEY MAY APPROVE
TO THE
FARMERS OF NEW YORK.

INTRODUCTION.

If an apology were needed for this compilation, the first public document issued by the Department of Agriculture, after its elevation to an executive department with a Cabinet officer at its head would offer the same; for the report of the Committee of the Association of Agricultural Colleges and Experiment Stations, therein quoted, contains the following pregnant passages: "To one familiar with the history of this sort of research, it is interesting to note how many of the problems suggested for study by the different stations are nearly, or quite, identical with those with which the work of the experiment stations was begun when the first ones were founded, over thirty years ago, and how large a proportion are, in fact, the same that have been the object of the bulk of the study of these and other institutions of research in this country, in England, and, to a far larger extent, on the Continent of Europe, for half a century." And again: "The difficulties which the newer stations have to meet are enhanced by the fact that nearly all the accumulated experience is recorded in foreign literature, and is accessible only to those who have at hand the great accumulation of journals and other publications in which the results of earlier and later research are set forth." Therefore, the committee is strongly of the opinion that "one of the most useful services to the cause would exist in the compilation of the main results of this research in various special lines, and the putting of them not only into English, but in forms conveniently suited to the use of American investigators."

An attempt to lay before the large body of intelligent American farmers, in clear, concise, intelligible language, the latest practical results of agricultural science in Germany, may, therefore, hope to be not altogether unwelcome. Destined mainly to enlighten the tiller of the soil about the great importance of soil nutrition, and to impress upon his mind in a brief way the latest discoveries regarding the problem of fertilization, this publication does not claim to enter deeply into the scientific aspect of the subject matter, but to give only, in a popular way enough of it to render the subject perfectly easy of comprehension to any and all readers. As Professor Atwater, the Director of the Office of Experiment Stations, regards it as an auspicious circumstance that the initial publication, issued under the Secretary of Agriculture, is one relating to an enterprise in which science joins hands with the art of agriculture in an effort to secure the greater welfare of mankind, so does the hope appear also permissible that the effort of German enterprise to lend its willing aid and assistance to the great work undertaken by the United States, may meet with a friendly reception.

A list of the works and publications which furnished the material for this compilation is appended at the end. More detailed information can be obtained on application to the office of the—

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Agricultural Science and Its Main Object.

The prosperity of any agricultural country depends upon the prosperity of its agricultural community, and the latter, in turn, depends upon the quantity and the quality of the crops raised on its land. That country takes the lead, in the long run, which raises on a given area twice as much as another country; that farmer is more prosperous who raises on a ten-acre field as much, if not more, than another does on twenty acres. This plain, simple and self-evident consideration establishes at once the pre-eminent position which in our days agricultural science should, and as a matter of fact, does occupy in civilized countries. For, the ultimate object of all scientific research, of all work in the laboratory, and of all field experiments, is not so much the unearthing of a scientific truth as rather the practical application of scientific truths to farming, so as to render this pursuit more profitable and less uncertain.

Agricultural science embraces necessarily a very wide field. The chemistry and physics of the atmosphere and soil, the exhaustion of the soil and its restoration to fertility by tillage and artificial manures, the composition of plants and their adaptation to different localities and climates, the feeding of animals, the production of milk, butter, cheese and other dairy matters, the diseases of plants and animals, fruit culture and a variety of other subjects belong legitimately to the science of agriculture. But of all these problems there is one which has occupied the main attention of science from the very start, and which at the same time concerns the most vital interests of the farmer and that subject is **artificial fertilization.**

Every farmer knows that even the richest soil, after a while, decreases steadily in fertility; that the ground becomes worn out, exhausted, unable to respond to the demands made upon it. To raise *paying* crops to-day, without artificial fertilization, is possible only where stable-manure of the best quality can be offered in abundant quantities to the fields, and that possibility is an exception and not the rule, least of all in a country like the United States, where the area under cultivation is disproportionately large to the number of cattle kept on it, and where, moreover, the amount of stable-manure produced is, owing to the mode of farming, much below the figure that might be produced.

ARTIFICIAL FERTILIZATION.

The necessity of artificial fertilization was recognized at an early day by American farmers, who were not slow in bringing to their service the commercial fertilizer, a commodity as indispensable to-day to profitable farming as food is for the sustenance of the body. But, after all, commercial fertilizers are nothing but food, not for the human body, it is true, but for the plant. Plants require food, like animals and human beings, and it is only natural that plants cannot thrive luxuriously unless they are properly and well fed.

Proper plant nutrition forms, consequently, that portion of agricultural science in which the farmer's interest centers and which, also (let it be emphasized), engages the most careful and diligent labor of the scientists. To solve this vexed and very complex problem successfully is the aim and ambition, not of one, but of all who devote their life-work and brain-energy, for the benefit of the farmers, to scientific research in this direction. At first sight it would seem that the solution could not be very difficult, because the progress made in agricultural chemistry is such that the scientist can tell exactly by analysis what each plant removes from the soil, and in what quantities. Now, if the analysis of the soil is compared to it, it would seem as if a comparison of the two would show at a glance what the soil requires, and in what quantities; but he who would act on the knowledge gained by such comparison would, in many cases, find out to his detriment that the conclusion so drawn was too hasty and one-sided. There was a time, indeed, and that time belongs to the very recent past, when even scientists held that a plant that contains in its crop-substance three and four times as much nitrogen as another plant, requires for that reason a more liberal quantity of nitrogen in the soil. But that time is past. It has been found that the requirements of plants for *nutrition* and for *fertilization* are by no means the same, and this discovery has done much towards elucidating the subject by directing the research to a closer study of plant-growth, that is of the principle of plant-life.

WHAT IS PLANT GROWTH?

Now, plant-growth, if a definition is to be attempted, might be defined as the transformation of inorganic into organic substances. All plants, without exception, require mineral substances out of which by means of certain raw materials they form organic matter, viz.: the grains of wheat, barley, oats, or the potatoes, beets, peas, tobacco leaves, cotton bolls, etc. The mineral substances, viz.: phosphoric acid, potash, lime, soda, etc., are furnished by the soil, while the air furnishes the carbonic acid, the sky the water; nitrogen has, in many cases, to be furnished with the mineral subtances by man.

The problem of plant-nutrition narrows itself down, therefore, to the question of **nitrogen**, **phosphoric acid** and **potash** (more correctly, kali), as nearly all other mineral substances are, as a rule, in entirely sufficient quantities in any soil, with the exception, perhaps, of lime. The absence of lime, however, manifests itself so easily and so surely, that for general observations lime need not be taken into consideration. Whereever it forms an essential element it will be mentioned.

WHEREIN CONSISTS RATIONAL FERTILIZATION:

Proper fertilization consists therefore in a thorough and correct understanding of the *nitrogen*, the *phosphoric acid* and the *potash question*. In that sense it has been taken up by science, and in that sense it has been taken up by all practical farmers. Science established, for instance, that phosphoric acid, in order to produce perceptible immediate results upon any crop, must be given to the plants in an available form; and so with potash and with nitrogen. The very fact that many State laws do not admit fertilizers for sale, unless they contain certain percentages of these elements in a form available to the plants, serves as a proof, if any were needed, that the farmer's interest lies in procuring such plant-food as science has established beyond gainsaying to be valuable as plant-food, and that the farmer's interests are properly protected by these State laws against imposition by unscrupulous parties.

Yet, while this protection of the farmer appears in a most favorable light in one sense, it checks agricultural progress in another sense. Hardly two soils are alike, and if two were exactly alike, location and other circumstances might alter their requirements entirely. Yet, considering allciraumctsnces, the fertilizer-laws of the several States require only to be made more uniform, and to be placed upon a more scientific basis than that upon which some of them rest at present, in order to attain the purpose for which they have been framed, namely, the protection of the most vital interest of the country, its agriculture.

THE REQUIREMENTS OF NUTRITION AND FERTILIZATION ARE NOT THE SAME.

The problem of fertilization and its solution depends, as has been stated, upon a thorough knowledge of plant-growth and plant-nutrition. It has also been remarked already that the requirements of plants for *nutrition* and for *fertilization* are not the same. Very careful investigations of the process of plant-growth and discoveries resulting from this research have thrown an entirely new light upon the whole subject of fertilization. To make, however, perfectly clear what will be said later on, it is necessary to make here a few remarks about plant-growth.

PLANT-GROWTH.

A grain of wheat put into the ground germinates in due course of time; it shoots out a tiny little leaflet, and this leaflet feeds on the organic substance of the seed; it lives, as it were, on mother's milk. Not until the second leaflet appears is the stock of food contained in the seed exhausted; then, however, a change of food takes place, the tiny wheat-plant, by means of its roots, looks up and takes up now the inorganic food of the soil, namely: phosphoric acid, nitrogen, potash, magnesia, lime, etc., and in proportion as this nutriment is abundant, and the season propitious, it grows and develops into a tall, rich stalk, with full heavy ears. There are, consequently, but two stages noticeable in its growth; the one, that of germination carried on by means of organic food; the other, the growth into maturity under exclusive inorganic nutriment.

Not so with leguminous plants. At first they do exactly what the cereals and all other non-leguminous plants do. The pea germinates and lives on mother's milk, that is to say, the organic food of the seed, and then, like the grain of wheat, changes its diet to inorganic food. But the second period of nutrition is followed by a third, requiring twice to four times as much nitrogen as the cereals do, for instance; the pea develops the capacity to draw its requisite amount of nitrogen from the air, and becomes, after the second stage of growth, altogether independent of the nitrogen supply of the soil.

NITROGEN CONSUMERS AND NITROGEN GATHERERS.

The practical bearing of this division of plants into *nitrogen-consumers* and *nitrogen-gatherers*, is of the utmost importance to the farmer, as will be seen later on. For the present it suffices to remark that to fertilize nitrogen-gatherers with anything but phosphates and potash, is sheer waste, is money thrown away. Rarely do cases occur where leguminous plants do not find sufficient nitrogen in the soil to bridge over from the first to the third stage of nutrition successfully. The few instances where they do require it are announced to the eye by the pale, yellowish color of the young plants, and in such cases a small application of nitrate of soda is not too late to still their hunger, so that it may be asserted as a rule that leguminous plants require no fertilization with nitrogen.

This long-disputed fact has been settled in a final manner through Professor Hellriegel, Professor Wagner, E. von Wolff and others, so that it is no longer a debatable question.

For the sake of furnishing an irresistible proof that fertilization with nitrogen produces no effect whatsoever upon the class of nitrogen-gathering plants, and of the very decided results produced upon nitrogen-consuming plants, the following table is reprinted from Prof. Dr. Paul Wagner's work "On the increase of the yield of the soil by rational nitrogen fertilization."

Wheat, barley, beans and luzerne were planted on one and the same field *without* nitrogen, with 18 pounds nitrogen per acre and with 31.5 pounds and 45 pounds with the following results, phosphoric acid and potash being furnished in all cases in like quantities:

	No Nitrogen.	18 lbs. N.	31.5 lbs. N.	45 lbs. N.
Barley........	100	161	220	272
Wheat........	138	212	270	316
Beans........	935	938	961	883
Luzerne......	976	983	1000	994

While nitrogen fertilization shows very decided results proportionate to the quantities furnished to the plants in the case of barley and wheat, it shows no effect whatsoever in the case of the two leguminous plants, beans and luzerne. It proves, however, something else. While barley was only able to take up from the soil enough nitrogen to produce a crop of 100 (barley being chosen as standard for comparison), and wheat only to give 138, beans and luzerne were able to procure enough nitrogen to produce at once 935 and 976 respectively. With nitrogen supplied to the soil the yield of barley nearly trebled, and that of wheat more than doubled, showing that these plants depend upon the nitrogen supply of the soil, while the others are independent of such supply.

Now, what is the practical value to the farmer of this study of the various phases of plant-life and of the experiments based upon that study? The result is this: all intelligent farmers who know of the difference between leguminous and non-leguminous plants, as regards their ability and inability to draw upon the limitless supply of nitrogen contained in the atmosphere, will no longer spend money for nitrogenous fertilizers for leguminous plants. And yet, as Prof. Wagner remarks, "but a few years ago the advice was given to fertilize peas, beans, etc., and all perennial plants like luzerne, clover, etc., with nitrate of soda. That advice was incorrect; it rested upon an insufficient knowledge about the nitrogen nutrition of these plants. They do require from two to three times as much nitrogen as wheat, oats, corn, etc., yet they do not show under normal conditions any increase worth mentioning, if fertilized with nitrogen."

Now, though it is perhaps unnecessary to state, nitrogen is the most expensive ingredient of any fertilizer; the doing away with nitrogen fertilization in case of all leguminous plants, saves therefore to the farmer all the money that might have been spent on it, if he did not know of this late scientific discovery. But this is not all. Nitrogen being, as has just been said, the most costly element of plant-food, the further question suggested itself: can the capacity of the leguminous plants, to take up nitrogen from the atmosphere, be utilized by the farmer to procure nitrogen for other crops without having to pay for it? And that question, certainly a downright practical question, has been answered also. Before, however, giving the answer, a few words about the part which nitrogen plays in the household of nature, or rather during the process of plant-growth, appear not out of place, because they will greatly facilitate the understanding of all that follows.

NITROGEN REGULATES PLANT-GROWTH.

Nitrogen acts as regulator of the productive capacity of all non-leguminous plants. The subjoined table shows the amount of potash (K_2O) phosphoric acid and nitrogen contained in the average crops of the several plants, the dry substance of the harvest products, grain as well as straw, being comprised therein.

TABLE

Showing how many pounds of the constituents mentioned are withdrawn per acre by an average crop.

	Potash (Kali). K_2O	Phosphoric Acid. P_2O_5	Nitrogen. N
Wheat	58	45	111
Rye	76	44	87
Barley	62	35	78
Oats	96	35	89
Corn	174	69	146
Rice	45	24	39
Sorghum	71	68	129
Buckwheat	17	40	63
Pea (pisum sativum)	69	39	153
Horsepea (Vicia faba)	169	64	254
Soja bean (Soja hispida)	87	62	297
Lupine, yellow (Lupinus luteus)	80	37	155
Lupine, green, for fodder	63	46	219
Potatoes	192	55	119
Sugar beet, beet-root	200	44	95
Cattle turnips	426	74	187
Carrots	190	65	166
Meadow hay	201	53	166
Corn, fodder, green	236	66	122
Clover (trifolium pratense)	29	18	37
Clover, green (trifolium pratense)	154	46	171
Lucerne (medicago sativa)	181	65	289
Clover (trifolium repens)	58	29	89
Red clover (trifolium incarnatum)	57	17	95
Esparsette	103	36	239
Seradella	196	57	128
Vetch (Vicia sativa)	113	35	149
Rape	124	79	154
Poppy	92	30	87
Hemp (cannabivs sativa)	54	34	—
Cotton	35	32	110
Hops	127	54	200
Tobacco	148	32	127
Sugar cane	107	37	518
Sorghum (Sorghum saccharatum)	561	90	446
White cabbage	514	125	213
Cauliflower	265	76	202
Lettuce (Lactuca sativa)	72	17	41
Cucumbers	193	94	142
Onions	96	49	96

Now the next question of practical importance is this: Does an average crop of these plants require the soil to contain as many pounds of nitrogen as the table indicates? To this science answers *no*, for the simple reason that the roots and the stalks which remain on the field, and are not included in the dry substance, contain also nitrogen, and because, moreover, it is impossible to assume that the entire supply of nitrogen can ever be taken up by any crop. Therefore, *more* than the table indicates must be in the ground. Of 100 pounds of nitrate of soda, analyzing on an average from fifteen to sixteen per cent. of nitrogen, probably not more than ten pounds are utilized for the production of a crop. Now 100 pounds of nitrate of soda per acre, that is to say, a fertilization of ten pounds of nitrogen per acre, should produce results which are easy to calculate. If sixty pounds of nitrogen are contained in a crop of 2140 pounds of oats, and 3500 of straw, then ten pounds of nitrogen should produce an additional quantity of some 350 pounds of oats and some 580 pounds of straw.

The average content of nitrogen of all plants which are generally being cultivated is known, hence the additional amount which ten pounds of nitrogen should produce in harvest substance, should be as follows:

Wheat	350	pounds of	grain and	500	pounds of	straw
Rye	330	"	"	850	"	"
Barley	420	"	"	600	"	"
Oats	350	"	"	580	"	"
Maize (corn)	420	"	"	580	"	"
Rice	1000	"	"	1200	"	"
Buckwheat	420	"	"	640	"	"
Potatoes	2600	"	tubers	300	"	"
Beet roots	4500	"	roots	900	"	leaves
Cattle turnips	3900	"	"	1000	"	"
Carrots	3700	"	"	560	"	"
Chicory	3400	"	"	410	"	"
Meadow hay	645	"	hay			
Green maize	5300	"	green plant substance.			
Rape	210	"	grain and 600 pounds of straw			
Poppy	170	"	seed	500	"	"
Cotton	270	"	"	100	"	"
Hops	70	"	flowers	320	"	leaves and tendrils
Sugar-cane	2000	"	sugar-cane			
White cabbage	4200	"	heads			
Cauliflower	1500	"	" and 1500 pounds of leaves			
Kohl-rabi	1400	"	bulbs	1200	"	"
Cucumbers	6000	"	cucumbers			
Onions	3700	"	onions			

These results are practically obtainable, have been obtained and are not fictitious, yet in reality they are *rarely* obtained; not, however, because science is wrong, but because generally, even if the proper nitrogen supply is put into the ground, the other conditions necessary for that surplus production are wanting.

ONE-SIDED FERTILIZATION DOES NOT PAY.

The experiments of Beseler and Maerker, as well as those of Prof. Wagner, the latter undertaken with a view to corroborate the former, have given the following information: Nitrogen only then serves as the means to produce a maximum crop, if the stimulus it imparts to plants to grow is not checked by the absence of those ingredients without which plants cannot grow, namely, phosphoric acid and potash. At the same time the propensity of nitrogen to be consumed by non-leguminous plants is such, that if the conditions are wanting for the production of a maximum crop, they will produce what the soil permits, with a *higher* content of nitrogen. For instance, if an oat-field contains, say forty pounds of nitrogen (by soil analysis), and forty pounds more are put into it to obtain a more profitable harvest, the dry substance of the harvest may be 11,500 pounds at 0.7 per cent. of nitrogen, or only 8000 pounds at one per cent. of nitrogen. If the farmer provided for 100 pounds of potash (K_2O), fifty pounds of phosphoric acid and twenty-five pounds of lime, besides providing for forty pounds of nitrogen, then the maximnm crop of 11,500 pounds can be obtained, but not otherwise. The nitrogen will be consumed, it will not remain in the soil, it goes toward making whatever is being harvested much richer in nitrogen, but it will and can do no more.

Given, however, the proper conditions to show its pre-eminent quality in stimulating plants to grow, that is to say, given an excess of potash and phosphoric acid in the soil, nitrogen does not fail to perform its office. Practical experiments establish this point beyond doubt. Nor is there much diversity of opinion among scientists as regards the value of nitrogen fertilization; there is only diversity of opinion as to whether nitrate of soda, sulphate of ammonia, blood, tankage, fish-scrap, or something else, is the best form in which it should be put into the ground. At all events the foremost agricultural chemist of Germany has not hesitated to affirm, that the whole question of the artificial fertilization of the soil turns round the one question: wherein consists the most rational economy with nitrogen.

And he says on that subject: "Schultz-Lupitz sees in the cheapest and most abundant securing of nitrogen, in the husbanding of the same, in its highest possible utilization, the real true task and the main object of fertilization. Is this standpoint one-sided? No." And this most emphatic declaration he bases first upon the fact that the leguminous plants possess the ability to draw upon the inexhaustible supply of nitrogen offered by nature in the atmosphere and upon the further fact, that the *nitrogen-gatherers* can be made nitrogen-hungry, that is to say, can be induced to draw much more freely upon the inexpensive supply open to them than they do under ordinary circumstances.

On average soils Prof. Wagner calculates the requirements of nitrogen per acre to be for the several crops as follows:

For cereal crops	from	13–50	lbs. of N.	=100–400	lbs.	of nitrate	of soda.
" potatoes	"	22–45	" "	=150–300	"		"
" sugar beets	"	22–50	" "	=150–380	"		"
" tobacco	"	13–26	" "	=100–200	"		"

In case of potatoes and sugar beets only nitrate of soda should be applied, because sulphate of ammonia does not prove advantageous. If it is possible at all to talk about controlling the vegetation of plants, that control is exercised by nitrogen. Whereas it is wise policy to mete out phosphoric acid and potash in abundance to all crops, it is unwise to give more nitrogen than is required for the production of a maximum crop. The excess of phosphoric acid and potash is not lost, not consumed, but stays in the ground, an excess of nitrogen, the most expensive element, would be consumed.

THE NECESSITY OF PHOSPHORIC ACID.

Nearly all kinds of soil contain phosphoric acid, but mostly in a form in which it is not easily taken up by the plants. Even in soils that are very rich in phosphoric acid, the quantity which becomes each day available for the roots of the plants is small, so small in fact that it only suffices for the production of an average crop in favorable seasons. But as really favorable seasons are again the exception rather than the rule, the natural supply proves generally inadequate. If it does not rain for a fortnight the plants stop growing, because they cannot take up phosphoric acid. When the next rain comes they are ready, not only for the amount which the earth can give them daily, but for a great deal more, and unless they find this "more" in available form in the soil, the extra exertion of the plants to make up for lost time are put forth in vain. Such contingencies render it therefore necessary to be most liberal with phosphoric acid; it should be given to every crop in abundance, so that a surplus is always in the ground, because whenever plants get abnormally hungry, as is the case after a rain following a spell of dry weather, their abnormal appetite can only be satisfied by such a surplus.

All agricultural chemists agree on this point, all recognize and consequentiy advise the farmer not to be sparing with the fertilization with phosphoric acid; first, because its presence is indispensable for any large crop; secondly, because it is never lost, but benefits succeeding crops.

WHEREIN CONSISTS THE POTASH QUESTION.

After these remarks about nitrogen and phosphoric acid, the very important practical question arrests our attention: How can nitrogen-gatherers be made nitrogen-hungry? and this brings us to *the potash question*, a subject which during the last eight or ten years has forced itself upon all scientists. Practical results obtained by practical men, who, while highly intelligent farmers, did not claim to be scientists, appeared to establish a set of facts hitherto unknown. The facts were irresistible and induced Prof. Maerker, Prof. Wagner and others to investigate the subject thoroughly, with a view of framing a scientific answer to the practical answer which experience had furnished to Schultz on his poor land in Lupitz, and to Rimpau on the peat soil of Cunrau. As Dr. Emil Wolff, Professor in the Agricultural Academy at Hohenheim remarks in the ninth edition of his work, *Practische Düngerlehre:* "The results of Schultz-Lupitz and Rimpau-Cunrau are examples of a new method of culture, which is of high importance to the whole of Germany." He says: "Schultz-Lupitz has proven in a convincing manner the great financial advantages, if the farmer, as far as possible, manures his soil with the nitrogen of the atmosphere. He plants leguminous plants and proper clover-species for a crop and leaves the roots and stubbles for the succeeding crop as fertilizer in the ground. In this way he has succeeded, under the exclusive application of potash and phosphate, to raise on very poor soil exceedingly paying crops under the following rotation:

1. *Rye* fertilized per hectar (1 ha. = 2.47 acres) with 200 kilogram (1 kg. = 2.2 lbs.) of superphosphate at twenty per cent. P_2O_5 and 600 kg. of kainit. In the stubbles Lupins are sowed with another 600 kg. of kainit.
2. Oats.
3. Potatoes fertilized with 16,000 kg. of stable manure.
4. Peas, with 200 kg. superphosphate and 600 kg. kainit.
5. Rye, with 200 kg. superphosphate and 600 kg. kainit.
6. Clover.

The only fertilizers used were kainit and superphosphates, and on soil that was not considered worth cultivation. Schultz succeeded by this exclusive potash-phosphate fertilization in producing sure crops and, what is more, paying crops."

On the peat soils of Cunrau similar results were obtained by a very liberal application of kainit, the soil not being deficient in nitrogen, but the difficulty consisting in getting the nitrogen taken up by the plants. Of course, such convincing practical results, which seemed to upset, as it were, the theories heretofore entertained, induced men like Wagner to experiment so as to ascertain the principle underlying this unexpected phenomenon.

What is the influence of potash (kali) upon plant-growth, was the first point that required a thorough clearing up. But Prof. Wagner may be allowed to tell the story in his own words:

PROF. WAGNER ON THE POTASH QUESTION.

"Exceedingly little is known, even to-day, about all questions referring to potash fertilization. This plant is fertilized with kainit, the other with muriate of potash, the third with sulphate of potash, but without knowing which is correct. It is not known how much the several plants can stand of potash salts without being injured; it is not known which are most, which are least, sensible to potash fertilization; it is not known which plants can only with difficulty draw upon the potash supply of the soil, and for that reason require ample potash fertilization; it is not known what influence potash fertilization exercises upon the quality of the grain, how the other ingredients of the potash salts affect the plants—in short, by the results of scientific research, exceedingly little is known about potash fertilization. *The experience of practical farmers* has furnished until now the only material.

"For several years past the experiment station at Darmstadt has undertaken to investigate some practically important questions about potash fertilization through exact experiments, and the results obtained enable me to examine several assertions of Schultz-Lupitz and to test them.

"I begin with the rather strange assertion of Schultz-Lupitz, which has found much opposition, that cereals, particularly rye, should be fertilized with potash, especially under the form of kainit. Is not this altogether irrational? Cereals are certainly no potash plants. While for the production of an average crop of lucerne, potatoes, sugar beets, etc., about 150 kg. (kali) potash per hectar are necessary—the cereals are content with about 50 kg.—is it possible, therefore, that, as Schultz-Lupitz has found out practically, a kainit application of 1,200 kg. per ha. for rye is not altogether irrational?

"It appears to be so, but still, on the strength of my experiments, I must answer the question with an affirmative, decided 'Yes.' First of all, I wish to call attention to the fact that a plant which contains six times as much potash (kali) in its dry harvest substance as another, does not require for that reason a proportionately larger amount of potash (kali) fertilization."

"The requirement of plants for nutrition—as I have emphasized already in previous publications—is by no means identical with the requirement by way of fertilization. On the contrary, a plant with a great demand has often a correspondingly greater capacity to satisfy that demand than another plant which is satisfied with much less, and does not require a correspondingly great supply of easily assimilable nutriment as that other. A relatively greater demand, as we perceive everywhere in nature, is generally accompanied by a correspondingly greater capacity for the satisfaction of that demand. Lucerne, for instance, requires nearly four times as much nitrogen as wheat, but for that reason the lucerne is equipped with the ability to utilize a much richer source of nitrogen (the atmosphere) than the wheat, which is compelled to rely for its nitrogen supply upon the soil. And so it is with the potash (kali) question. The capacity to take up the potash (kali) supply of the soil and to utilize the potash (kali) so taken up differs amongst the various plants."

"For several years, and particularly during the past summer, I have carried out a series of potash (kali) fertilization experiments in order to make this matter clear.

"In March experiments were started with summer cereals (wheat, rye, oats and barley), peas, potatoes, red clover, sugar-beets, vetches, lupines, summer rape, beets, partly in vegetation vessels, partly on the field, for the purpose of answering the following questions:

1. What is the potash (kali) requirement of the various plants?
2. To what extent can the various plants stand potash (kali) fertilization?
3. How does potash (kali) fertilization affect the quality of the crop?"

"Of several pot experiments photographs were taken on June 5th, and June 11th, and I have added these to the publication.

"The photographs represent:

1. Experiments with barley, potatoes and peas in larger vessels, holding 18 kilo earth (about 40 lbs. [39.6]).
2. Experiments which were made with peas, wheat, rye, oats and barley in smaller vessels, containing 6 kilo earth (13½ lbs. [13.22]). (See illustrations.)

"The soil was:

1. A loamy soil of 0.23 per cent. potash (kali), which gives for the larger vessels 35 gr. potash (kali) for the smaller 11½ gr. potash (kali).
2. A light sandy soil of 0.036 per cent. potash (kali), which makes 7½ gr. potash (kali) for the larger, 2½ gr. potash (kali) for the smaller vessels.

"As potash (kali) fertilization the smaller vessels received ¾ gr. potash (kali), the larger ones 2 gr. potash (kali). In all cases enough nitrogen and phosphoric acid was supplied for the production of a maximum crop.

"The results, as far as I can briefly give them in this publication (a more extensive publication is under way) are the following:

1. Potash (kali) fertilization has in all cases shown decided effects, except with potatoes (more about these potatoes later on).
2. On the sandy soil, poorer in potash (kali), the effect is much more pronounced than on richer soil.
3. The potash (kali) requirement of the various plants varies very much. It appears most pronounced in the case of cereals.

"These experiments confirm therefore Schultz-Lupitz's assertion of the great importance of potash (kali) fertilization for cereals."

PROF. WAGNER'S CONCLUSIONS.

On the strength of these experiments and the lesson they teach, Professor Wagner proceeds to lay down in the following paragraphs what he feels justified in saying about potash (kali) fertilization.

1. A high rate of advantage from potash (kali) fertilization appears most probable on light sandy soils and on peat soils. These soils are as a rule so poor in potash (kali) that they require a large supply of potash (kali) salts in order to produce satisfactory crops. The potash (kali) salts best adapted for these soils are kainit and carnallite. Richer soils should

be carefully examined upon their potash (kali) requirements before deciding upon regular potash (kali) fertilization; but care is to be taken not to be deceived by the examination. How easy it is to be deceived, an example will illustrate.

Suppose two farmers have the same soil and both determine to prove by an experiment whether the soil requires potash (kali). Farmer A applies ninety pounds per acre and chooses barley as the plant to make the experiment on. Farmer B uses the same quantity of potash (kali) but chooses turnips. How much should the yield be increased in each case? We suppose that one-half of the potash (kali) application, that is to say forty-five pounds, should be contained in the harvest product, and that a supply of forty-five pounds was already in the soil. This is easy to calculate. For the production of an average barley crop, there are required per acre forty-five pounds, of potash (kali), and for the production of an average crop of turnips about 226 pounds of potash (kali). For the barley requirement the quantity of potash (kali) has been doubled, but on the beet-field only ⅙ has been added of what the crop requires. Farmer A finds the yield of barley doubled, and considers his soil very much in need of potash (kali); farmer B is hardly able to see any result, and believes his soil does not require potash (kali). Yet, as a matter of fact, the potash (kali) requirement of the soil is necessarily the same, only the plant requirement differing. It became quite evident in the one case and not so in the other.

2. Meadows are to be considered as pre-eminently requiring potash (kali), and as paying well for its application. Meadows, as a rule, have lost much more of phosphoric acid and potash (kali) than has been returned to them by manure, and the yield of meadows are considerably below what they might be if properly fertilized with phosphates and potash (kali), as has been proven in recent years in a final manner.

Nitrogen fertilization on meadows is unnecessary. The meadow should not live on the nitrogen of the soil, because it should enrich the farm by catching the nitrogen of the air and transforming it into stable-manure nitrogen. That meadows are able to do that, can be easily observed, for nowhere does the difference between nitrogen-gatherers and nitrogen-consumers appear more clearly. If a very neglected meadow is fertilized with potash (kali) and phosphate, it will be seen how clover species and leguminous plants, of which nothing has been visible before, will begin to vegetate luxuriously, while the grasses will hunger and take second place in the first year. In the second year the grasses will also thrive luxuriously, because the leguminosae have fertilized the meadow with nitrogen, that portion, namely, which their roots contain, of which portions continually decay and decompose, and which portion furnishes all the nitrogen the grasses require.

In that way a farmer can take every year from 100 to 200 pounds of nitrogen per acre in shape of hay, clover, etc., and gain it for the farm, without supplying any nitrogen to the meadow. Exclusive potash (kali) phosphate fertilization enables such a tremendous gain of nitrogen, that no farmer should fail to avail himself of this cheap mode of enriching his land.

3. The same rate of advantage which potash (kali) phosphate fertilization promises on meadows, may of course be expected in the culture of peas, beans, clover, etc. Under no condition should the nitrogen-gatherers be left without an ample supply of phosphoric acid and potash (kali), as they are rendered thereby nitrogen-hungry; the more potash (kali) and phosphate they can assimilate, the more greedily do they utilize the atmosphere's nitrogen.

4. Just as the nitrogen-gatherers should be richly supplied with potash (kali) and phosphate, so that they may take as much nitrogen as possible from the air and convert it into harvest substance, so it is also necessary to give to all nitrogen-consumers an excess of potash (kali) and phosphate because then alone can they utilize fully the nitrogen of the soil, of the stable manure and of the nitrogenous fertilizers.

It is, however, not all the same in regard to cereals, as to whether the potash (kali) is offered in shape of natural salts, such as kainit and carnallit, or in shape of muriate or sulphate.

On the strength of what is known up to to-day on that subject I can lay down the following general principles:

(*a*) I consider it as suited to the purpose to fertilize with potash (kali) not only all plants intended to be used on the farm as food for animals, but also all cereals, which furnish straw, in quantities not merely sufficient for the production of a maximum crop, but with enough to induce the plants to take up an excess of potash (kali). Animal food rich in potash (kali) gives manure rich in potash (kali), and the potash (kali) of the manure is for some plants most advantageous.

(*b*) For potatoes and sugar beets, give the potash (kali) in form of stable manure, and apply potash (kali) to the crop preceding or else fertilize with muriate of potash in the fall.

(*c*) On loamy soils potatoes stand direct potash (kali) fertilization better than on sandy soils.

(*d*) Among the cereals oats requires the least, barley the largest quantity of potash (kali).

(*e*) To tobacco apply the potash (kali) only in form of sulphate.

5. Wherever the conditions of soil and plants admit of the application of the natural potash salts (kainit, carnallit, etc.), they are to be given the preference before the concentrated potash (kali) salts.

6. The quantities of potash (kali) that should be given to the various plants depend, of course, upon the content of potash (kali) of the soil, and its conditions.

   They vary per acre from 50–120–18; lbs. of potash (kali) on peat soils; (400–900–1,200 lbs. of kainit; 100–240–360 lbs. of potassium chloride.)

7. Potash (kali) salts succeed best when applied in the fall or during the winter. They can be spread broadcast with the hand or with a machine, and plowed under. On meadows the simple spreading is sufficient. If phosphates are also applied, it is best to mix them just before use. If the mixture stands for awhile it is apt to get hard.

8. Care is to be taken that the soil contains enough lime when potash (kali) salts are richly applied. With enough lime, sure and considerable results will not fail."

So far, Professor Wagner, whose injunctions do not savor of uncertainty or hesitancy, and whose positive statements deserve all the more credit, because they are made after a careful and long-continued study of the nitrogen and phosphoric acid fertilization.

WHAT IS THE EFFECT OF SODA.

It was during these researches that Prof. Wagner was led to think that the potash (kali) salts possessed an effect upon plant-growth, particularly nitrogen absorption, which had escaped observation. It was Schultz-Lupitz who contended that not only the potash (kali, K_2O) of the kainit, but likewise the other salts, exert a most favorable influence upon the crop. Concerning this side-effect, as it were, Professor Wagner says that magnesia and soda are there to be considered, the former of which is recognized as a necessary element of plant-food, so that its presence can, of course, only be advantageous. As regards soda (natron), however, it has been assigned so far only an *indirect* influence. "This is an error," he says; "there is a direct effect of it, and this direct effect of soda, that is to say of soda entered into the plant, has proven during my investigations of such importance that further researches in that direction are of very great moment."

In his opinion, "the decided preference expressed by Schultz-Lupitz for kainit as potash (kali) salt is, like the better yield, produced by the use of nitrate of soda as against sulphate of ammonia, attributable to the effect of the soda which kainit, as well as nitrate of soda, contains, and which, heretofore, has not been properly valued."

OPINIONS OF PROMINENT GERMAN FARMERS ABOUT POTASH FERTILIZATION.

What Schultz-Lupitz thinks about the potash (kali) question, and its importance for agriculture, may be inferred from the following quotation from an address delivered before the Club of the Landwirthe (farmers): "Section 4 of my resolution is to the effect 'that the securing of the potash (kali) or kainit deposits for the German agriculture should, in proper manner, be brought about.' "

"This point, gentlemen," so he said, "concerns, as far as I can see, the cardinal—the main question for the future of our German agriculture. It is recognized already on all sides that the application of potash (kali) salts on peat soils forms the basis of their culture; it is recognized that the application of potash (kali) salts to stable-manure effects a preservation of the nitrogen by preventing its escape. This has been established through the labors and researches of Jules Reiset, Lawes and Gilbert, E. Peters, König and Kiesen, Morgen, Dietzell and others; they have proven that without the application of potash (kali) salts the nitrogen of stable-manure, as also the nitrogen-economy of the soil, suffers permanent, considerable losses through the formation of free, volatile ammonia; it is beyond doubt to-day that potash (kali) salts and, foremost among them, kainit, are, in the hands of the farmer, the infallible means to keep nitrogen; it is also the case that potash (kali) salts are for the richest producers of nitrogen, the leguminosae, an exceedingly suitable fertilizer, provided, of course, rain is not wanting. In one word, the potash (kali) question is to-day no longer a mere question of supplying to the soil potash (kali), but it is in an eminent sense a question of nitrogen, a question how everywhere, on each farm, this most expensive element of plant-food, this carrier of life, can be procured and husbanded. It is my duty to give here before you expression to my opinion, an opinion firm and without doubt, that the potash (kali) deposits form the foundation and future of our German agriculture."

And in an article published in No. 559 of the *Magdeburger Zeitung* he writes: "I see that in the race of nations America especially shows sharp weapons. To the virgin soil there is added on the state institution of a homestead law, canals, elevators, and cheap, quick and easy railway transportation. I see that our home agriculture has to fight for life, and that if she succumbs large circles will suffer. I see that the fight has to be fought by us with an exhausted soil, from which our fathers took, without knowing it, the essential elements without replacing them. I see, by my experience of replacing them, in the potash (kali) salts properly used, the salvation—the main weapon for the fight which will lead us to victory and will regenerate our soil."

These utterances from one who, for over ten years, had succeeded in raising profitable crops on very poor land, paying crops against constantly decreasing prices of wheat, etc., acquire a great significance. They are a word of warning to his fellow-farmers, a patriotic appeal to keep, by an act of the government, these valuable deposits for the exclusive use of Germany, and an attestation that the question of fertilization turns almost exclusively round the proper, judicious application of potash (kali) salts. Privy Counsellor Rimpau, who, on his domain, Cunrau, owing to the liberal use of potash (kali) salts, had attained equally satisfactory results, had already proposed in 1881 a large export duty on all potash (kali) products. And yet, in spite of these overwhelming proofs as to the unquestionable value of the potash (kali) salts, the United States impose upon some of these salts a duty of twenty per cent, because they are capable of being used also for industrial purposes! Let American farmers and American agriculturists ponder over this strange legislative wisdom! Germany, certainly a strong, great country, well governed, highly cultured, and bent upon progress, considers the propriety of preventing the export of potash (kali) salts; and the United States, pre-eminently an agricultural country, feeling already the absolute necessity of artificial fertilization, and having no potash (kali) salt deposits, imposes upon them an import duty of twenty per cent.

HOW DOES PROF. WAGNER SUM UP THE SITUATION?

But let us sum up in a few words what the latest scientific results, thoroughly verified by many years experience of experienced agriculturists, have to say on the question of proper soil nutriment. They say: In rational economy with nitrogen lies the key to the situation, and, therefore, to use again Professor Wagner's words, the task is quite clear, viz.:

1. All leguminous plants such as peas, beans, lupins, clover, seradella, lentils, esparsette should be rendered nitrogen-hungry, so that they may draw to the utmost extent upon the nitrogen supply of the atmosphere, and this is effected by potash (kali) phosphate fertilization.

2. For the nitrogen consumers the requisite amount of nitrogen should be secured from the cheapest possible source, the atmosphere. Extensive cultivation of leguminous plants, fertilized by potash (kali) phosphates, and their use as nitrogen-fertilizers effects this.
3. As far as nitrogen, procured without cost from the air does not suffice, the nitrogen-consumers should be supplied with the requisite amount of nitrogen, sufficient for the production of a maximum crop.
4. Whatever nitrogen has been secured from the air by green cattle food, and passes on into their manure, should be preserved from losses. This is effected by spreading potash (kali) salts, containing magnesia, either in the stable or the dunghill.
5. Whatever nitrogen has been secured to the soil by way of stubbles, roots, etc., of leguminous plants, should also be protected from loss, which is done by planting after fruits, or leguminosae, for fertilization alone, properly fertilized with potash (kali) phosphates.
6. All nitrogen furnished to the crop by the soil, by the stable manure, or by commercial fertilizers, should be induced to produce the highest effect, which again is effected by liberal fertilization with potash (kali) phosphates.
7. Wherever lime is deficient, the soil should be supplied with it, so that the potash (kali) salts may develop their whole efficacy.

These are the theses Prof. Wagner extracted from his investigations and experiments, and they carry within themselves a convincing power. They all aim at preservation of the most expensive element of plant-food on one side, and on the other at obtaining and utilizing it to the fullest extent at the least expense to the farmer.

THE AMOUNT OF POTASH REMOVED BY EACH CROP.

A glance at the quantity of potash which the crops of 1887 removed from the soil, cannot fail to be highly instructive in this connection. The crop of 1887, as reported by the Department of Agriculture, consisted in:

1,456,160,000	bushels of	corn,	and removed	189,290	tons of potash (K_2O)
456,320,000	"	wheat,	"	85,696	"
659,618,000	"	oats,	"	54,331	"
20,693,000	"	rye,	"	2,860	"
56,812,000	"	barley,	"	8,431	"
10,884,000	"	buckwheat,	"	618	"
134,103,000	"	potatoes,	"	10,045	"
386,240,000	pounds of	tobacco,	"	6,949	"
41,454,000	tons of	hay,	"	1,112,011	"
7,020,209	bales of	cotton,	"	6,673	"
			In all,	1,476,904	tons of potash.

For the replacement of it no less than 11,538,281 tons of kainit, at 12.8 K_2O, would have been required. The very *alpha* of farming demands the replacement of that proportion which can in no way reach the soil, in another form, again. The quantity of potash contained in the cereals and other products exported is, of course, lost to the land; again, the quantity of cereals and agricultural products consumed in the large cities and towns find, as a rule, their way into sewers or canals, and into the river or sea and are again lost; and what is contained in the dropping of animals is only in a very small way returned to the ground; therefore, it seems safe to affirm that the replacement of at least one-tenth of what the crop removes is absolutely necessary to prevent a gradual, but sure impoverishment of the soil.

POTASH AND BARLEY.

Let us consider what Professor Wagner says regarding barley: "It is practically known that barley repays much less a fertilization with nitrogen than oats; it is also practically known that fertilizing with nitrogen produces barley that is too rich in nitrogen and too rich in protein; but it has not been known how exceedingly great the requirement of barley for potash fertilization is, and that barley can be forced, by sufficiently liberal fertilization with potash and phosphoric acid, to produce a much larger harvest of less protein in the crop-substance, and hence much more valuable for brewing purposes." Professor Märker's experiments, and those of Hellriegel, demonstrate how much barley stands in need of potash fertilization.

An average crop of barley takes about fifty pounds of potash (K_2O) per acre out of the soil. Averaging the crops of 1885, 1886 and 1887, each year about 70,000 tons of potash have been removed by the barley crops of the United States. Provided phosphoric acid and potash (kali) had been furnished in sufficient quantities, the barley crops on the area in barley could have been doubled.

Barley, the most grateful of all cereals for liberal kainit supply, was planted in the—

Year 1885 on	2,729,359	acres,	yielding	58,360,000	bushels.
" 1886 on	2,652,957	"	"	59,428,000	"
" 1887 on	2,901,953	"	"	56,812,000	"

Now there were imported according to the Report of the Department of Agriculture, in—

1885—	9,986,507	bushels,	at a cost of	$7,177,889.
1886—	10,197,115	"	"	6,173,208.
1887—	10,831,461	"	"	8,076,082.

Now by referring to what Professor Wagner says, namely, that the yield of barley per acre can be easily doubled by giving it a proper fertilization with potash and phosphate, namely 300 pounds of kainit per acre or a ton for 7 acres, the aggregate cost of this proper potash fertilization would have amounted to about 400,000 tons of kainit, costing, freight included, about $3,000,000. The result calculated at only one-third of what might reasonably be expected, would have represented according to the figures of the Report of the Department of Agriculture $9,821,463, because the crop instead of being only 56,000,000 bushels, would have amounted to 74,000,000 bushels. The money spent for foreign barley would have remained in the country, and the farmer would have been better off by the differencc between the cost of the potash and the increased value of the crop, some $6,000,000.

This is but one out of many instances that might be given as to what might be done by proper rational fertilization

NEVER USE POTASH ALONE.

The success of the various potash salts, as fertilizers, depends upon their proper application. They should never be used alone, because they only furnish one important element of plant food ; the full effect of potash fertilization is only obtained in connection with a proper supply of phosphoric acid and nitrogen.

In a general way practice and experience has established the following rules for their use : On low, peat soils, rich in nitrogen, the application of nitrogen is unnecessary, and also when the nitrogen has been supplied by green manuring; that is to say, by planting peas, etc., and inducing them, by a liberal supply of potash and phosphates, to an increased absorption of nitrogen from the air, and ploughing them under. Except in these two cases nitrogen should always be with the potash and phosphates supplied to the soil.

The potash salts act, to some extent, as a solvent upon the phosphates, and the use of Thomas slag has proven particularly successful in connection with potash.

In soils deficient in lime it is quite essential, when applying potash, to give them also the requisite amount of lime.

Potash salts should never be applied as a top dressing; they should be applied as early in the Fall as possible and worked into the ground by deep ploughing.

THE VARIOUS POTASH SALTS AND THEIR COMPOSITION.

ANALYSES

OF THE

RAW-PRODUCTS AND MANUFACTURED ARTICLES

OF THE

GERMAN KALI WORKS.

A. NATURAL PRODUCTS OF THE MINES.	K_2SO_4	KCl	$MgSO_4$	$MgCl_2$	$NaCl$	$CaSO_4$	Insoluble in water.	Water.	K_2O	Salts neutral-izing am'nia
Kainit	21.3	2.0	14.5	12.4	34.6	1.7	0.8	12.7	12.8	28.6
Carnallite	....	15.5	12.1	21.5	22.4	1.9	0.5	26.1	9.8	35.5
Kieserite	....	11.8	21.5	17.2	26.7	0.8	1.3	20.7	7.5	39.5
Sylvinite *a*	7.1	24.7	5.8	4.0	46.2	1.9	1.9	8.4	19.4	11.7
Sylvinite *b*	17.2	11.1	11.8	8.1	38.2	3.6	0.3	9.7	16.3	23.5
Sylvinite *c*	16.3	14.0	11.8	9.3	34.9	3.6	1.8	8.3	17.6	24.7
B. CONCENTRATED PRODUCTS.										
a. Sulphates of Potash.										
1. Sulphate of potash, high-graded, 96%	97.2	0.3	0.7	0.4	0.2	0.3	0.2	0.7	52.7	
2. Sulphate of potash, high-graded, 90%	90.6	1.6	2.7	1.0	1.2	0.4	0.3	2.2	49.9	
3. Double sulphate of potash and sulphate of magnesia (double manure salt)	50.4	....	34.0	....	2.5	0.9	0.6	11.6	27.2	34.9
4. Calcined kieserite	....	....	65.8	....	0.9	6.5	15.7	11.1	....	72.3
b. Muriates of Potash.										
Muriate of potash 90/95%	....	91.7	0.2	0.2	7.1	....	0.2	0.6	57.9	
Muriate of potash 80/85%	....	83.5	0.4	0.3	14.5	....	0.2	1.1	52.7	
Muriate of potash 70/75%	1.7	72.5	0.8	0.6	21.2	0.2	0.5	2.5	46.7	
Calcined manure salt, high grade	....	44.5	22.5	4.6	12.4	2.9	5.3	7.8	28.1	30.0
Calcined manure salt, low grade	....	25.6	31.1	6.3	10.3	3.5	10.6	12.6	16.2	40.6

The various potash salts are not entirely equal in their action upon different soils and different plants. The following rules are given as a general guide for their proper selection :

NATURAL PRODUCTS OF THE MINES.

KAINIT.—Is a natural product of the mine, reduced to a powder for the purpose of facilitating the even distribution. It contains the potash in form of sulphates and chlorides, which are mixed with the chlorides and sulphates of sodium and magnesium. These companions of the potash proper are quite valuable as disintegrators upon the soil constituents. For tobacco no crude salts should be used, because the presence of chlorides reduces the combustibility of tobacco and impairs therefore the quality of the leaf. Kainit is most valuable in light, sandy soils, and also in peat soils. It has a tendency to keep the soil moist and make it more compact. Whilst this property is very desirable in light, sandy soils, it is not desirable in heavy clay soils, where the concentrated salts are to be preferred. Kainit benefits all kinds of crops, particularly the cereals, potatoes, beets, cabbages, peas and beans, clover, etc. With flax and hemp it produces not only larger crops, but also a superior fibre.

The amount to be applied depends of course upon the quality of the soil, as a rule from 300 to 800 pounds per acre may be considered the right quantity. On low peat soils not less than 700 pounds per acre should be applied. The Fall is the best time to put the kainit into the ground. For potatoes and sugar beets, which require a large amount of potash, it should be applied to the ground on the preceding crop, and an additional amount early in the Fall. Kainit should be always well ploughed under, as otherwise the potash salts remain on the surface, and are not so easily accessible to the lower roots of the plants. Upon meadows and clover fields the effect of kainit is most excellent. The use of from 350 to 550 pounds, with from 175 to 350 pounds of phosphates, will increase the quality as well as quantity of the crop. If this mixture is used on sour meadows, with proper drainage, and if necessary with an application of lime, the effect is most decided. . The unwholesome grasses will disappear and be replaced by more nutritious and palatable grasses and herbs.

For the preservation of nitrogen, and humus substances in stable manure, kainit is highly to be recommended. By the action of the magnesium salts in kainit the nitrogen of the manure is retained, which would otherwise escape in the form of ammonia and be entirely lost.

CARNALLITE is the principal raw product from which the concentrated articles are manufactured. It is not imported in this country for manuring purposes.

KIESERITE AND SYLVINITE. Kieserite has been imported for sometime; sylvinite has only lately been introduced. Both are valuable as manure preservers, also as potash fertilizers. Sylvinite contains more potash (kali) than kainit; kieserite contains less. Their application and effect is similar to that of kainit.

MANUFACTURED ARTICLES—CONCENTRATED POTASH SALTS.

The Concentrated Potash Salts contain from four to five times as much potash as the crude salts. The great saving in the cost of their transportation is obvious, and where the effect of potash alone is wanted, they deserve the preference over the crude salts.

SULPHATES OF POTASH. On heavy soils the sulphates are preferable. They are best adapted for tobacco, on account of the absence of chlorine; also for the production of sugar and starch in plants, like sugar-beets and potatoes and sugar-cane. From 150 to 300 lbs. per acre will suffice for most soils. They should be applied in the Fall or Winter and ploughed under.

SULPHATE OF POTASH (KALI) AND MAGNESIA (DOUBLED MANURE SALT).—Is in its effect similar to the sulphate. It is also very valuable as a manure preserver, and produces manure free from chlorides. Hence the manure treated with this salt forms an excellent tobacco fertilizer. If mixed with other fertilizer ingredients, it brings these into a better mechanical condition for spreading over the field. From 175 to 525 pounds per acre should be used.

CALCINED KIESERITE is valuable for its contents of magnesia, acting as dissolving agent and manure preserver.

MURIATE OF POTASH is the richest of any of the potash salts, and the most soluble. It may be used with all crops, except tobacco, etc., and has proven of great advantage with all cereals, with rape, peas and beans, beets, asparagus, cabbage, etc. It should be applied in the Fall in quantities of 175 to 350 pounds per acre. It is not efficient however as a manure preserver.

CALCINED POTASH (KALI SALTS. (MANURE SALTS.) In composition and effect upon the plant they are quite similar to kainit, and they should be used in the same manner. They are however richer in potash (kali) than kainit, hence may be used in smaller quantities. The proper application per acre is 250 to 500 lbs. of the low grade (15 % potash—kali), and 175 to 400 lbs. of the high grade (20 % potash—kali.) As manure preservers they are valuable, and the low grade has the preference above the high grade salts for this purpose.

NO FERTILIZER CAN GUARANTEE A CROP.

Elementary causes of failure of crops can never be done away with, as long as neither heat nor cold, nor rain, snow, wind and hail are under man's control. Failures arising from such causes, and failures arising from self-deception, by neglecting to observe carefully all the injunctions of science, do not invalidate the favorable results that can be obtained, and are obtained, whenever no array of adverse circumstances combine against them. No fertilizer can guarantee a crop, nor should any farmer expect it. All that science can do is to lay down the conditions, under the strict observance of which favorable results and paying crops may be looked forward to.

The practical questions with what ingredients and in what amounts should the ground be fertilized to insure *paying* crops are, by the very nature of the case, the most difficult to answer. For a correct answer depends first upon the fertilizer-requirements of the several plants; secondly, upon the condition of fertility of the soil, and the latter is an exceedingly variable quantity.

PROF. STUTZER'S ADVICE REGARDING ARTIFICIAL FERTILIZATION.

What is stated hereafter are those quantities which, by reason of scientific investigation and practical experience, have been found to be average quantities; it remains with the farmer to judge in each special case how far he can deviate from them. Dr. A. Stutzer's work, crowned with a prize by an international commission of the most prominent agricultural scientists forms the basis of the subjoined practical instructions.

(A) *Cereals.*

Amongst all plants this class repays in an eminent degree proper fertilization. Nitrate of soda is for this class the most advantageous form of nitrogen.

Low	fertilization	*90*	lbs.	nitrate of soda per acre.
Medium	"	*180*	"	" " " "
High	"	*350*	"	" " " "
Low	"	*200*	"	acid phos. (14% avail. ph. acid) per A.
Medium	"	*350*	"	" " " " " "
High	"	*550*	"	" " " " " "
Low	"	*200*	"	kainit at 12/50% K_2O per acre.
Medium	"	*350*	"	" " " " "
High	"	*550*	"	" " " " "

For barley and rye the quantity of nitrogen may be decreased and those for potash (kali) should be increased.

On humid, heavy soil, decrease nitrogen and increase phosphoric acid.

On dry, light, warm soil, decrease phosphoric acid and increase nitrogen.

If the soil is rich on nitrogen, or if the preceding crop consisted in a nitrogen gatherer, the nitrogen should be decreased.

(B) *Leguminous Plants.*

No nitrogen, except in some cases a slight top dressing with nitrate of soda, but phosphoric acid and potash (kali) in abundance. Therefore for all leguminous plants, clover species, etc.: From *300 to 400 lbs.* of acid phosphate at 14% available phosphoric acid per acre; *500 to 600 lbs.* of kainit at 12½% K_2O per acre. These quantities are very apt to secure a very paying result.

(C) *Tobacco, per acre.*

250 pounds acid phosphate at 14% available phosphoric acid.
150 pounds sulph. of potash (kali) at about 50% K_2O.
125 pounds nitrate of soda.

(D) *Hemp, etc., per acre.*

250–275 lbs. of acid phosphate at 14% available.
125–250 lbs. of nitrate of soda.
350–500 lbs. of kainit.

Fleischmann and Nessler emphasize the good effect of kainit upon these crops.

(E) *Potatoes, beets, etc.*

This class of plants require very large amounts of potash (kali), yet direct fertilization with potash (kali) salts is not advantageous. It should be put into the ground with the preceding crop, and only phosphoric acid and nitrogen be directly applied.

For potatoes apply 125–250 lbs. nitrate of soda,
100–200 lbs. 14% acid phospate,
nearly the same quantity for beets, only for these more phosphoric acid.

(F) *Meadows.*

Apply from 600–700 lbs. of kainit at 12½% K_2O.
250–350 lbs. acid phosphate at 14% avail.

These figures were given by Dr. Stutzer before the peculiar effect of the potash (kali) salts had been known, and compared with what has been said before on that subject, an increase in potash (kali) appears in all cases as only advisable.

EXPERIENCE WITH POTASH IN THE UNITED STATES.

It would be erroneous to believe that the value of potash has been recognized only on the other side. The experiments made at the various experiment stations here bear out the assertions of the German Agricultural Chemists on that subject. So we read, for instance, in the bulletins issued by the experiment station in Kentucky, "That the results of the experiments regarding potash are so marked as to strongly indicate that for corn, *potash* is the fertilizer needed on the soil of the experiment station," and the report continues to say, "that this holds true also for potatoes, that the results on hemp and tobacco prove the same to apply to these crops, and that there are strong indications that wheat will likewise be benefitted by the application of potash. Therefore," it continues to say, "it would seem that the soils of like character in the Blue Grass region would be benefitted by potash fertilizers."

Very striking results have been obtained in the State of New Jersey by the use of potash salts.

In the Second Annual Report of Texas Agricultural Experiment Station, we read on page 80, "Of the fertilizers, kainit has proved the most beneficial. Many correspondents in other cotton States mention kainit as valuable in keeping cotton root-rot in check."

But of singular importance appears also what Dr. Dabney, as Director of the North Carolina Experiment Station, wrote as long ago as 1882 with reference to kainit. A comparison of what he says on that subject, with what Prof. Wagner has more recently established, proves conclusively, that the investigations carried on by Dr. Dabney corroborate in full those of Prof. Wagner. Referring to what Schultz and Rimpau had accomplished by rational potash fertilization, Dr. Dabney says: "A large portion of all the South Atlantic States are covered with just such lands, while nearly all the arable land in the eastern portions of these States are exactly of the same character which we find to be so wonderfully improved by Schultz-Lupitz plan. With the aid of potash salts what prevents us from making all these waste places blossom all over with fruitfulness?"

These prophetic utterances are evidence that years ago the great value of kainit was correctly recognized in this country by Dr. Dabney. We refer the reader to the Report of the North Carolina Station for 1882 for the testimony the farmers themselves offer on that subject. Dr. Dabney also recognized at that early day, that the action of kainit consists not only in supplying potash where potash is needed, but has also an indirect effect through the agency of the secondary salts present. To quote from that report, he says: "As far as our experience goes, kainit appears to be the most effective agent which has ever been used against that destructive and mysterious disease in cotton which we call "rust" or "blight". It is Dr. Dabney likewise who advised the planting of peas fertilized with kainit for the permanent improvement of the soil. He says, "ammoniated super-phosphates, that is to say, complete guano, proved upon peas a failure, even worse than a failure, a permanent injury in some cases, whereas kainit is the manure particularly fitted to make good pea crops." This confirms again what Prof. Wagner states regarding the enrichment of the soil by cultivating luguminous plants properly fertilized with kainit and phosphates. For this reason did Dr. Dabney call kainit a God-send to the farmer, and he also discovered the high value of the magnesia contained in kainit, advised its use instead of plaster, and observed the effect of the potash salts to render the phosphates and nitrogen more available to the plants.

In view of these irresistable facts it would seem that the work done by the North Carolina Station in 1882 foreshadows what the German scientists of a more recent date have done.

List of Works Quoted From.

Practische Düngerlehre. Dr. Emil Wolff, 11th ed. Berlin, 1889.

Anleitung zu einer rationellen Düngung mit Phosphorsäure. Prof. Dr. Paul Wagner. Darmstadt, 1889.

Die Steigerung der Bodenerträge durch rationelle Stickstoff-Düngung. Prof. Dr. Paul Wagner. Darmstadt, 1889.

Zur Kali-Phosphat Düngung nach Schultz-Lupitz. Prof. Dr. Paul Wagner. Darmstadt, 1890.

Die Kali-Düngung auf leichten Boden. Schultz-Lupitz. Berlin, 1884.

Vorträge über Kalidüngung und Steigerung der Bodenerträge im Club der Landwirthe. Berlin, 1883.

Practische Düngetafeln. E. Lierke. Berlin, 1887.

Untersuchungen über die Stickstoffnährung der Graminen und Leguminosen. Prof. H. Hellriegel and Dr. H. Wilfarth. Berlin, 1888.

Der Chilisalpeter, preisgekrönte Schrift von Dr. A. Stutzer, bearbeited von Prof. Dr. Paul Wagner. Berlin, 1886.

Die Bewirthschaftung des Rittergutes Cunrau. T. H. Kimpau. Berlin, 1887.

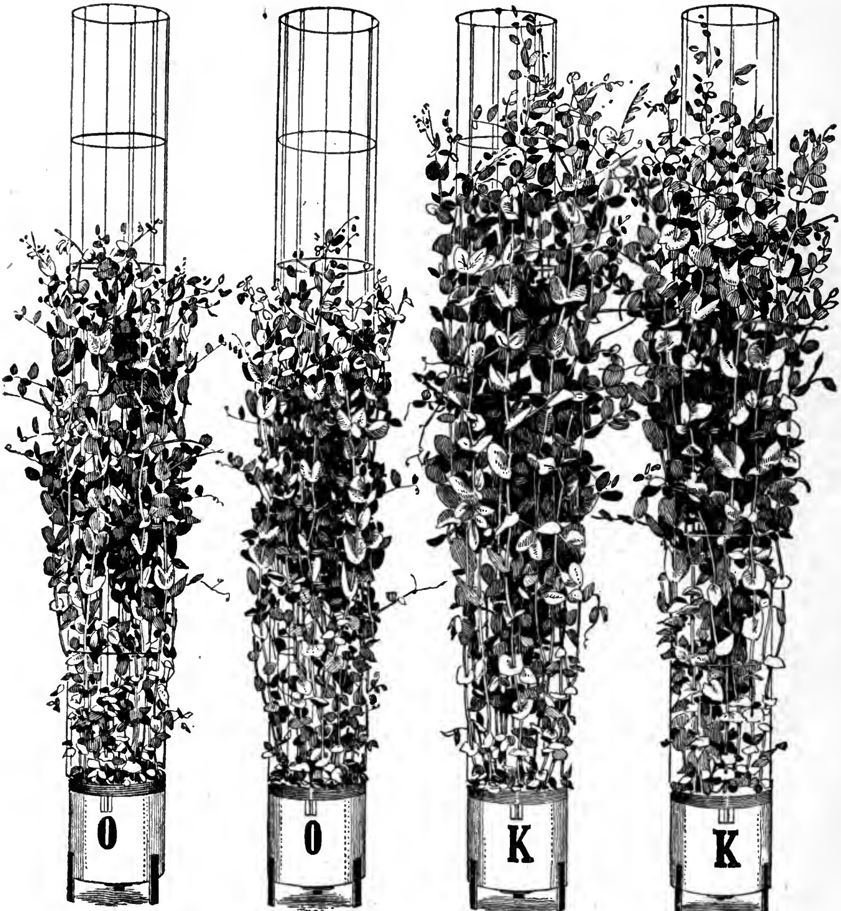
Die Thätigkeit der Central-Moor-Commission nach amtlichen Protocollen. Dr. Fleischer. Berlin, 1882.

Aschen-Analysen. Dr. Emil Wolff. *1 Theil.* Berlin, 1870.

Aschen-Analysen. Dr. Emil Wolff. *2 ter Theil.* Berlin, 1880.

Einige praktisch wichtige Düngungsfragen von Prof. Dr. Paul Wagner. Darmstadt, 1885.

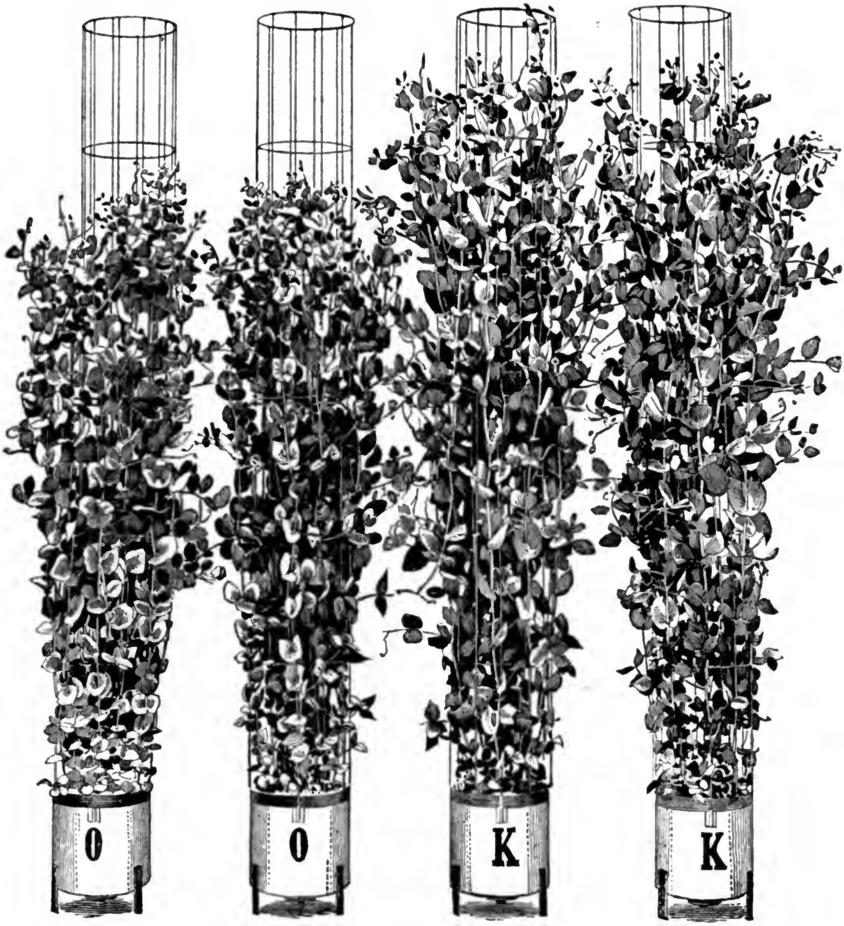
Die Kali Salze und ihre Anwendung in der Lanwdirtschaft von Dr. Max Märker. Berlin, 1880.



Without Potash. With ¾ g. Potash.

PEAS ON POOR SOIL.

(See page 19.)



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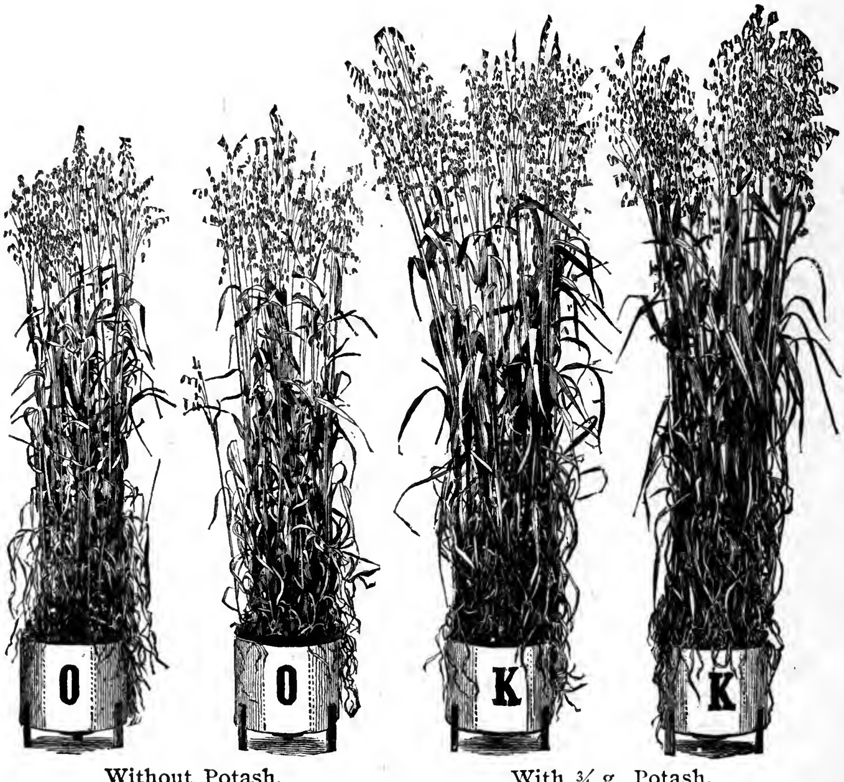
PEAS ON RICH SOIL.

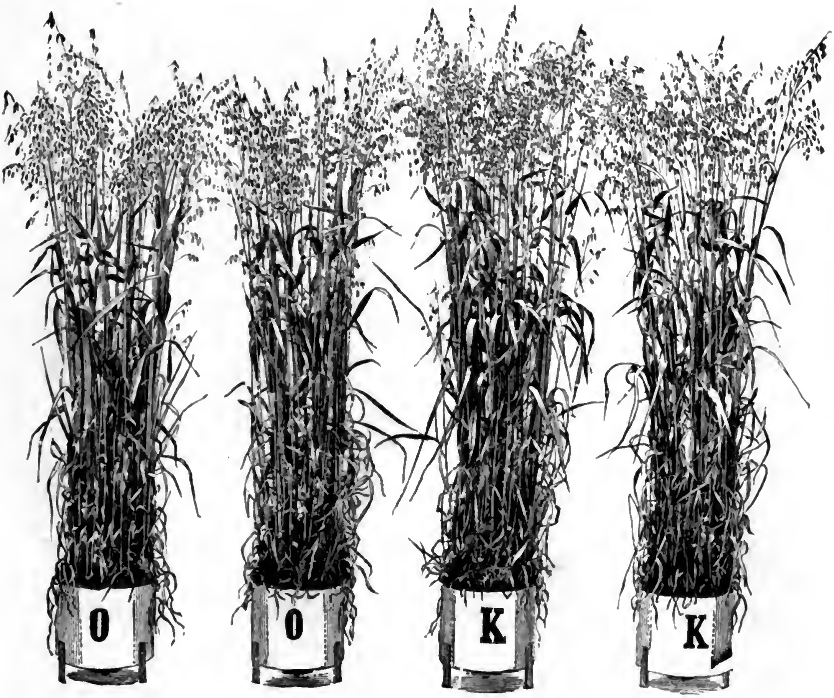
(See page 19.)



Without Potash. With ¾ g. Potash.

OATS ON POOR SOIL.

(See page 19.)



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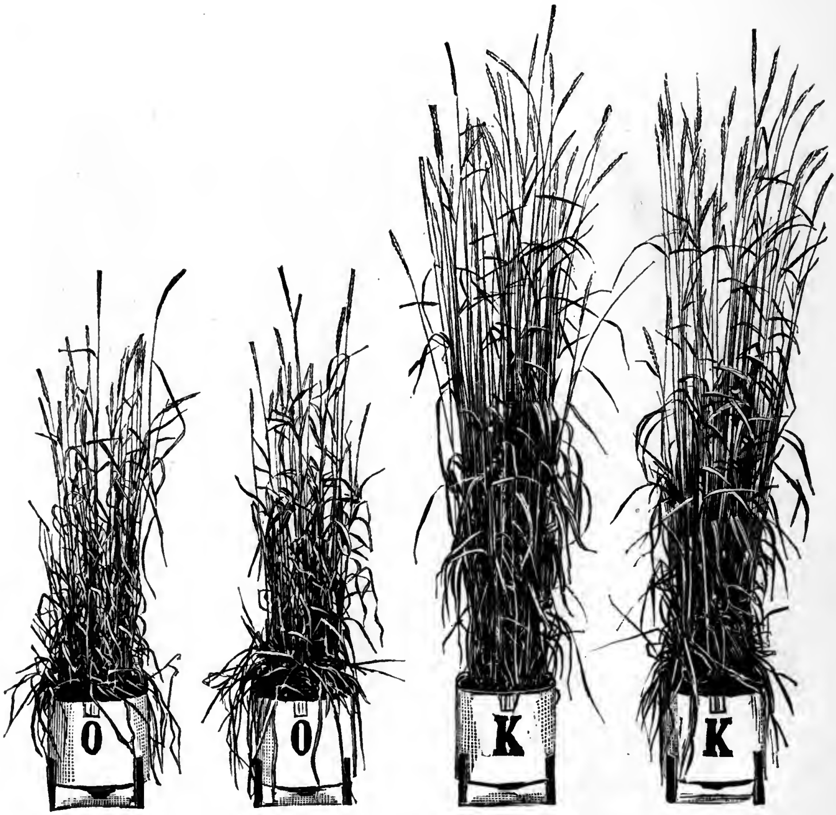
OATS ON RICH SOIL.

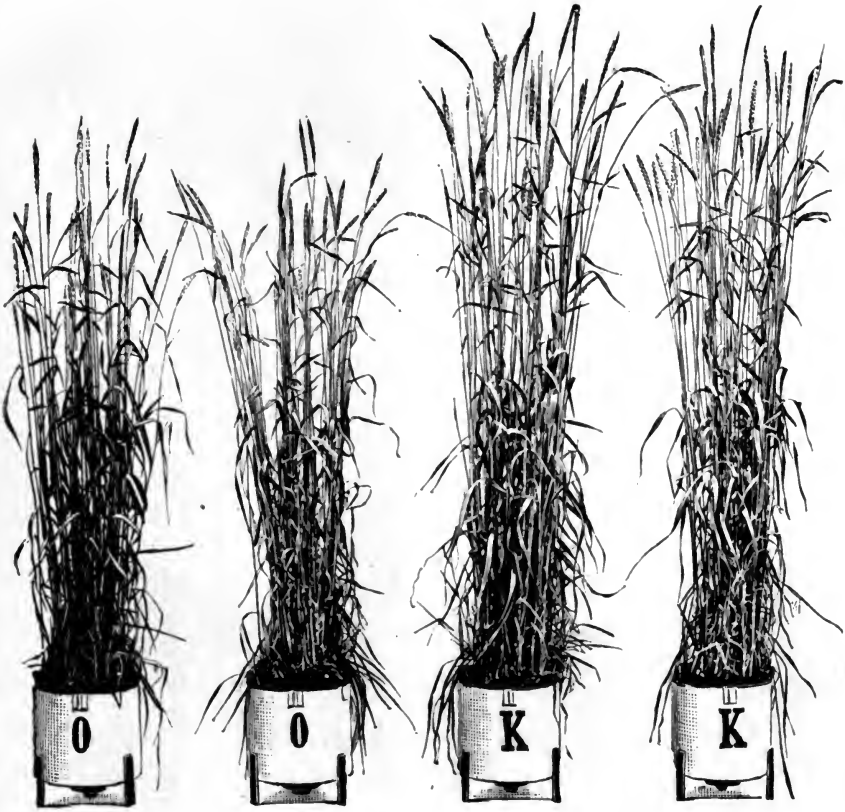
(See page 19.)



Without Potash. With ¾ g. Potash.

RYE ON POOR SOIL.

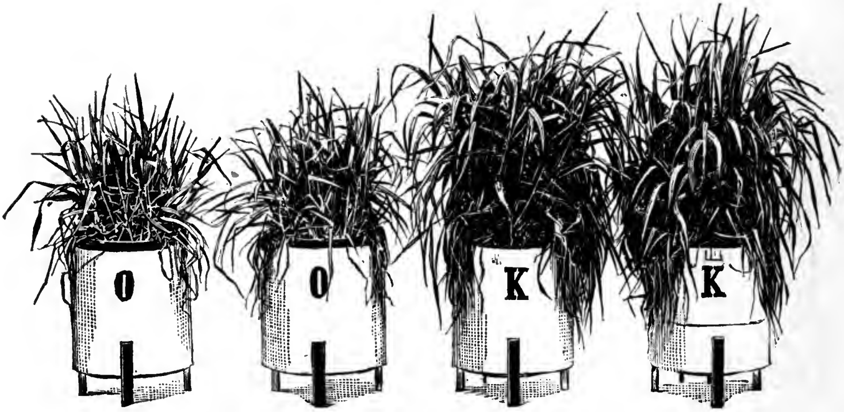
(See page 19.)



Without Potash. With ¾ g. Potash.

RYE ON RICH SOIL.

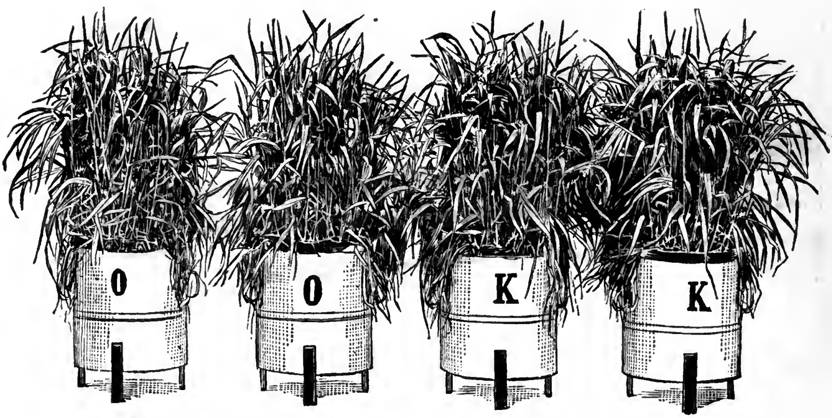
(See page 19.)



Without Potash. With 2 g. Potash.

BARLEY ON POOR SOIL.

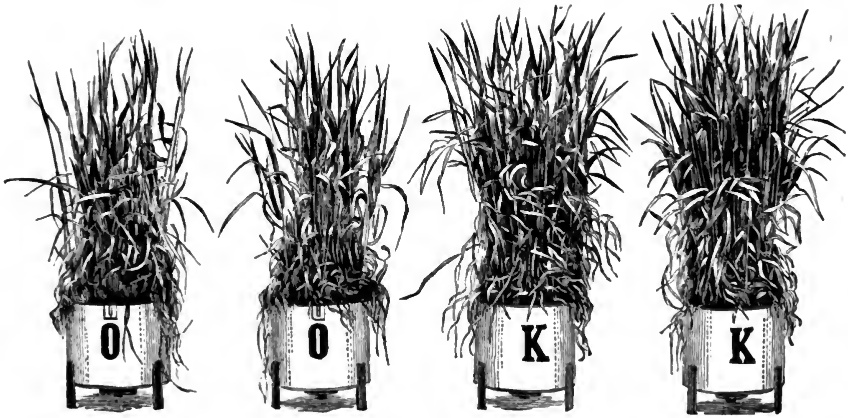
(See page 19.)



Without Potash. With 2 g. Potash.

BARLEY ON RICH SOIL.

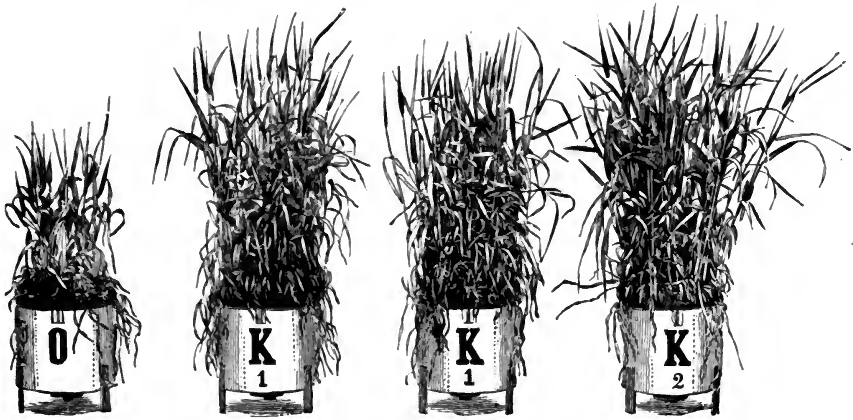
(See page 19.)



Without Potash. With ¾ g. Potash.

BARLEY ON AVERAGE SOIL.

(See page 19.)



Without Potash. With ¾ g. Potash. With ¾ g. Potash. With 1½ g. Potash.

BARLEY WITH POTASH INCREASED.

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