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The Gain by Echinochloa crusgalli of P-32 Lost From Roots of Glycine Max.[1]

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Mineral elements (Emmert, 1959; Hevesy, 1946; Moore, 1949), organic compounds (Börner, 1960; Katznelson, Rouatt, and Payne, 1955; Rovira, 1956; Virtanen, Laine, and Hansen, 1936), and water (Bormann, 1957; Breazeale, 1930; Breazeale and Crider, 1934; Volk, 1947) can be lost through the roots of plants. That this occurs suggests that there may be competition not only for minerals and water in the soil but also for minerals and moisture already absorbed by the plant.

Virtanen, Laine, and Hansen (1936) have shown that legume nodules normally secrete significant amounts of the amino acids, particularly lysine and aspartic acid, into the medium in experimentally controlled cultures. Amino acid excretion and loss of several unidentified reducing compounds have also been shown to occur from the roots of several species, including soybean, as a result of drying and remoistening of the roots (Katznelson, Rouatt, and Payne, 1955). Rovira (1956) found 22 amino acid compounds to be excreted by pea roots and 14 amino acid compounds from oat roots in addition to fructose and glucose.

Hevesy (1946) used a parted root technique to show that wheat plants lost P-32 from untreated roots in addition to a minor amount of labeled nucleotides. Moore (1949) detected losses of P-32 from corn roots. Emmert (1959) studied the losses of P-32 from foliar-treated bean plants to a graded series of phosphorus solutions, tap water and distilled water. He showed that there were increasing losses with increases in stable phosphorus in the root environment. Losses to the distilled water and the tap water root solutions were also high.

Nutrients lost to the soil by plant roots may become available to other plants and soil microorganisms with which they are growing (Loehwing, 1937). The same is true for water lost by plants to the soil. Breazeale (1930) and Breazeale and Crider (1934) have shown that plants can transport water from soil areas of high moisture to areas of low moisture where water can be exuded and made available to other plants. More recently Bormann (1957) has shown moisture transfer to occur in tomatoes from plant to plant directly and through an intermediate plant in sufficient quantities to delay or prevent wilting.

The following experiments were done to determine whether losses of phosphorus-32 from soybean to other plants occurs and to determine the magnitude of those losses at various ages of the plants.

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MATERIALS AND METHODS: Two seeds of soybean (*Glycine max* (L.) Merr. var. Ottawa Mandarin) and 100 seeds of barnyard grass (*Echinochloa crusgalli* (L.) Beauv.) were planted together in each clay pot filled with soil; the soybean seeds were planted at one side of the pot and the barnyard grass at the other side. These seeds were then allowed to germinate and grow in a greenhouse set at 21° C.

Four soybean plants were selected for uniformity of growth for each leaf to be treated. Phosphorus-32 was delivered to each cotyledon or to both primary leaves as 5-ul drops containing 25 uc of P-32 in the experiments in which loss from soybean was studied. Where phosphate loss was studied from soybeans treated to the first or second trifoliate leaf, a 10-ul drop containing 50 uc was delivered to the terminal leaflet of this leaf. In all treatments, each plant received a total of 50 uc P-32.

Phosphorus-32 was obtained from the Oak Ridge National Laboratory. The chemical form of the P-32 as received is carrier-free $H_3P^{32}O_4$ in a weak HCl solution 1 N $\pm$ 50%. A standard stock solution was prepared by evaporating this solution to dryness and re-dissolving the residue in 20 mM NaH_2PO_4. The NaH_2PO_4 also functioned as carrier phosphorus.

After treatment the plants were allowed a 4-day uptake period, then harvested. At harvest the plants were removed from the pots with tops, roots and soil intact. The soybean and barnyard grass roots were separated from each other. The soil was shaken away and the roots of both species were washed with running water until the remaining soil was removed. The barnyard grass was separated into roots and tops by cuting with a razor blade approximately 2 cm above the junction of the roots and shoots. The roots and shoots were placed separately into 30-ml beakers and oven-dried for at least 24 hours, then weighed. They were then prepared for assay with a Geiger counter by digesting the dry material with concentrated nitric acid. The samples were corrected for decay to the treatment day. Correction for self-absorption, however, was not found to be necessary.

RESULTS: When barnyard grass plants were grown with soybean which had received a foliar application of radioactive phosphorus this element moved from soybean to the barnyard grass.

Figures 1-6 illustrate data for the leaves treated (cotyledons, primary and first two trifoliate leaves). Only the activity from the shoots was used as roots of soybean and barnyard grass were so intertwined that separation was impossible.

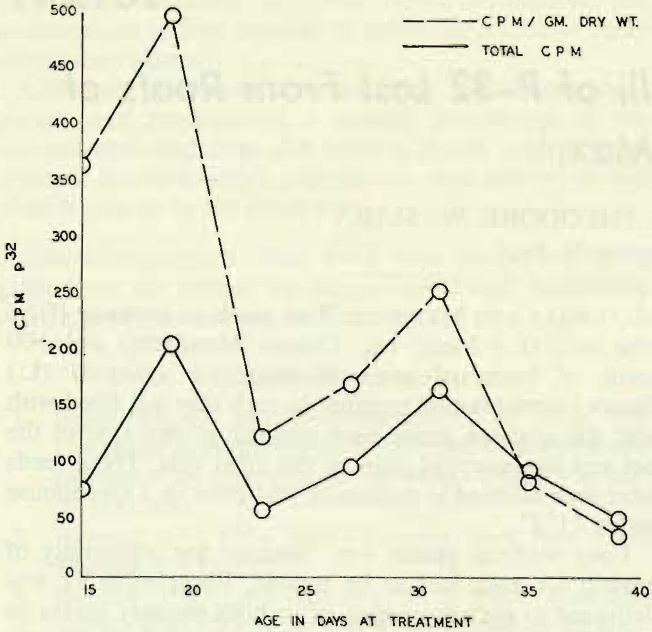

FIGURE 1. P-32 activity in barnyard grass shoots that were growing with soybean plants which had been treated with 50 uc P-32 applied to the cotyledons at different ages in the life of the plant. A 4-day uptake was allowed after each treatment.

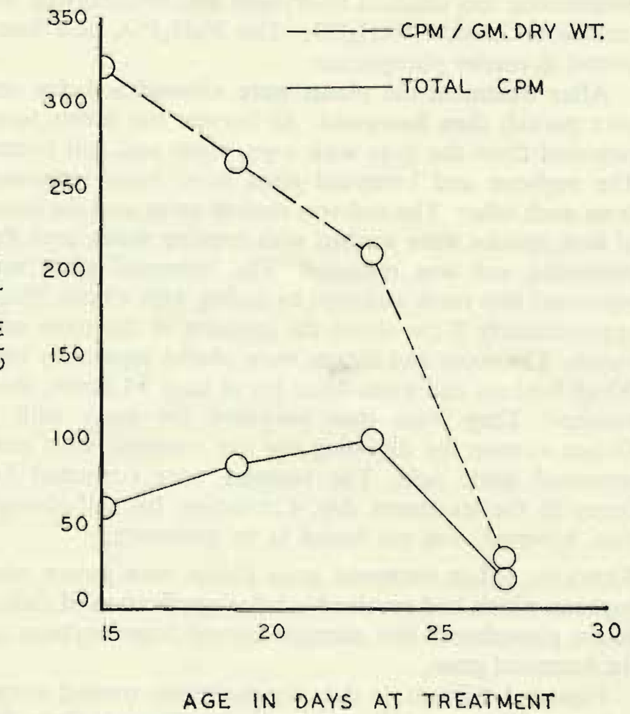

FIGURE 2. P-32 activity in barnyard grass shoots that were growing with soybeans plants which had been treated with 50 uc P 32 applied to the primary leaves at different ages in the life of the plant. A 4-day uptake was allowed after each treatment.

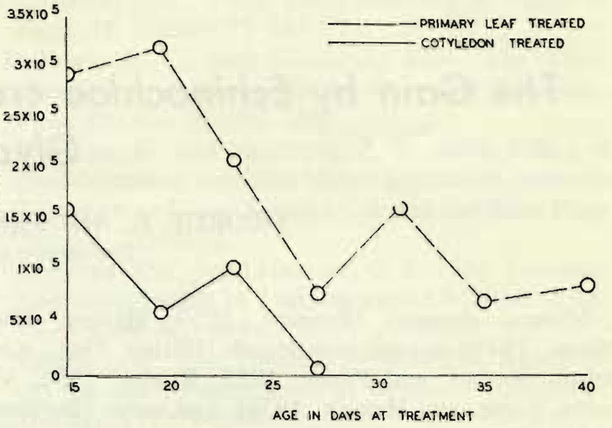

FIGURE 3. The total activity of P-32 in cpm in soybeans which had been treated with 50 uc of P-32 applied to the cotyledons and primary leaves at different stages of growth.

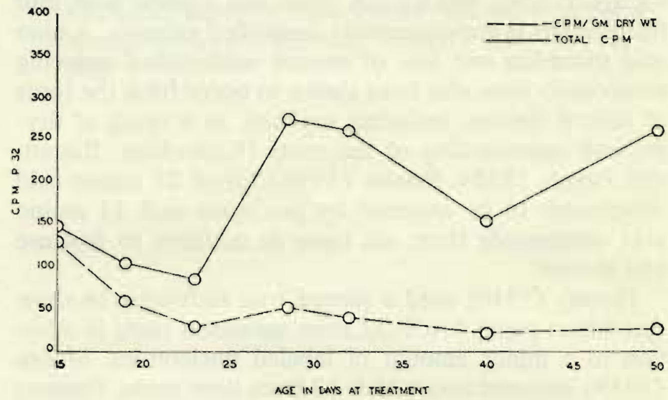

FIGURE 4. P-32 activity in barnyard grass shoots that were growing with soybean plants which had been treated with 50 uc P-32 applied to the terminal leaflet of the first trifoliate. A 4-day uptake was allowed after each treatment.

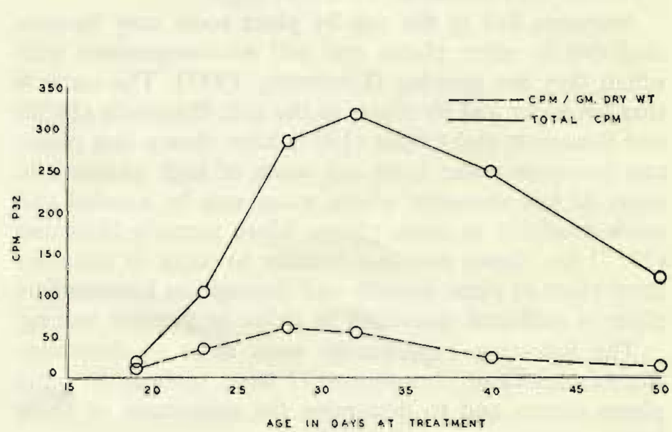

FIGURE 5. P-32 activity in barnyard grass shoots that were growing with soybean plants which had been treated with 50 uc P-32 applied to the terminal leaflet of the 2nd trifoliate. A 4-day uptake was allowed after each treatment.

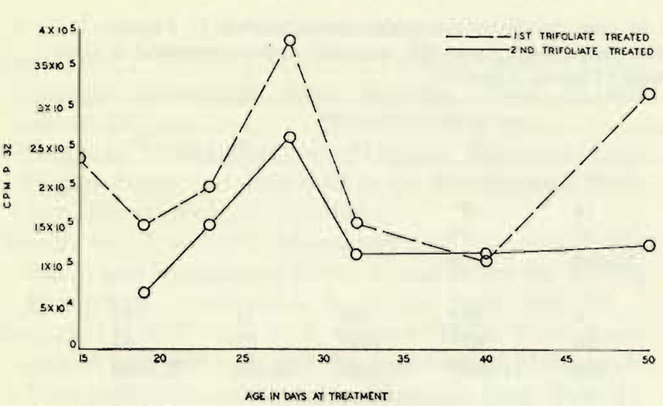

FIGURE 6. The total activity of P-32 in cpm of soybeans which had been treated with 50 uc of P-32 applied to the terminal leaflet of the first and second trifoliate at different stages of growth. These plants had a 4-day uptake after treatment.

Cotyledon treatments: When cotyledons of the soybean at different ages were treated with 50 uc P-32 there was a loss of phosphorus by the soybean and a gain by the barnyard grass at each age. Figures 1 and 2 show the activity which appeared in the barnyard grass 4 days after treatment. There was a slight increase in total P-32 activity of the barnyard grass tops up to the treatment of the 23-day-old plants which was followed by a sharp decrease in P-32 activity appearing in the shoots of 27-day-old plants. This can be compared to the activity of P-32 in these shoots on a per gram dry weight basis where there was a decrease from 320 cpm/g dry weight in the 15-day-old plants to 210 cpm/g in the 23-day-old plants which was followed by a rapid decrease to 30 cpm/g in the 27-day-old plants. This indicates that the amount of phosphorus gained by the barnyard grass was fairly constant and did not seem to be affected by an increase in the size and intermeshing of the root systems.

With the roots included, the activity of barnyard grass was considerably higher but, as stated earlier, it was difficult to determine whether or not the root sample contained small particles of the treated soybean.

The total activity of the soybeans to which P-32 was supplied to the cotyledons growing with barnyard grass is shown in Figure 3. The amount of P-32 in the soybeans decreased with applications of P-32 made to older plants. There was a sharp decrease from 106,300 total cpm in a 23-day-old plant to 5,900 total cpm in the 27-day-old plant.

Primary leaf treatments: Barnyard grass grown with soybean on which P-32 was applied to the primary leaves also gained P-32. Figure 2 shows the activity in cpm in the barnyard grass when P-32 was applied to soybean plants of different ages. Application of P-32 to primary leaves of 15-day-old soybeans resulted in 80 total cpm phosphorus-32 in shoots of barnyard grass after a 4-day uptake period. This increased to 210 cpm in the 19-day-old plants after which there was a decline in subsequent applications to 50 cpm in the tops of 39-day-old plants.

On a cpm/g dry weight basis, activity in the treatments made to the young plant was higher than on a total cpm basis. This decreased rapidly in the subsequent treatments made to older plants. The 35-day-old plants had 85 cpm/g dry weight of barnyard grass tops compared with 100 cpm on a total cpm basis. As with the cotyledon-treated plants, gain of P-32 was fairly constant at the various ages and even though there was an increase in size and complexity of the shoots and their root systems there was no corresponding increase in loss of P-32 to the barnyard grass.

The total activity of the treated soybeans is shown in Figure 3. Phosphorus-32 activity in soybeans decreased when plants of greater age were treated. The amount of P-32 translocated from the treated primary leaves of soybean was greater at all ages than translocation of P-32 from the cotyledons. The amount of P-32 in barnyard grass which had ben grown with soybeans treated with P-32 applied to the primary leaves was also higher at all ages than were plants where application of P-32 was made to the cotyledons.

First trifoliate treatments: Plants with P-32 applied to the first and second trifoliate leaves were grown later in the spring and plant development was more rapid than in the above tests; therefore, it was possible to begin treatments earlier in the life of the plant. The barnyard grass grew more quickly also under these conditions and this is shown in Figure 4 by the fact that activity expressed on a cpm/g dry weight basis is considerably lower at all stages of growth than is total cpm. This decreased activity is due to the large increase in plant dry weight without a corresponding large increase in the amount of P-32 gained.

Gain of P-32 in barnyard grass tops decreased with age in the first 3 treatments from 150 cpm in the 15-day-old plants to 85 cpm in the 23-day-old plants. It then increased to 275 cpm in the 28-day-old plant after which it remained fairly steady to the last treatment.

The total activity of the treated soybean plants with which the barnyard grass had grown is shown in Figure 6. By comparing the graph for total activity of the soybean and activity of the weed shoots it is apparent that both have the same pattern of activity.

Second trifoliate treatments: When soybean plants were treated with P-32 applied to the second trifoliate leaf at different ages there was a gain of P-32 in barnyard grass growing with the treated soybean. Figure 5 shows the amount of P-32 in the shoots of barnyard grass grown with soybeans treated in this manner. The amount of P-32 increased from 20 total cpm at the 19-day treatment to a high of 320 total cpm at the 32-day treatment which was followed by a decrease in following treatments to a low of 120 total cpm from the 50-day-old plants.

The amount of P-32 in the soybeans with which these plants were growing is shown in Figure 6. In the first treatment at 19 days the amount of P-32 transported from the treated leaf was small (70,300 cpm). The amount of P-32 lost to the barnyards grass at this stage was also low because very little P-32 reached the roots during the treatment period.

To provide a measure of the variability within the treatments standard errors were computed for each of the

TABLE 1. Standard errors[a] computed for the activity values of P-32 in cpm for barnyard grass shoots shown in Figures 1, 2, 4, and 5 (cotyledon, primary leaf, and first and second trifoliates, respectively) and the standard errors computed in cpm for the activity in the soybeans (Figures 3 and 6)

	Age in days at treatment							
	15	19	23	28	32	35	40	50
Cotyledon treatment (Fig. 1)								
Total cpm barnyard grass	8	20	18	2*				
Cpm/g dry weight barnyard grass	87	82	42	7*				
Total cpm soybean (Fig. 3)	1,900	32,000	15,000	1,900*				
Primary leaf treatment (Fig. 2)								
Total cpm barnyard grass	28	51	6	23*	60†	34	9‡	
Cpm/g dry weight barnyard grass	120	310	30	67*	148†	25	4‡	
Total cpm soybean (Fig. 3)	32,000	24,500	1,800	16,000*	15,000†	18,000	11,300‡	
First trifoliate treatment (Fig. 4)								
Total cpm barnyard grass	28	17	12	12	54	.....	9	111
Cpm/g dry weight barnyard grass	23	9	4	6	4	.....	5	110
Total cpm soybean (Fig. 6)	21,700	2,500	15,700	16,000	20,300	.....	6,000	30,000
Second trifoliate treatment (Fig. 5)								
Total cpm barnyard grass	.....	6	12	82	44	.....	91	50
Cpm/g dry weight barnyard grass	.....	9	8	18	1	.....	9	6
Total cpm soybean (Fig. 6)	.....	17,000	19,000	27,500	18,000	.....	11,600	14,600

[a] $S\bar{x} = \frac{s}{\sqrt{n}}$ * 27 days old.   † 31 days old.   ‡ 39 days old.

values which appear in Figures 1-6. These standard errors appear in Table I.

DISCUSSION: It was shown in these experiments that a loss of P-32 does occur from the roots of a crop plant and that the phosphorus lost can be taken up by a neighboring weed. When barnyard grass was grown with soybeans which were foliar treated with P-32 to either the cotyledons, primary leaves, or to the first or second trifoliates there was a loss of this radioisotope from the roots of the soybean plants and a gain in the barnyard grass. The amount of P-32 lost to the weed competitor by soybean was always small relative to the amount of radioisotope in the crop plant but it varied with the age and position of the leaf to which the P-32 was applied.

It had been expected in these experiments that any loss of P-32 from the soybean to barnyard grass that might occur would increase as the plants grew older, root contact became more intimate and more root surface was exposed. The results of these experiments show that this is not so. There was only a slight increase in the amount of P-32 gained by the barnyard grass when cotyledons of different age soybeans were treated. This was followed by a sharp drop in treatments made before the cotyledons senesced. At this time the amount of P-32 absorbed and translocated from the cotyledons also decreased sharply. The rapid decrease in cpm/g dry weight of barnyard grass shoots indicates clearly that the weeds were rapidly increasing in dry weight but not at the expense of phosphorus in the soybean.

A similar pattern of loss was shown when the primary leaves of soybean were treated. The amount of P-32 lost (gained in barnyard grass) was somewhat higher but the amount of P-32 absorbed and translocated by the primary leaves was considerably higher.

The first and second trifoliate treated soybeans have a pattern of loss and gain somewhat more like the expected results. The first treatments resulted in only a small amount of P-32 gained in the barnyard grass followed by an increase in amount of P-32 gained in barnyard grass in the following treatments. This might be due to an increase in age but since young cotyledons and primary leaf treated soybean lost considerable amounts of P-32 this phenomenon is better explained by differences in the absorption and translocation characteristics of soybeans of different age.

The amount of phosphorus-32 in barnyard grass shoots follows more or less closely the amount of P-32 which was absorbed by the treated soybean with which it was growing. It would seem that rather than age affecting the amount of P-32 lost from soybean and gained in barnyard grass, that age affects more the amount of P-32 absorbed and translocated to the root from a particular leaf. The technique used here does show that P-32 is lost by soybean and gained in barnyard grass but it is not certain whether age of plants *per se* affects loss. It is doubtful that competition for in-plant phosphorus results in substantial losses of P-32 from soybean. However, the amount of P-32 appearing in barnyard grass shoots may represent only a small percentage of that lost and much more of that lost may have been absorbed on the roots or absorbed and retained by the roots.

SUMMARY: Phosphorus-32 applied to cotyledons and leaves of soybean is taken up in barnyard grass growing in the same soil. The amount of P-32 lost from soybean (gained in barnyard grass) was affected by the age of the 2 species and the position of the treated leaf.

Losses to barnyard grass from soybeans foliar treated with P-32 followed a pattern similar to the pattern of P-32 absorbed by soybean. It was concluded that, rather than age or position of the applied leaf affecting the amount of P-32 lost from soybean, age and position affected more the amount of P-32 absorbed and translocated in soybean leaves.

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