NUTRITION OF PLANTS CONSIDERED AS AN ELECTRICAL PHENOMENON[1]

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INTRODUCTION

When wheat seeds are placed in a suitable nutrient solution and germination begins, the demand of the embryo and tiny seedling for food is first upon the stored up material in the seed. As the plumule and radicle develop, however, absorption of food from the nutrient solution begins and gradually increases with increased growth. During the germination process there is first an exudation of plant food, particularly phosphorus and potassium, from the seed, with little or no absorption from the nutrient solution, but, when the plumule has reached a length of 2 or 3 cm. and has broken through its sheath, a distinct demand for food begins to be manifested in the tissues.

It is of much importance in fertilizer investigation to note that this demand of the plant for nutrient material may be measured by its pull upon the nutrient solution, and it is equally important from a physiological standpoint to note that this demand may be modified in certain ways and may even be augmented or built up by withholding any of the food elements. There is a "residual effect" that is very pronounced in plants; the desire for food when not available is carried over a long period of time and it seems to be cumulative. In this respect a plant seems to behave very much like an animal organism, the demand for food increasing as a fast continues. There is another very pronounced phenomenon that might well be termed a "time factor." A plant will not necessarily absorb twice as much nutrient material in two hours as it absorbs in one. It seems to possess the power to prepare reserves—that is, to form compounds in one part of its system which may be translocated to another part when needed.

It seems that this "demand" for food must be taken into account in all studies of absorption.

DEMAND OF WHEAT PLANTS IN THE PRESENCE OF A CONTINUOUS SUPPLY OF PLANT FOOD

About a dozen culture pans were prepared, each pan holding 2,500 cc. of nutrient solution and containing about 500 plants. The plants were grown by sprinkling seed upon floating perforated aluminum disks, and the nutrient solutions, containing 125 parts per million each of nitrogen (N), potash (K_2O), and phosphoric acid (P_2O_5) as sodium nitrate, potassium chlorid, and sodium phosphate, were changed daily. There was thus an abundance of plant food always at the disposal of the plant, and this was determined by measurements made from time to time. A

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concentration of 125 parts per million is just about the concentration producing the best growth under these conditions, as shown by other work; and as will be seen later, there was very little likelihood of the plant absorbing very much more plant food than was actually needed for its development.

Beginning with the fifth day after the seeds were placed in the solution, on every third day enough plants for an analysis were drawn from the pans, care being taken to draw some plants from each pan to equalize variations in the cultures as much as possible. When one of the culture pans fell below the normal it was discarded. In this way a representative set of plants could be withdrawn each time. The analyses of the plants, together with that of the original seeds, are shown in Table I, the results being expressed on the basis of 100 plants.

TABLE I.—*Analyses of 100 wheat seedlings, grown in nutrient solutions, at different stages of growth*

No.	Stage of growth.	Dry weight.	N	K_2O	P_2O_5
		Gm.	*Gm.*	*Gm.*	*Gm.*
1	Original seeds	2. 14	0. 0490	0. 0295	0. 0210
2	5 days old	1. 89	. 0565	. 0272	. 0184
3	8 days old	2. 05	. 0742	. 0489	. 0250
4	11 days old	1. 82	. 0812	. 0869	. 0308
5	14 days old	1. 95	. 0924	. 1203	. 0336
6	17 days old	2. 30	. 1160	. 1311	. 0570
7	20 days old	3. 04	. 1410	. 1466	. 0740
8	23 days old	3. 50	. 1946	. 1610	. 1020
9	26 days old	4. 64	. 2110	. 2018	. 1220

It will be noticed that there is a falling off in dry weight, in potash, and in phosphoric acid, but not in nitrogen, up to the fifth day. The loss in weight is, of course, due largely to the decomposition of starch and sugar of the seeds and to the evolution of carbon dioxid. This loss often amounts to as much as 40 per cent of the dry weight before enough plant food and carbon dioxid are absorbed to balance the loss. Many experimenters with wheat seedlings, when using dry weight as a criterion, fail to realize the fact that in the first stage of growth they are dealing with a diminishing quantity. The loss of potash and phosphoric acid always takes place at the beginning of germination, due to the exudation of these plant foods from the seed. It might be added that these very salts that are exuded from the seeds are absorbed by the seedling in a few days or as soon as the radicle has become sufficiently developed. There is usually little exudation of nitrogen for the reason that the nitrogen of the seed exists in organic combinations, protein, and is not readily dissolved out by water.

These results when plotted are represented by figure 1.

By cutting the curves through any particular date it seems possible to determine the relative demand of the plant at that age for the three important plant foods. It is also evident that the relative demand for food changes very rapidly as the plant develops. Beginning about the fifth day, when the plants begin to feed, the curve for potash rises very rapidly. The little seedling awakes to life with a ravenous appetite for potash, out of proportion to other plant foods. When the seeds are moistened and warmed preparatory for germination, the potash which is stored up in the seed, and which is fairly evenly distributed through it, begins to move very rapidly toward the end containing the germ or embryo. In the germination, when the embryo has broken through the bran coating and is just large enough to get hold of with the thumb and finger nails, it contains about 50 per cent of the total potash of the seed. The seed does not contain enough potash to satisfy the demand of the little seedling, so it begins early to feed heavily on the nutrient of the solution. Probably, in the natural course of life, the very first food absorbed by the little seedling is potassium. The absorption of nitrogen is steady and comparatively uniform, so after 18 or 20 days the curves for potash and nitrogen cross each other. The absorption of phosphoric acid is regular also.

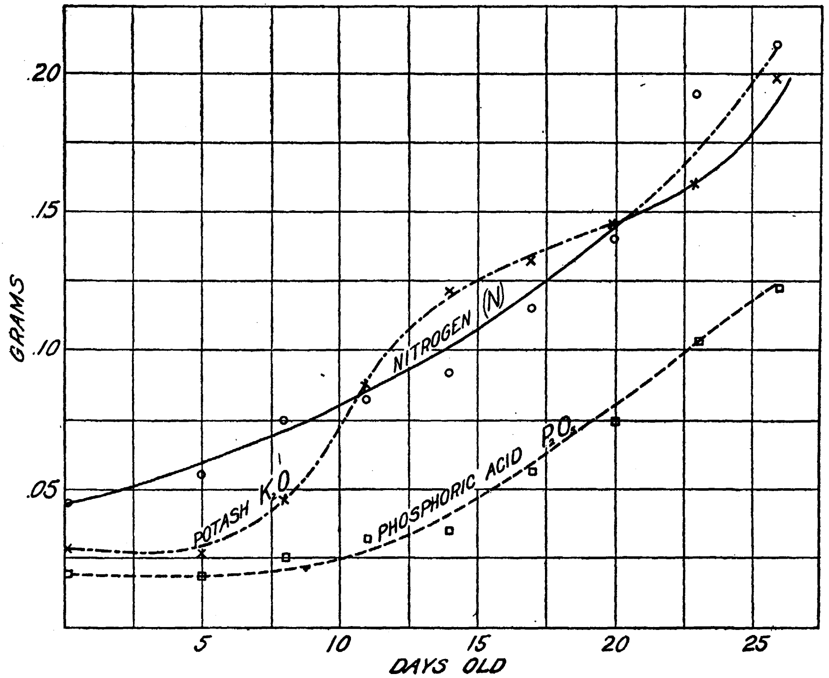

FIG. 1.—Graph illustrating the absorption of plant foods from nutrient solutions by wheat seedlings at different stages of growth.

Without submitting all the data, the curves for a duplicate determination, made about one month later, are given in order to bring out the crossing of the curves of nitrogen and potash (fig. 2).

The data presented give an idea of the nutrition of a plant when feeding full time and under favorable conditions. But a plant in nature does not necessarily have ideal conditions in which to grow. A low moisture content of the soil may temporarily put a stop to nutrition or the fluctuation of plant food, particularly nitrates, in the soil solution may also slow down, or even stop, absorption. It is, therefore, important to know what percentage of the time is actually necessary for absorption and whether a plant can absorb enough plant food in one period of time to last it over another.

DEMAND OF WHEAT PLANTS GROWN IN NUTRIENT SOLUTIONS FOR FRACTIONAL PARTS OF A DAY

Seedlings were placed in culture pans containing a full nutrient solution of a concentration of 125 parts per million each of nitrogen, potash, and phosphoric acid, as before described, and allowed to feed for fractional parts of the day. At the end of the period allotted to each lot to remain in the nutrient solution, the disks with the seedlings were taken up and washed off and placed in distilled water for the remainder of the day. This process was repeated daily for 10 days, and the plants then analyzed for nitrogen, potash, and phosphoric acid. In Table II is shown the number of hours each day the plant remained in the nutrient solution and the quantities of plant food absorbed.

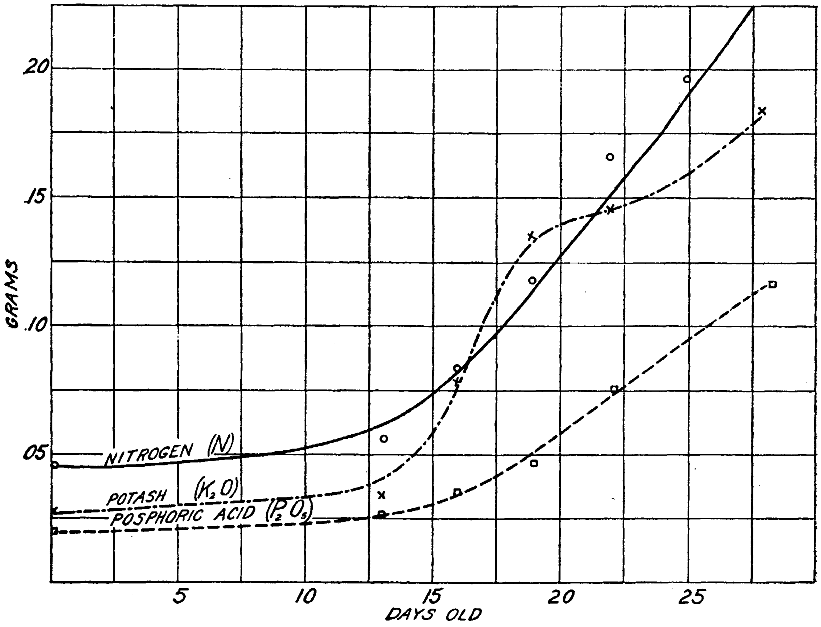

FIG. 2.—Graph illustrating the absorption of plant foods from nutrient solutions by wheat seedlings at different stages of growth.

TABLE II.—*Analyses of 100 wheat seedlings feeding fractional parts of the day for 10 days*

No.	Hours per day in nutrient solution.	Dry weight	N	K_2O	P_2O_5
		Gm.	*Gm.*	*Gm.*	*Gm.*
1	Control 0	5.32	0.0770	0.0318	0.0420
2	1	5.15	.0882	.0838	.0560
3	2	5.60	.1022	.1047	.0750
4	4	5.20	.1120	.1366	.0840
5	6	5.80	.1540	.1862	.0960
6	8	5.30	.1680	.1940	.1040
7	12	5.73	.2072	.1858	.1060
8	24	6.28	.2352	.2475	.1190

It will be seen by referring to Table II and figure 3 that the absorption of plant food for 1 hour per day, and other fractional parts, is out of proportion to what might be expected if time alone governed absorption. For example, subtracting the amount of potash in the original seed, or in the control, from the analysis of the plants grown 1 hour a day in the nutrient solution, we get 0.0520 gm. of potash actually absorbed by the plants during that time. In the same way by subtracting the control from those grown 24 hours a day in the nutrient solution, we get only 0.2157 gm. of potash actually absorbed in 24 hours. If the rate of absorption of the plants kept in the nutrient solution 1 hour a day had been maintained in the plants kept in 24 hours a day, we would have had an absorption of 1.248 gm. instead of 0.2157 gm. In other words, we get over five times as much potash absorbed in the 1-hour periods as might be expected if time alone governed absorption. This phenomenon is true with other plant foods; the curves rise very abruptly from the start and flatten out as the time increases. The demand or desire for food seems to accumulate until the food becomes available; then an abnormal rate of absorption takes place. The figures, when plotted, are represented in figure 3.

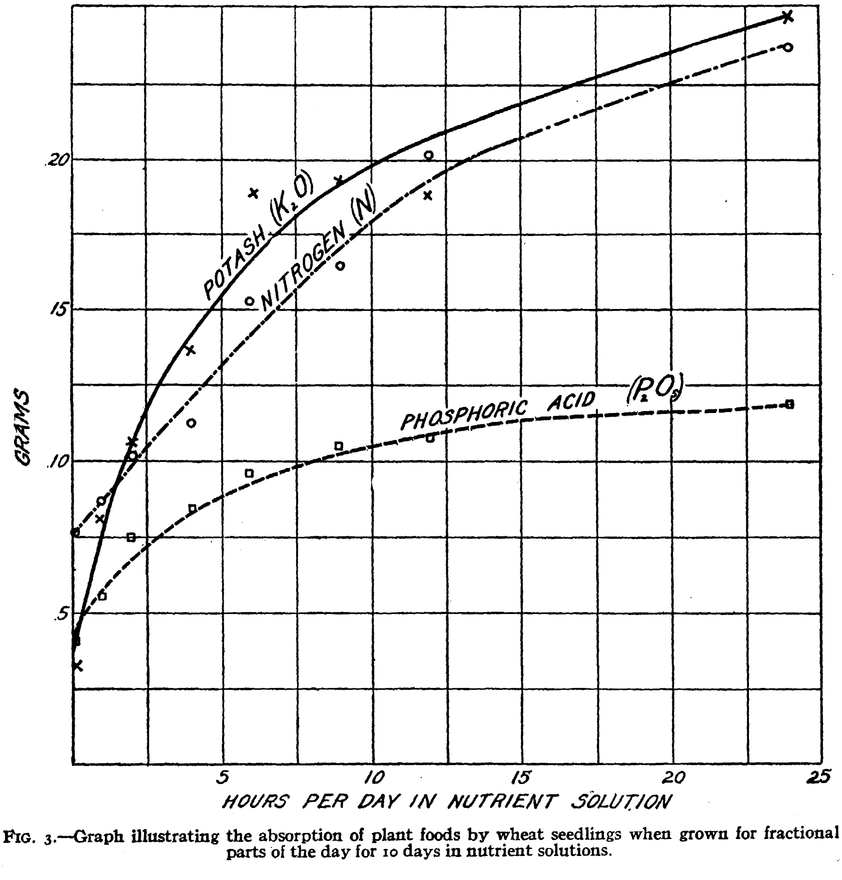

FIG. 3.—Graph illustrating the absorption of plant foods by wheat seedlings when grown for fractional parts of the day for 10 days in nutrient solutions.

The abrupt rise of the potash curve is noticeable, showing the demand for potash in the seedling was out of proportion to that for other plant foods. The cumulative demand, brought out in this experiment, seems to be true, not only for fractional parts of the day but for much longer periods.

DEMAND OF WHEAT PLANTS AFTER BEING HELD IN DISTILLED WATER FROM 2 TO 17 DAYS

Seven culture pans of soft wheat were germinated and grown in distilled water for 4 days. One pan was then transferred to a nutrient solution of 125 parts per million each, nitrogen (N), potash (K_2O), and phosphoric acid (P_2O_5), while all the others were kept in distilled water. At the end of 3 more days a second pan was placed in the nutrient solution, and this process continued every 3 days until six of the lots had been taken from distilled water and placed in nutrient solution. They were then allowed to grow for 2 more days, when they were taken down and analyzed. Thus the first pan had been feeding from a good nutrient solution for 17 days, while the last pan had been feeding only 2 days. The last pan having been grown in distilled water for 15 days had no increase in growth over the control when placed in the nutrient solution. The results of the analyses are shown in Table III.

TABLE III.—*Analyses of 100 wheat seedlings grown two or more days in nutrient solutions*

No.	Days in nutrient solutions.	Dry weight.	N	K_2O	P_2O_5
		Gm.	*Gm.*	*Gm.*	*Gm.*
1	Control 0	6.28	0.0840	0.0613	0.0400
2	2	6.60	.1410	.1154	.0587
3	5	6.52	.1904	.1685	.0750
4	8	7.12	.2268	.2090	.0813
5	11	6.80	.2674	.2350	.0973
6	14	6.80	.2604	.2361	.0908
7	17	7.00	.2912	.2580	.1440

It will be seen by referring to Table III that with each plant food element the absorption for the 2-day period was out of proportion to that of the 17-day period. By subtracting the quantity of potash in the control, for example, from that of the plants grown for 2 days in the nutrient solution, we get 0.0541 gm. of potash actually absorbed in 2 days. In like manner, by subtracting the control from the 17-day plants, we get only 0.1967 gm. potash actually absorbed in 17 days, when we should get 0.459 gm. of potash if time alone governed absorption. These results plot very well, showing that the demand is fairly regular and cumulative. This experiment was repeated, changing the plants in 2-day periods, with similar results.

If Tables IV and V, showing the rates of absorption of the different plant foods, are studied, other interesting relations are brought out. From Table IV it appears that the absorption of potash for the short period is much more pronounced than the absorption of other plant foods. On the other hand, when seedlings are left in the nutrient solution for a number of days (Table V), the absorption of potash and nitrogen shows a remarkable agreement in the rate. This is brought out in figures 4 and 5.

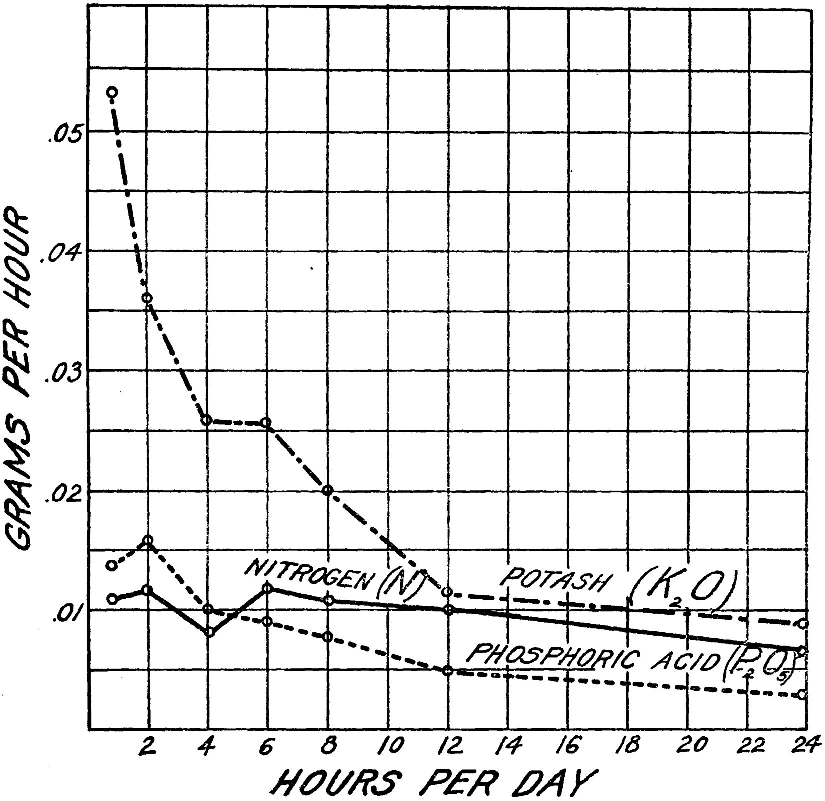

FIG. 4.—Graph illustrating the rate per hour of the absorption of plant foods by wheat seedlings when grown for fractional parts of the day in nutrient solutions.

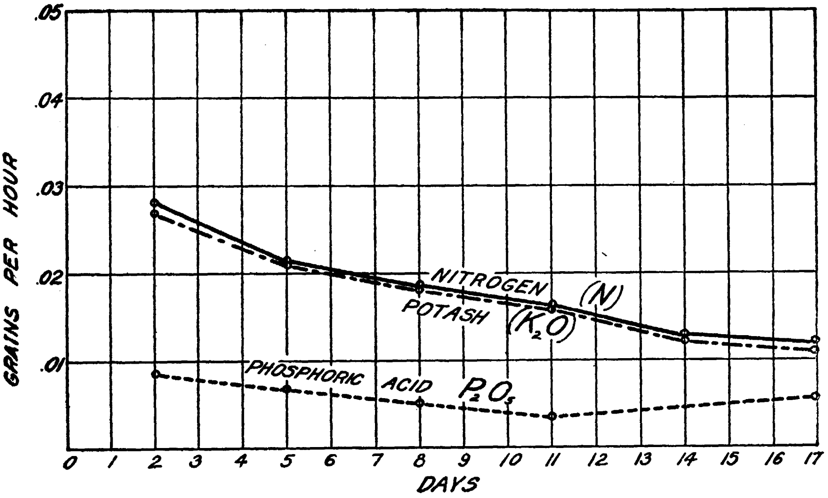

FIG. 5.—Graph illustrating the rate per day of the absorption of plant foods by wheat seedlings when grown for two or more days in nutrient solutions.

TABLE IV.—*Rate of absorption of plant foods per hour when wheat seedlings were feeding fractional parts of day*

[From Table II]

Hours per day.	Rate of absorption per hour.		
	N	K_2O	P_2O_5
	Gm.	*Gm.*	*Gm.*
1	0.00112	0.00520	0.00140
2	.00126	.00364	.00165
4	.00087	.00262	.00105
6	.00128	.00257	.00090
8	.00114	.00203	.00078
12	.00108	.00128	.00053
24	.00066	.00090	.00032

TABLE V.—*Rate of absorption of plant food per day when wheat seedlings were feeding for long periods*

[From Table III]

Days in solution.	Rate of absorption per day.		
	N	K_2O	P_2O_5
	Gm.	*Gm.*	*Gm.*
2	0.0285	0.02705	0.00935
5	.0213	.02144	.007
8	.01785	.01846	.00516
11	.01667	.01579	.00521
14	.0126	.01249	.00363
17	.01219	.01157	.00612

DEMAND OF WHEAT PLANTS GROWN FOR AN INITIAL PERIOD IN A FULL NUTRIENT SOLUTION AND SUBSEQUENTLY STARVED

The second of the two experiments described above was made in an effort to measure the demands for plant food that might be developed in plants that had been grown in distilled water and had never had any food supply except that contained in the seed. It was thought probable that other results might be obtained if the plants were first fed heavily, then allowed to fast, and the demand brought about by this fast measured in a second feeding period. A separate set was started, and when the plumules had reached a length of about 1 cm. all the culture pans were placed in a full nutrient solution of a concentration of 100 parts per million each nitrogen (N), potash (K_2O), and phosphoric acid (P_2O_5) and allowed to remain in this solution with frequent changes of solution for seven days. All were then placed in distilled water and allowed to stand seven days or more, when No. 4 was again placed in the nutrient solution. After one more day No. 3 was placed in the nutrient solution, and after another day No. 2 was put in the nutrient solution. After one more day all four sets were taken down for analysis. In this way, the plants were all given plenty of food for the first period, then allowed to fast and to develop an appetite during the second period, which was measured in the third period. This is shown in Table VI.

TABLE VI.—*Analyses of 100 wheat plants given an abundance of plant food in the first period, placed in distilled water for the second period, and again placed in nutrient solution for two or more days*

No.	Days in nutrient solution in third period.	Dry weight.	N	K_2O	P_2O_5
		Gm.	*Gm.*	*Gm.*	*Gm.*
1	Control 0	3.92	0.1596	0.1500	0.0960
2	1	5.88	.2172	.1998	.1320
3	2	5.68	.2320	.2506	.1400
4	3	5.90	.2605	.2670	.1380

By subtracting the nitrogen in the control, 0.1596 gm., from the nitrogen in the 1-day plant (No. 2), 0.2172 gm., we get 0.0576 gm. nitrogen absorbed in one day. By subtracting the control from the 3-day plants, we get 0.1009 gm. instead of three times 0.0576 gm., or 0.1728 gm., which we might expect if time alone governed absorption. In the K_2O column one determination, the absorption in 2 days, seems to be a little out of line and high. From these experiments one would judge that a demand for any of the plant foods can be developed in the plant, that this demand is cumulative, and that it is possible to measure this demand by analytical means.

DEMAND OF WHEAT PLANTS GROWN IN NUTRIENT SOLUTION FULL TIME AND ALTERNATE DAYS

As nitrates, and possibly other plant foods, are likely to vary in the soil solution from day to day, it was thought of interest to measure the rate of absorption when nutrients were given at varying intervals—that is, to measure the rate of absorption when cultures were placed in nutrient solution one day and in distilled water the next, and in nutrient solution on the third day and so on, feasting for one day and fasting the next. These seedlings were grown both with an abundance of plant food (100 parts per million each N, K_2O and P_2O_5) and also with a limited amount (10 parts per million). Analyses of the 12-day-old plants are given in Table VII.

TABLE VII.—*Analyses of 100 wheat plants grown continuously in nutrient solutions for 12 days, compared with similar series placed in distilled water every other day*

No.	Treatment.	Dry weight.	N	K_2O	P_2O_5
1	Distilled water control	4.44	0.0924	0.0597	0.0720
2	Nutrient solution 100 p. p. m. full time.	4.68	.1988	.2561	.1080
3	Nutrient solution 100 p. p. m. one day, distilled water one day.	5.36	.2100	.2856	.1280
4	Nutrient solution 10 p. p. m. full time.	5.76	.1932	.2273	.1200
5	Nutrient solution 10 p. p. m. one day, distilled water one day.	5.92	.1736	.1940	.1180

This was repeated several times with similar results. The total quantity of plant food absorbed, when plenty of plant food was present, was greater in the plants that had grown in the nutrient solution only half time than in the plants that had grown all the time in the same nutrient. When a limited quantity of plant food was present, the quantity absorbed was reduced by removing the plants from the nutrient solution for half the time. But when calculated upon the rate of absorption per day, both the plants in the strong solution and those in the weak had a higher rate when grown only half time in the nutrient solution.

It is somewhat surprising to note that not only the rate of absorption but the general appearance of the plants—color, size, root development, and vigor of growth—is usually better when the plants are grown in a good nutrient solution for one period and in distilled water the next. This is not always the case but seems to be characteristic of plants that are grown during warm weather; when growth and absorption are rapid, and is not so likely to be true of plants grown in cold weather, when growth and absorption are relatively slow. Better looking plants are often obtained when they are kept in the nutrient solution at night and in distilled water during the day.

The experiments here described seem to demonstrate that a demand for plant food may exist within the plant, that this demand may be modified in different ways, and that the demand may be determined by analytical methods. The author has demonstrated the fact that it is possible to go out in the field, to take up a plant and put it in a full nutrient solution, and to determine what plant food it is hungry for by the way it feeds upon the nutrient solution.

TRANSFER OF PLANT FOODS WITHIN THE PLANT

The plant seems to feed upon the ions and not upon the molecules, and no plant seems to require a base and an acid in exactly the proper proportion to form a salt. It has been shown by Breazeale and Briggs [2] that a plant is even particular as to the kind of ion that it absorbs. Plants that had a high demand for potassium when placed in a solution of orthoclase were unable to feed upon the dissolved potassium. The solution was dilute, it is true, but not so dilute as to prevent the absorption of potassium. It is probable that the potassium existed in the solution as a double ion in combination with aluminum. The plant did not need and could not utilize the aluminum and therefore would not take up either the potassium or the aluminum.

That the transpiration rate has little to do with absorption can easily be shown by placing a bell jar over a pan of cultures, cutting down the transpiration, and measuring the rate of absorption in comparison with controls. Plants will feed just as rapidly when transpiration has thus been reduced to a minimum as they will when transpiring a maximum amount of water.

One can scarcely conceive of a plant feeding upon ions or exercising selective absorption in such a decided way if the transpiration stream or the osmotic concentration, or any other phenomenon except the specific demand of the plant, dominates the process of absorption.

In the same way, practical field results indicate that all plants do not possess the same ability to feed when placed in competition with each other. We find that if an oat and a mustard plant be grown in the same pot with a very limited supply of nitrogen, the mustard probably will get nearly all of that plant food and the oat very little. Plants vary widely in their ability to cope with each other when placed in keen competition.

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[2] BREAZEALE, J. F., and BRIGGS, LYMAN J. CONCENTRATIONS OF POTASSIUM IN ORTHOCLASE SOLUTIONS NOT A MEASURE OF ITS AVAILABILITY TO WHEAT SEEDLINGS. *In* Jour. Agr. Research, v. 20, p. 615-621. 921.

An experiment with corn and kafir seedlings seems to throw some light upon this subject. Six treatments in duplicate were run, 12 pans in all, with corn and kafir seedlings growing upon the same disks and in the same nutrient solutions. The disks were about 12 inches in diameter and were like those used in the wheat culture work except that the perforations were larger. The corn seedlings were planted upon one half of the disk while the kafir grew upon the other. There were about 50 corn to 300 kafir plants. These seedlings were placed in the following solutions:

No. 1. Control, distilled water.
No. 2. 2 parts per million each N, K, and P.
No. 3. 5 parts per million each N, K, and P.
No. 4. 25 parts per million each N, K, and P.
No. 5. 50 parts per million each N, K, and P.
No. 6. 100 parts per million each N, K, and P.

They were allowed to grow for 17 days. In each pan, 2,500 cc. of solution were used and the experiments were run in duplicate. For convenience the average of the duplicates is given in Table VIII.

Table VIII.—*Nitrogen absorbed by corn and kafir seedlings competing in nutrient solutions of various strengths*

No.	Strength of solution.	Total N added.	Nitrogen absorbed.	
			By corn.	By kafir.
		Gm.	*Gm.*	*Gm.*
1	Water	0	0	0
2	2 p. p. m.	0.0450	0.0466	[1] 0.0073
3	5 p. p. m.	.1125	.1094	[1] .0091
4	25 p. p. m.	.5625	.2475	[2] .0180
5	50 p. p. m.	1.1250	.3344	[2] .0504
6	100 p. p. m.	2.2500	.3821	(3)

[1] Loss. [2] Gain. [3] Poor plants.

From this one experiment the indications are that when corn and kafir are placed in keen competition as in solutions containing 2 and 5 parts per million the corn may get all the nitrogen and the kafir little or none. An actual loss of nitrogen is noticed in the kafir in the two lowest concentrations, which might be explained by the exudation of this element into the solution or by the probable error of the experiment. The solutions were well mixed and not stirred while the plants drew out the nitrogen. In places the kafir roots were 6 inches away from the corn and in contact with the nitrates in the solution but, the kafir being a sluggish feeder while the corn was a vigorous feeder, the nitrates seem to have gone to the corn and not to the kafir. The absorption of the small quantity of nitrates was so rapid that it does not seem reasonable to assume that diffusion carried it all to the corn side of the pan. The difference is so marked that one must admit that in this case the kafir had no chance in competition with corn and that the nitrogen must have moved as far as 6 inches in a very short time. If, in a soil at optimum moisture content, the plant is dependent upon the soil grains that touch its roots, this competition is rather difficult to conceive of. Practically speaking, the absorbing surface of the roots of different plants would hardly touch the same soil grains often enough to be of serious consideration.

MOVEMENT OF PLANT FOODS IN THE SOIL

Ions are mobile and bear plus or minus charges of electricity. It has long been the opinion of the writer that the demand for food originates in the tissues of the plant and is carried to the absorbing surface of the root by means of an unsaturated carbon compound bearing a plus or minus charge. In the case of potassium, for example, the plant protoplasm in a leaf cell may remove an atom of K from a colloidal compound and use it in building up a permanent compound, which is to be one of the final constituents of its tissues. The removal of the atom K, bearing a plus charge, from its colloidal compound leaves that compound or molecule out of equilibrium and with a minus charge. This charge is transmitted, by replacement and not by bodily movement, down through the cells to the root tips and there appears as a minus charge. If potassium chlorid appears in the nutrient solution ionized as a plus K and a minus Cl, the plus ion will be attracted to the negative charge, and a chemical combination will take place, with the formation of a molecule in equilibrium, with respect to plus and minus electrictity. The potassium could, in this way, be transported from the absorbing surface of the root to the extreme tips of the plant without a bodily movement through the sap. In the case of nitrates the opposite conditions might prevail. A demand for NO_3 might originate in the tissues and be carried to the root as an unsaturated compound bearing a plus charge. This would be neutralized, for example, by the NO_3 ion of $NaNO_3$.

It is possible that the absorbing surface of the root or its walls are actually impermeable to the salts needed in nutrition, and it is possible to assume that food material may be transported from the roots to the rest of the plant without materially affecting the osmotic pressure of the sap. If the food materials are flowing freely in the sap and were it necessary for the plant to remove these materials in the localities where they were needed, it seems probable that there might be times when a high demand and a low supply, or the reverse, might cause considerable fluctuation in the concentration of the sap. As the writer understands it, the sap of plants of like varieties grown in the same localities is fairly constant. The tendency of the plant seems to be to keep its solutions in equilibrium, and the writer can conceive of a plant acting much like the battery of an automobile—the needle of the indicator may register a charge at one instant and a discharge at the next. The plant probably vibrates around the equilibrium point as closely as possible, taking up a plus charge at one time and a minus charge at another. The ordinary plant uses more of the mineral bases than it does of the mineral acids, and the writer is fairly well convinced that in order to maintain equilibrium the plant can absorb otherwise useless acids or bases, use them as ions when necessary, and eliminate them in various ways. With certain plants, if the system is basic, they seem to absorb CO_3 as an acid radical for the purpose of maintaining equilibrium; and in case the system becomes too acid they seem to possess the power of exuding the carbonates as CO_2. The absorption of calcium by certain plants and its elimination as an oxalate might be explained in this way. The absorption of silica in large quantities may probably be traced to the presence of an excess of basic radicals in those plants. The plants that have this characteristic have usually had waterlogged marsh lands for their habitat, and in the ages of their adaptation have had a large quantity of soluble silica and a small quantity of carbon dioxid at their disposal and as a matter of necessity have adapted themselves to the former.

The plant seems to feed upon ions, and these ions are certainly mobile. If an ionic movement takes place between the root tips and the rest of the plant, it seems equally reasonable to assume the possibility that a similar movement might exist outside the plant and that the plant might draw its food from relatively long distances.

The potassium concentration of young plants, sometimes having small root systems, often runs very high. The soil solution is relatively low in this element, and water movement and diffusion are neglible factors. The absorbing surface of the root is small, and, assuming that the root is obliged to come in contact with a soil grain before it can draw upon the potassium, it is rather difficult to account for the high potassium content of the plant. In the same way the writer has analyzed many samples of Australian saltbush that ran 8 per cent or more of sodium chlorid upon the basis of their dry weight. These plants had grown in a soil that was very low in sodium chlorid and in a semiarid climate where the soil moisture was very low for the greater part of the year. It seems hardly possible for a plant with growing habits like that of the saltbush to be able to absorb such quantities of salt as it does, if obliged to feed in the manner usually attributed to plants. It also seems hardly possible to conceive of this plant being forced to absorb sodium chlorid against its will, so to speak, because the salt is carried into the system by the transpiration stream or other agencies. A noticeable feature of this sodium-chlorid absorption is that the sodium (Na) is absorbed in much larger quantities than are necessary for combination with chlorin (Cl) in the formation of sodium chlorid (NaCl). The excess sodium exists in the plant in organic combinations and is broken down into carbonates upon ashing. Evidently there exists in the Australian saltbush a demand for sodium and chlorin, and the demand for sodium is greater than the demand for chlorin. This absorption of the sodium ions in excess of the chlorin, from a soil solution where the source of supply of these ions is sodium chlorid, which is in equilibrium, seems to eliminate the idea of "forceful feeding," as applied to this plant. The high salt content of the plant, with such a low transpiration, would also indicate a wider field of absorption than is usually attributed to it.

If a soil solution is in equilibrium and the salts are ionized and the ions are mobile, if an atom of the K, for example, bearing a plus charge is removed from solution by the root, the writer sees no reason why the position of this ion can not be filled by replacement and the charge carried along through the soil, as it is in a battery, to where the source of supply of potassium exists. If this be true, the plant will not be dependent upon the soil grains that touch the root tips, but it may actually feed at a distance, the distance probably following some well-known physical law. In practical agriculture we, involuntarily, think of the plant as having all the moist soil surface at its disposal. We also think that the water movement in the soil is neglible as far as nutrition is concerned, that the plant has to grow for its water, and that diffusion is also a neglible quantity. With plants that have a limited root system and with the absorbing zone of the root but a small part of the root itself, if we do not attribute to the plant the ability to feed at a distance, we will have to admit that only a small part of the soil is at the disposal of the plant.

CONCLUSIONS

(1) A demand for plant food may be developed in the tissues of plants, and this demand may be measured by analytical methods.

(2) The demand of the plant seems to be for particular foods, and the effect of an application of plant food as a fertilizer seems to be largely a direct action upon the plant itself and not an indirect action upon some constituent of the soil.

(3) Plants probably feed upon ions, and these ions probably penetrate the root membrane and move through the colloids to the tissues as an electrical charge; therefore the feeding of plants may be looked upon as an electrical phenomenon.

(4) Ions are mobile and may move through the soil solution freely as such; and, this being the case, the plant may not be dependent upon the soil grains that touch its roots for nutrient material but may feed at a distance from the source of supply.