ROLE OF PHOSPHORUS IN THE GROWTH AND RESPIRATION OF TOMATO PLANTS

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Different levels of phosphorus were supplied to the tomato plants, growing in sand culture. Plants treated with 272 p.p.m. of phosphorus were growing healthy whereas 544 and 816 p.p.m. concentrations of phosphorus were found toxic and growth limiting.

Maximum rate of respiration was noticed in the plants growing in complete (normal) mineral nutrient solution containing 272 p.p.m. of phosphorus. A marked decrease in respiration rates was noticed if the concentration of phosphorus is changed from this critical level. The rate of respiration in minus phosphorus and minus half phosphorus plants were found nearly one-third in comparison with plants growing in complete solution. An increase in the concentration of the phosphorus above the critical level gradually lowered down the rate of respiration.

The effects were attributed to the key position of phosphorus in respiratory mechanism.

The effects of phosphorus deficiency on the growth and metabolism of the plants have been a subject of great interest since the last twenty years. Considerable investigations have proved that phosphorus is one of the most viable essential mineral element in plants.[1,2] The symptoms and physiological effects of various levels of deficiency and toxicity of phosphorus have been studied by different workers [3–8] but the results are not in complete agreement for various plants. Sugars are translocated mainly in the form of phosphate in the plants, and phosphorus deficiency is reported to build high concentrations in the leaves. The accumulation of sugars further results in synthesis of anthocyanin, imparting purple coloration in the stem and leaves.[5,7]

Present investigation was carried out with the concept that, if phosphorus deficiency causes accumulation of sugars in the leaves, it should also enhance the rate of respiration as sugars are reported main respiratory substrate. On the other hand, phosphorus is highly essential in respiratory mechanism. It is energy-bond constituent of adenosine-triphosphate, adenosine-diphosphate and phosphopyrin-nucleotide. Thinking on these lines, the deficiency of phosphorus should decrease the respiratory activity of the plant. It was thought quite interesting to study the effect of different levels of phosphorus deficiency and toxicity on the respiration of tomato plant.

Tomato plants (*Lycopersicum esculentum* Mill.) were grown in sand culture and were made toxic and deficient in various levels of phosphorus. Leaves of these plants were used for respirational studies. Seeds were sieved down for uniformity and were placed in culture dishes on moist sand for germination. After 20 days the seedlings were transplanted in plastic pots of 1.5 kilo capacity.

Quartz grading in size from 2-4 mm. was used for rooting medium. Plastic pots were irrigated from a basal hole which was covered by glass wool to retain quartz. These pots were placed in enamelled cups containing nutrient solutions up to certain level, which was kept constant by adding solution daily. In this way nutrient solution was delivered in the pot up to the solution level easily and the rest of the pot was irrigated by capillary action. Solution was completely replaced every week. Covers of hard board were placed on the enamelled cups around the pots to check contamination from any external source.

Modification of Hoagland's macro-nutrient and iron solutions were prepared as mentioned by Meyer et al.,[9] and according to the formulation of Arnon.[10] In phosphorus deficient solutions potassium dihydrogenphosphate was totally replaced by potassium chloride[9] whereas in minus-half phosphorus solution this replacement was partial. In solutions containing higher levels of phosphorus the amount of potassium dihydrogenphosphate was increased by twice and thrice. A corresponding increase in the level of potassium ion is not toxic up to this extent as potassium tolerance in plants is considerably high. The pH of solution was maintained at 4-6 throughout the experiment.

Respirational studies were made with the help of Warburg's manometer. Forty leave discs were taken from the leaves with the help of 8 mm. cork borer and were placed around the central cup of Warburg's flask. The rate of oxygen uptake was calculated later on.

Plants, in which the supply of minus phosphorus mineral solution was started just after transplantation, show severe phosphorus deficiency symptoms even after fourteen days of transplantation. Root and shoot growth much restricted; stem weak and developed purple tints; leaves small, narrow and developed dull purple colour due to accumulation of anthocyanin pigment, margins curled back and gradually died out.

These plants were not having enough leaves to carry on respirational studies, therefore seedlings were kept in complete nutrient solution for twenty-two days and later were supplied with minus phosphorus culture solution. Observations were taken after thirty-five days of the treatment. Shoot growth found approaching to that of complete nutrient solution cultures. Leaves were slightly thick, broad and dark green in colour. Enough leaves were obtained for respirational studies.

In order to get all the plants in the same age and condition for further investigations they were kept in complete culture solution for twenty-two days prior to starting the differential treatment. All the respirational readings were taken after sixty days of treatment.

Plants treated with minus half phosphorus (136 p.p.m.) solution, did not show any characteristic visual symptoms except that root and shoot development was somewhat intermediate to that of complete and minus phosphorus treatments.

Plants treated with culture solutions of higher levels of phosphorus showed stunted growth. Leaves became chlorotic and margin showed burning effect rapidly increasing towards mid-rib. Plants started flowering, indicating early maturation. Flowers showed abnormal growth in calyx and corolla and did not reach to the fruiting stage. These symptoms were more severe in the plants treated with triple concentration of phosphorus (816 p.p.m.) than those treated with double concentration (544 p.p.m.), while only 272 p.p.m. phosphorus was present in normal solution.

The mean respirational rates expressed in microliter oxygen/gram dry weight/minute, shown in Table 1, were calculated from thirty readings taken from the leaves of individual plant undergoing one kind of treatment.

TABLE 1

Minus phosphorus	Minus half phosphorus	Complete	Double toxic	Triple toxic
11.806	10.505	29.650	22.349	16.097

Comparative rate of respiration for various treatments is further illustrated in Fig. 1.

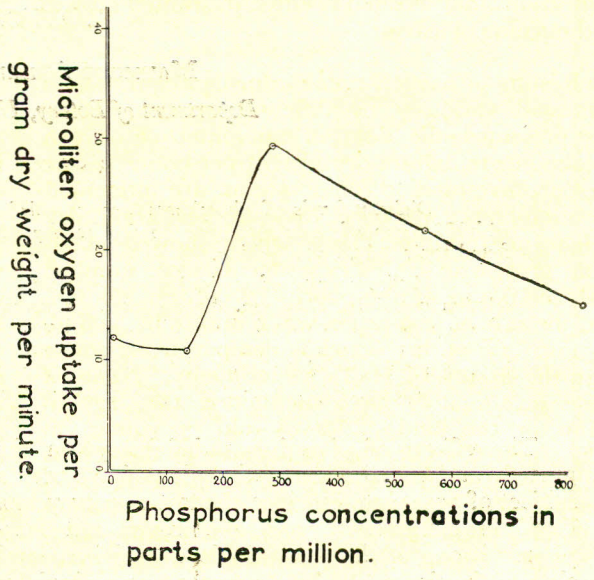

Fig. 1.—Effect of various levels of phosphorus on the rate of respiration.

Discussion

Plants which were provided with minus phosphorus culture solution in the seedling stage showed characteristic symptoms of phosphorus deficiency. These results are in complete agreement with Eaton, [3,4,5] and Wallace.[7] On the other hand, plants provided with complete solution for twenty-two days prior to supply of minus phosphorus solution did not show characteristic deficiency symptoms. This might have been the case with the above-mentioned series of plants. The supply of complete solution for twenty-two days was sufficient up to certain extent to meet phosphorus requirement of plants, and deficiency of phosphorus in the latter stage was responsible for few symptoms which appeared after forty days of minus phosphorus treatment. The supply of phosphorus for twenty-two days in early stages eventually delayed the phosphorus deficiency in the above-mentioned experiments.

The effects of different levels of phosphorus on the growth of tomato plant was studied by Hall.[6] He found 200 p.p.m. phosphorus was necessary for the optimum growth, whereas higher concentrations (800 to 2000 p.p.m.) proved toxic. Plants provided with normal (complete nutrient) solution during present investigation were getting 272 p.p.m. of phosphorus solution. These plants showed optimum growth, whereas plants provided with 136 p.p.m. of phosphorus (minus half phosphorus) were less vigorous in growth. Increase in the con-

centrations than normal resulted in stunted growth and burning of leaves.

Results of oxygen uptake during respiration is expressed variously by different workers. Hall[6] has presented the data in microliter of oxygen uptake per milligram dry weight per hour. In the present investigation observations are presented in microliters uptake of oxygen per gram dry weight per minute. Plants which showed maximum growth in Hall's experiments were supplied with 200 p.p.m. of phosphorus in culture solution and the rate of respiration was found to be 3.06 µl. O_2/mg. dry wt./hr., which is comparatively lower than the results of Hall's experiments. None of these investigators have mentioned the age of plants or the kind of leaves (old or young) in their work. Considerable differences in the results could be attributed to the variation in age and varieties of tomato plant. The rate of respiration in tomato plants grown in complete culture solution in the present investigation was found 1.779 µl. O_2/mg. dry wt/. hr. This is approaching to respirational rate of improved Wasath Beauty variety.

Plants supplied with various concentrations of phosphorus have shown different rates of respiration. Maximum rate of respiration was obtained in complete (normal nutrient) plants provided with 272 p.p.m. of phosphorus. This concentration appears to be optimum for respiration and the amount of phosphorus is just sufficient for intermediary metabolism. Any decrease in the supply of phosphorus affects markedly in lowering down the rate of respiration.

Plants provided with minus half phosphorus concentration were getting 136 p.p.m. of phosphorus and rate of respiration is about one third in comparison with the plant grown in complete nutrient solution. The difference in the rate of respiration between phosphorus deficient plants and those provided with minus half concentration of phosphorus is very slight (1.301 µl. O_2/g. dry wt./minute) and is insignificant. It indicates that below certain levels of phosphorus supply there is not much difference in the rate of respiration. Plants supplied with higher levels of phosphorus indicated as double (544 p.p.m.) and triple (816 p.p.m.) toxic showed lower rate of respiration in comparison with plants grown in complete (normal) mineral solution. The decrease in the respirational rates as a result of higher phosphorus concentration is still not as much as that caused by low phosphorus levels. This shows that higher levels of phosphorus gradually inhibit the rate of respiration whereas its deficiency below half of the phosphorus concentration (full concentration being 272 p.p.m.) may reduce the rate of respiration by one third.

Eckerson[11] observed an accumulation of starch and sugars in phosphorus deficient tomato plants. He has also stated that starch begins to break down in sugars in the leaves of such plants. In present work in spite of sugar accumulation in phosphorus deficient plants the rate of respiration was found comparatively lower than plants growing in complete nutrient solution. This could be attributed to the requirement of phosphorus during respiration mechanism. Eckerson[11] has mentioned about the disturbance in the protein and carbohydrate balance in phosphorus deficient plants. The deficiency was also reported to cause abnormality in the metabolism in black mustard.[4] The irregularities in the intermediary metabolism have a great effect in slowing down the respiration.

In the light of present investigations it would appear that the presence of higher concentrations of sugars is not the only requirement for increasing the rate of respiration but the presence of certain level of phosphorus (which may vary in different species of plants) is highly essential for it. Any increase or decrease in the amount of phosphorus above and below this critical level may become respiration limiting factor.

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