THE ACCUMULATION AND DISTRIBUTION OF P^{32} IN VARIOUS TISSUES OF NITROGEN-, POTASSIUM-, CALCIUM-, AND MAGNESIUM-DEFICIENT CORN PLANTS[1]

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The absorption of mineral nutrient elements by a plant may be affected by a number of factors, including the synergisms and antagonisms of different elements. The effect of such factors on the distribution and accumulation of the mineral elements in various plant tissues has not been thoroughly investigated. In the experiments reported here P^{32} was used to measure the phosphorus accumulation and distribution in corn plants that had been deficient in nitrate-nitrogen, ammonium-nitrogen, potassium, calcium, and magnesium.

Experimental Method

The corn hybrid, Ohio W64, was grown in the greenhouse, in 3-gallon pots containing quartz gravel, and was irrigated periodically with a mineral nutrient-solution by a compressed air system (Sayre, 1952). Four seeds were planted in each pot and the pots received only rain water for the first two weeks. Then the seedlings were thinned to two per pot and all pots received an optimum nutrient solution for three weeks, after which the solutions were changed to those shown in table 1. All treatments were replicated four times. After two weeks, these solutions were renewed except that P^{32}-tagged phosphate replaced ordinary phosphate. The plants were harvested two weeks later, after a total of nine weeks of growth and four weeks of deficiency treatment.

The plants were dissected into tassel, buds, leaves, sheaths, nodes, and internodes. All corresponding tissues (counting from the one just below the tassel) from replicated plants were composited and dried in a 70°C oven for 72 hours. Then samples were ground with a portable mill and passed through a 30-mesh sieve. Duplicated samples were analyzed in a Geiger counter for the radioactivity of P^{32}. All data were corrected with the conventional factors (Yuan, 1952) and computed to the radioactivity of P^{32} in the corn tissues at the time the plants were harvested.

Results and Discussion

Plants in optimum solution.—The accumulation of P^{32} in various tissues of the different positions on the plant is shown in figure 1. Phosphorus ^{32} accumulated in the leaves and sheaths was at a lower but more uniform concentration than in the other tissues. The node, followed by the internodes, had the highest concentrations in the top of the plant. Both fell off sharply in the basal part of the plant.

Since the phosphorus is utilized largely in young, meristemic cells of the growing regions for the formation of nucleoproteins and other phosphorus-containing compounds, it would seem logical for the lower, older leaves, sheaths, nodes and internodes to contain less phosphorus. Figure 1 shows only a small downward gradient for that phosphorus in the lower leaves. The phosphorus in

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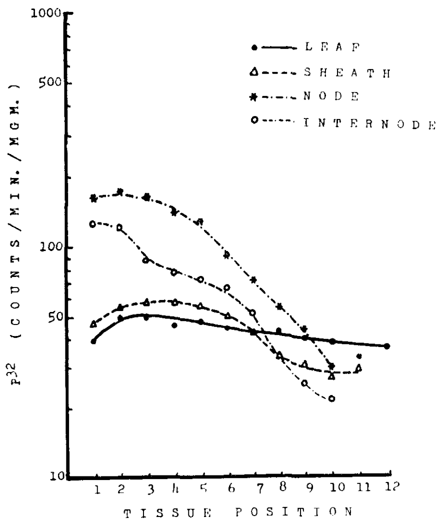

FIGURE 1. Accumulation of P^{32} in the individual tissues of normal corn plant.

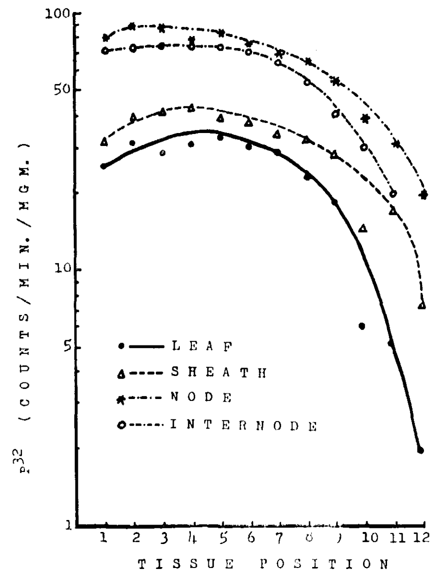

FIGURE 2. Accumulation of P^{32} in the individual tissues of nitrate-nitrogen deficient corn plant.

the sheaths showed a gradient that was greater than in the leaves, but less than in the nodes and internodes at different positions on the plant.

Nitrate-nitrogen deficient plants.—The accumulation of P^{32} in the tissues of nitrate-nitrogen deficient plants is shown in table 2 and figure 2. The P^{32} content of all tissues except the nodes was much lower than that in the other treatments. The P^{32} concentration in different tissues of corresponding positions decreased in the order of nodes, internodes, sheaths and leaves without exception and fell off very sharply in the older leaves and sheaths as well as the nodes and internodes. The gradient was greater than in any of the other treatments.

TABLE 1

*Concentration (ppm) of various elements in the nutrient solution of different treatments**

Element	Treatment					
	Check (opt.)	NO_3-N deficient	NH_4-N deficient	K deficient	Ca deficient	Mg deficient
Na	29	29	37	89	144	66
K	100	100	100	0	100	100
Ca	100	100	100	100	0	100
Mg	20	20	20	20	20	0
NH_4-N	5	5	0	5	5	5
NO_3-N	95	0	95	95	95	95
P	10	10	10	10	10	10
S	52	52	52	52	52	52
Cl	16	253	16	16	16	16
Total**						
cations	254	254	257	214	269	271
anions	173	315	173	173	173	173

*All solutions also received a half unit of minor elements mixture used by Sayre (1952).
**Ions from micronutrients are not included.

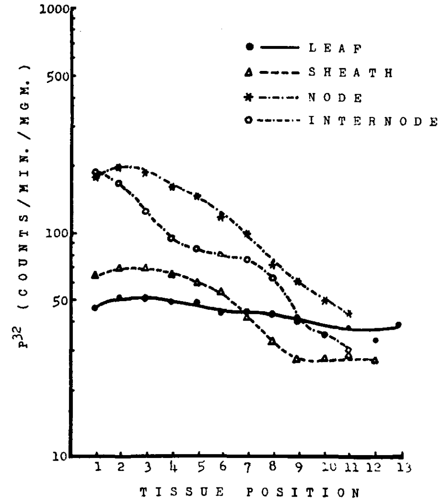

FIGURE 3. Accumulation of P^{32} in the individual tissues of ammonium-nitrogen deficient corn plant.

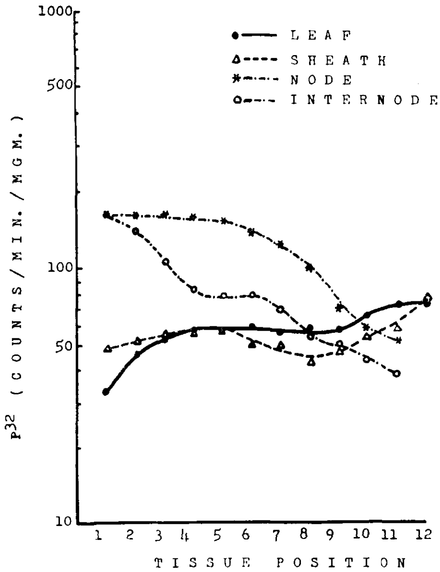

FIGURE 4. Accumulation of P^{32} in the individual tissues of potassium-deficient corn plant.

The low uptake of P^{32} found in the plant tissues from this treatment is believed to have been caused by the deficiency of nitrate-nitrogen, or total nitrogen, or to an excess of chlorides. Leonard et al. (1948), in their studies on sweet potatoes, concluded that nitrate and phosphate ions mutually benefit each other with respect to absorption but no adverse effect was observed. In our experiment, in order to maintain the same concentration of calcium in the nitrate-nitrogen deficient mineral nutrient solution, calcium nitrate was replaced with calcium chloride. Therefore, the concentration of chloride ions was greatly increased (see table 1). Since the chloride ions may contribute a large share to total anion content of the plant and may be involved in ionic competitive effects indicated by Wallace et al. (1949), the high concentration of chloride ions in the mineral nutrient solution may also suppress the phosphorus absorption.

The phosophrus uptake was low under the nitrate-nitrogen deficient treatment and the plants suffered a phosphorus deficiency despite its ample supply in the solution. The extremely low P^{32} concentration in the older leaves may indicate

TABLE 2

*Concentration of P^{32} accumulated in different tissues**

Plant Tissue	Treatment					
	Check (opt.)	NO_3-N deficient	NH_4-N deficient	K deficient	Ca deficient	Mg deficient
Tassel	52.7	43.2	63.2	97.2	57.6	63.7
Buds	115.8	75.4	126.3	182.0	114.5	107.4
Leaves	44.4	27.0	45.7	58.0	38.9	52.4
Sheaths	46.7	34.5	46.2	51.6	42.5	49.1
Nodes	78.4	62.2	87.7	103.8	74.6	79.4
Internodes	55.3	60.4	60.9	66.0	57.6	66.6

*Counts per minute per milligram tissue.

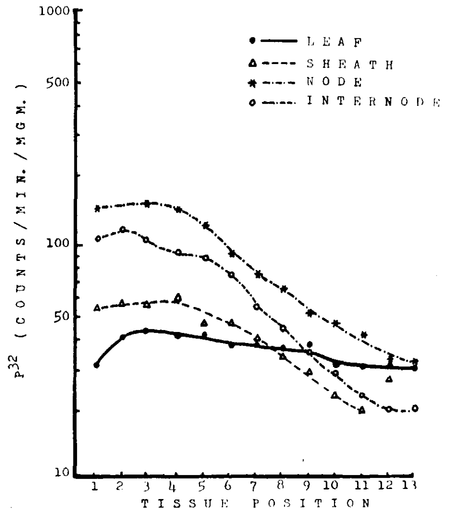

FIGURE 5. Accumulation of P^{32} in the individual tissues of calcium-deficient corn plant.

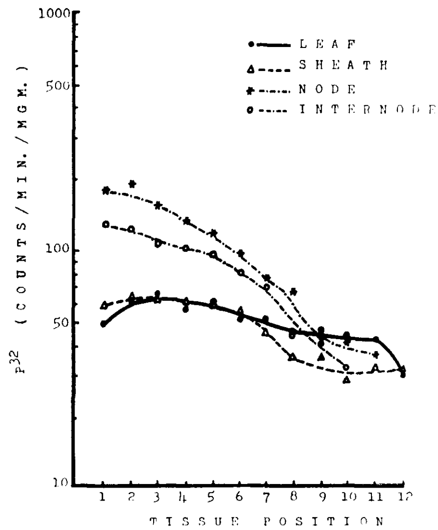

FIGURE 6. Accumulation of P^{32} in the individual tissues of magnesium-deficient corn plant.

that these leaves were no longer functioning and that an upward redistribution of phosophorus occurred. The young growing tissues gained in phosphorus content at the expense of the older ones.

Ammonium-nitrogen deficient plants.—Figure 3 shows the accumulation of P^{32} in various tissues of the corn plant in which ammonium-nitrogen deficiency was supposed to occur. The curves are very similar to those obtained from the check plants except that the phosophrus concentrations in nodes, internodes and the upper sheaths were higher than in the corresponding tissues of the check plants. It seems that ammonium-nitrogen deficiency had little effect on the accumulation of phosphorus, probably because the ammonium-nitrogen comprised only five percent of the total nitrogen in the nutrient solution.

Potassium deficient plants.—The differential accumulation of P^{32} in the different tissues of the plants grown in the solution in which potassium was deficient is shown in figure 4. The omission of potassium from the solution resulted in an increased accumulation of P^{32} in the older leaves and sheaths, a condition opposite to that occurring when a complete nutrient solution was used.

The increase of phosphorus accumulation in plant tissue due to potassium deficiency has been observed previously. Mulder (1952) studied the nutritional interrelationship of magnesium, potassium, and phosphorus in apple leaves and found that samples with a low potassium content contained larger amounts of phosphorus than did normal ones. The results of our experiment show that the same relationship may occur in the different parts of the same plant. Phosphorus was building up in the older leaves and sheaths which are known to lose their potassium to the younger tissues under early stress of potassium deficiency.

Calcium deficient plants.—Figure 5 shows that the accumulation of phosphorus in the individual tissues of calcium deficient plants was very similar to that occurring in normal plants, as shown in figure 1. The lower nodes had a higher concentration of phsophorus than did those in normal plants. The deficiency of calcium might cause a stunting of the root system and reduce the absorption of total phosphorus by the plant.

Magnesium deficient plants.—Phosphorus accumulation in various tissues of magnesium deficient plants, as shown in figure 6, was the same as that for normal plants, except for minor differences between the curves for leaves and internodes.

Accumulation and distribution of P^{32} in different tissues.—Table 2 shows the unit concentration of P^{32} in different tissues of the corn plant. The highest concentration is found in the buds (ear), twice as much as in any other tissues except the nodes which had about two-thirds the concentration of the buds. Internodes and tassel came next. Sheaths and leaves had the lowest concentrations. The deficiency treatments influenced the P^{32} concentration mostly in the tassel, buds, leaves and nodes.

All deficient treatments reduced the percentage distribution of P^{32} in the tassel, buds, and sheaths except for the plants deficient in potassium which had a slightly higher percentage of P^{32} distributed in the tassel (table 3). The nitrate-nitrogen deficiency increased the P^{32} percentage in nodes and internodes. Other treatments apparently had no effect. The greatest influence of deficiency treatments seemed to be on leaves. Nitrate-nitrogen deficiency decreased the percentage content of phosphorus, but the percentage accumulation of P^{32} increased in leaves of all corn plants of other treatments. This latter observation is in accordance with those reported by Evans et al. (1950).

TABLE 3

Percentage distribution of total P^{32} in various tissues of the aerial part of the corn plant

Plant Tissue	Treatment					
	Check (opt.)	NO_3-N deficient	NH_4-N deficient	K deficient	Ca deficient	Mg deficient
	%	%	%	%	%	%
Tassel	13.0	11.4	10.9	14.0	12.5	10.5
Buds	3.2	0.5	1.4	1.1	1.0	1.6
Leaves	38.5	29.9	44.2	47.3	42.6	45.6
Sheaths	17.2	16.7	14.5	14.8	16.1	15.6
Nodes	7.3	10.2	7.4	7.0	7.4	6.3
Internodes	20.8	31.2	21.6	15.8	20.4	20.4

Summary

The accumulation and distribution of P^{32} in various corn tissues as influenced by the deficiencies of various major nutrient elements were studied. The highest concentration of P^{32} was found in the upper leaves, sheaths, nodes, and internodes with a gradual decrease down the stalk. The gradient was less in the leaves and sheaths than in the nodes and internodes in most of the treatments, except that involving nitrate-nitrogen deficiency. High concentrations of P^{32} were observed in the lower leaf and sheath tissues of the potassium deficient plants.

About 40 percent of the total P^{32} in the aerial part of the plant accumulated in leaves, 20 percent in internodes, 17 percent in sheaths, 13 percent in tassel, and seven percent and three percent each in nodes and buds of the check or normal plants. This distribution was somewhat different in plants growing in deficient nutrient solutions. Nitrate-nitrogen deficiency decreased the total P^{32} absorption and the proportion in the leaves, increased the proportion of P^{32} in the nodes, and internodes, with no change in other tissues. Ammonium-nitrogen, calcium, and magnesium deficiency treatments increased the accumulation in the leaves and decreased it in tassel, buds and sheaths while in nodes and internodes, the percentage was constant. A deficiency of potassium resulted in plants with a much

higher percentage of P^{32} in leaves, higher in tassel but lower in buds, sheaths, and internodes as compared with the normal plants while the percentage of phosphorus in the nodes was constant.

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