

THE EFFECT OF MOLYBDENUM ON THE ORGANIC AND INORGANIC PHOSPHORUS OF PLANTS

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[Manuscript received March 3, 1954]

Summary

Molybdenum, applied 2 days before harvest, had a marked effect on the phosphorus metabolism of molybdenum-deficient tomato plants grown in water-culture solutions. The molybdenum increased the concentration of organic phosphorus, with a corresponding decrease in the concentration of inorganic phosphorus. Molybdenum increased the yield of dry matter, the absolute amount of phosphorus, and the absolute amount of organic phosphorus; but did not increase the absolute amount of inorganic phosphorus. The concentration of total phosphorus did not change.

I. INTRODUCTION

Molybdenum is known to be concerned in the nitrogen metabolism of legumes and non-legumes (Mulder 1948; Anderson and Spencer 1950), and many workers have attempted to elucidate this effect of molybdenum in plant metabolism (Hewitt, Jones, and Williams 1949; Agarwala 1951; Nicholas, Nason, and McElroy 1953).

It has also been shown that molybdenum inhibits the acid phosphatases of plants (Bossard 1947; Courtois and Anagnostopoulos 1949). Acid phosphatases occur extensively in plant tissues (Ignatieff and Wasteneys 1936; Yin 1945), and have been shown to attack a wide variety of organic phosphorus compounds which are important in intermediary plant metabolism (Spencer 1954).

The present experiments were done to examine the effect of molybdenum on the distribution of phosphorus between the organic and inorganic fractions within the plant.

II. METHODS

Tomato (*Lycopersicon esculentum* Mill. var. Pan America) plants were used. These were grown in culture solutions essentially the same as those recommended by Stout and Arnon (1939), but using KH_2PO_4 instead of K_2HPO_4 . The macro-elements were purified with 8-hydroxyquinoline in chloroform at a reaction between pH 1.6 and 5.6 (Gentry and Sherrington 1950). The micro-elements were all purified by repeated recrystallization. Tomato seeds, germinated on paraffined gauze placed over glass-distilled water, were transferred at the two-leaf stage to 3-l. Pyrex glass beakers. There were 20 cultures in the experiment and each culture pot held eight plants.

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TABLE 1
EFFECT OF MOLYBDENUM ON THE YIELD AND PHOSPHORUS CONTENT OF YOUNG TOMATO PLANTS

Time of Harvest	Material Analysed	Treatment	Mean Yield per Plant (mg dry wt.)	Inorganic Phosphorus ($\mu\text{g P/mg dry wt.}$)	Organic Phosphorus ($\mu\text{g P/mg dry wt.}$)	Total Phosphorus ($\mu\text{g P/mg dry wt.}$)	Inorganic Phosphorus per Plant ($\mu\text{g P}$)	Organic Phosphorus per Plant ($\mu\text{g P}$)	Total Phosphorus per Plant ($\mu\text{g P}$)
Day 0	Tops	Untreated	31.8	6.16	1.33	7.49	194	42	236
	Roots	Untreated	5.8	6.07	1.69	7.76	34	10	44
	Whole plant	Untreated	37.6	6.16	1.39	7.55	228	52	280
Day 2	Tops	Untreated	37.6	6.05	1.30	7.35	227	49	276
		Plus Mo	45.3**	4.67**	2.57**	7.24	214	114**	328**
	Roots	Untreated	6.8	5.86	2.05	7.91	39	13	52
		Plus Mo	7.5	6.90*	3.06**	9.96**	51	23**	74**
	Whole plant	Untreated	44.4	6.00	1.41	7.41	266	62	328
Day 4		Plus Mo	52.8**	5.03**	2.59**	7.62	265	137**	402**
	Tops	Untreated	51.1	6.09	1.20	7.29	311	60	371
		Plus Mo	67.8**	4.52**	2.66**	7.18	305	180**	485**
	Roots	Untreated	7.9	6.88	2.72	9.60	54	21	75
		Plus Mo	8.9	7.10	2.83	9.93	63	25*	88**
	Whole plant	Untreated	59.0	6.20	1.40	7.60	365	81	446
		Plus Mo	76.7**	4.85**	2.74**	7.59	368	205**	573**

* Effect of molybdenum significant at $P < 0.05$.

** Effect of molybdenum significant at $P < 0.01$.

After 3 weeks in the culture solution the plants showed the symptoms of molybdenum deficiency described by Arnon and Stout (1939). Molybdenum as sodium molybdate ($\equiv 0.05$ p.p.m. Mo) was applied to eight of the 20 cultures at this stage. Also, at this stage, plants from four of the cultures were harvested. Two days later, plants from four of the molybdenum-treated and four of the molybdenum-deficient pots were harvested. A similar harvest was made after a further 2 days.

Harvests were taken by cutting the plants immediately below the cotyledons. The upper part is referred to as "tops," the lower part "roots." Samples of the tops and roots were taken separately for dry-weight and phosphorus determinations.

Extracts for phosphorus estimation were prepared by grinding the plant material with cold trichloroacetic acid followed by low-speed centrifugation (Heard 1945). Inorganic phosphorus was estimated by the method of Ennor and Stocken (1950), in which the colour complex is formed under conditions which do not cause hydrolysis of labile phosphorus compounds. Total phosphorus was estimated after the extracts had been digested with perchloric and nitric acids (Piper 1944). Organic phosphorus values were obtained by difference from the values for total and inorganic phosphorus.

III. RESULTS

The results are summarized in Table 1. Molybdenum increased the yield of the whole plants, the yield of the plant tops, but not the yield of the roots, over the short periods of 2 and 4 days.

Molybdenum altered the distribution of phosphorus between the organic and inorganic fractions within the plant. The total phosphorus per gram dry weight of the whole plants remained constant, but the concentration of organic phosphorus was increased markedly 2 days after treatment with molybdenum. The concentration of inorganic phosphorus correspondingly decreased.

The changes in the concentrations of phosphorus in the tops corresponded with those in the whole plant. The changes in phosphorus concentration in the roots did not parallel those of the tops, but were much smaller and more variable. The nature of the effect of molybdenum on the concentrations of the phosphorus fractions was the same at the 4-day harvest as at the 2-day harvest.

The addition of molybdenum caused large increases in the absolute amounts of organic phosphorus and total phosphorus in 2 days. Over this period there was no change in the absolute amount of inorganic phosphorus. The increase in the absolute amount of organic phosphorus was approximately equal to the increase in total phosphorus uptake. The increases in the absolute amount of organic phosphorus occurred in both tops and roots. The changes in the absolute amounts of phosphorus brought about by molybdenum were of the same nature, but greater in magnitude at the 4-day harvest.

IV. DISCUSSION

The evidence presented shows that molybdenum deficiency affects the phosphorus metabolism of tomato plants. An outstanding feature of molybdenum-deficient plants was their low absolute amount and concentration of organic phosphorus.

Spencer (1954) has shown that molybdate *in vivo* inhibits the acid phosphatases of tomato. This suggests that phosphatase inhibition may be one of the metabolic functions of molybdenum in plants. It would seem therefore that the lowered level of organic phosphorus in the molybdenum-deficient tomato plants may be due to an increased activity of acid phosphatases.

There is also the possibility that all or some of the changes in phosphorus metabolism recorded in this experiment may be a result of other changes in metabolism brought about by molybdenum. An increase in organic phosphorus may possibly result from any treatment which stimulates growth through correcting a deficiency. It is perhaps of significance that in the present experiment the tops, which showed a greater increase in yield than the roots, also showed a greater increase in concentration of organic phosphorus.

In the present study it was shown that deficiency of molybdenum increased the concentration of inorganic phosphorus in the plants. Reed (1946) showed by histochemical techniques that the stems of zinc-deficient tomato plants had a much higher concentration of inorganic phosphorus than those of normal plants. Similar results with boron-deficient plants were obtained by Reed (1946), but the details were not given. No information on the effect of these deficiencies on the content of organic phosphorus was presented. The present data show that even in 2 days molybdenum increased the ratio of organic to inorganic phosphorus.

V. ACKNOWLEDGMENT

The author wishes to express his gratitude to Professor J. G. Wood, Botany Department, University of Adelaide, under whose guidance this work was initiated.

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