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EFFECTS OF PHOSPHORUS DEFICIENCY ON ION TRANSPORT AND ITS CORRELATION WITH ANATOMICAL STRUCTURE IN WHEAT (*TRITICUM AESTIVUM* L.) SEEDLINGS

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Abstract

Phosphorus deficiency caused an increase in accumulation of K^+ in the root and decrease in the shoot of wheat seedlings. Sodium accumulation was decreased early followed by an increase of that in the root and it increased initially followed by a decrease in the shoot under P-deficiency stress. Concentration of NO_3^- increased both in the root and shoot of wheat seedlings. Reducing and total sugar declined in wheat under phosphorus deficient condition. Anatomical study showed that phosphorus deficiency resulted in an inhibition of growth of vascular area with elements. Vascular area was found to decrease and occupied less area with smaller size of metaxylem cavity in the root and stem of wheat plant. In phosphorus deficient plant, phloem elements were poorly developed and occupied smaller area.

Introduction

Phosphorus plays a vital role as a structural component of cell constituent and metabolically active compounds i.e. phytin, nucleic acid, protein, flavin nucleotides and several enzymes. Phosphorus (P), an essential macronutrient for plant growth, provides indispensable foundation to agricultural production (Nagarjan *et al*. 2011).

Phosphorus deficiency inhibited accumulation of K^+ in the root and shoot but enhanced that of Na^+ both in the root and shoot of lentil (Sarker and Karmoker 2011). Das and Sen (1981) reported that potassium uptake increased in the shoot and sodium uptake both in the root and shoot in Bengal gram. It increased NO_3^- accumulation in the root but decreased that in the shoot of lentil (Sarker and Karmoker 2011) and in *Pelargonium* (Taylor *et al.* 2010) and soybean (Rufty *et al.* 1993). Phosphorus deprivation increased carbohydrate concentration in the root of bean (Ciereszko *et al.*1996). Phosphorus deficiency developed smaller radius of root and stem of spinach (Fohse *et al.*1991) and reduced number of xylem vessels in the root of maize plant (Sarker *et al.* 2010).

Triticum aestivum L. var. BARI Gom-26 was chosen as plant material because reports on the effects of phosphorus deficiency on ion transport, reducing and total sugar content in this plant is rare. So in this study the effect of phosphorus deficiency on the accumulation and distribution of K^+, Na^+, NO_3^-, reducing and total sugar and correlation of ion transport with anatomical structure is reported.

Materials and Methods

The seeds were collected through the courtesy of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Plants were grown in solution culture to study the accumulation of ions, reducing and total sugar. Phosphorus (+P) nutrient solution was used as control while solution deficient of phosphorus (–P) was used as phosphorus lacking treatment. Plastic lid covered with cotton gauze was placed upon the beaker painted black filled with +P and –P nutrient

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solution. After 48 hrs of sowing the seeds were germinated and then the beaker with the germinated seeds were transferred to light bank at a day/night temperature of 25 ± 1ºC/18 ± 1ºC and day/night length of 11 hrs/13 hrs and light intensity was 160 $\mu Em^2/s$. The solution was continuously aerated through bubbler with the help of air compressor. Root and shoot samples were collected at 24, 48, 72 and 96 hrs of treatment and dried at 75ºC for 48 hrs. K^+, Na^+ and NO^{3-} in the root and shoot were extracted by water digestion. K^+ and Na^+ ions were measured using a flame analyzer (Jenway, PEP-7, UK) at wavelengths of 767 and 589 nm, respectively while NO_3^- was measured according to the method of Cataldo *et al.* (1975). Reducing sugar was measured following Somogyi-Nelson method (Nelson 1944, Somogyi 1952) and total sugar was measured by the method of Dubois *et al.* (1956).

To study anatomical structures, plants were grown in sand culture (Hewitt, 1966). Sterilized seeds were sown in pots filled with purified quartz sand. The sand was soaked with +P solution. The seeds germinated within 48 hrs of sowing. After germination of seeds, phosphorus deficiency treatment was applied. The sand was always moistened with +P or –P solution every 24 hrs. Root and stem segments were collected from 45-day-old wheat seedlings. Free hand sectioning was made throughout the investigation. The sections were stained in safranin and mounted in glycerin (20%) and studied immediately after preparations with the help of a microscope (Model: Nikon ECLIPSE E2000MV R, Japan) and photographs of the sections were taken using a digital microphotography attached to the microscope.

Results and Discussion

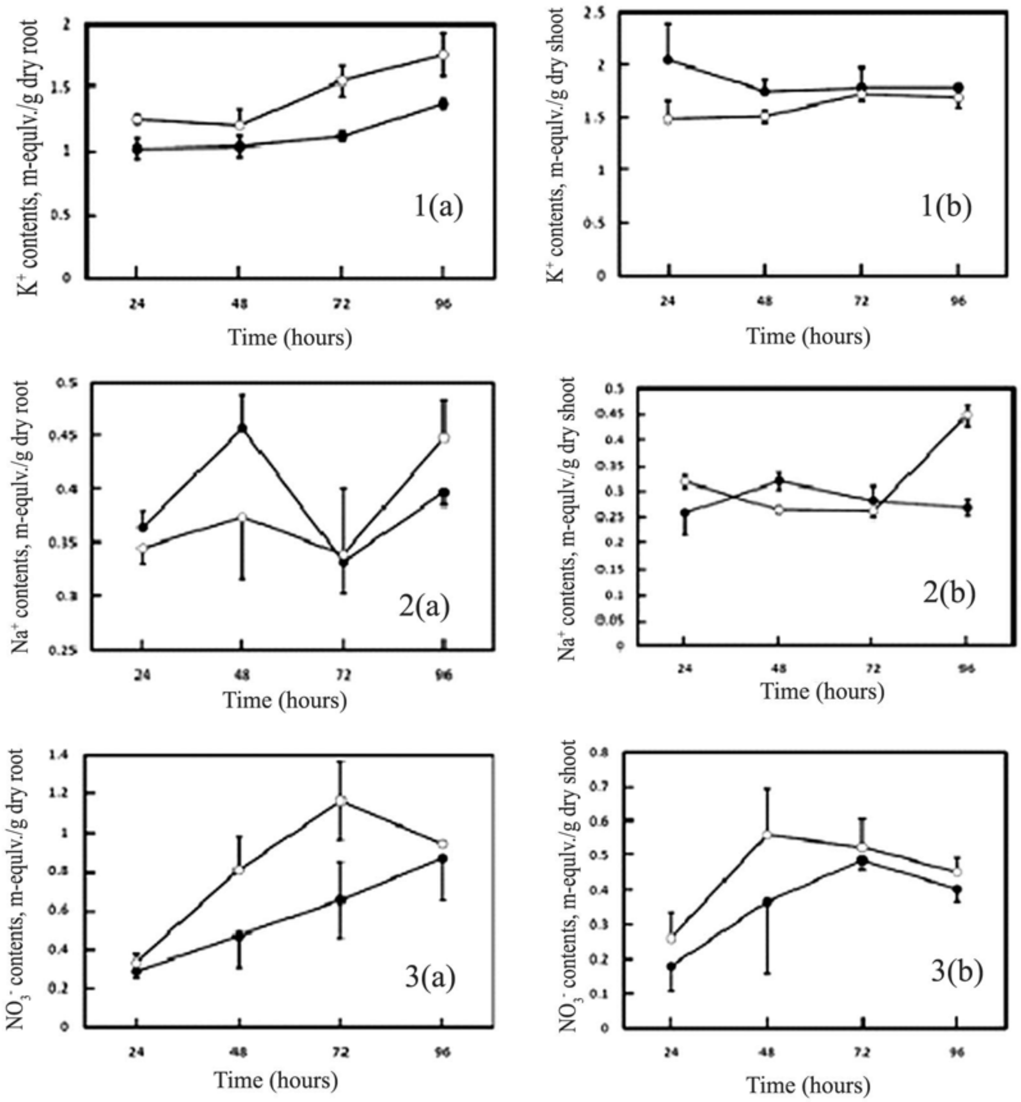
Phosphorus deficiency increased K^+ accumulation by 22.8 to 40% from 24 to 72 hrs and the stimulatory effect was sustained up to 96 hrs of treatment in root (Fig. 1a) and .decreased in the shoot (Fig. 1b). Similar increase in K^+ content was observed in rape and radish following P-deficiency treatment (Cui *et al.* 2003). Dinkelaker and Marschner (1992) showed that phosphorus stress increased K^+ accumulation in the root but decreased that in the shoot of chickpea.

Phosphorus deficiency decreased the accumulation of Na^+ in the root by 5.2 to 18.2% from 24 to 48 hrs of treatment and increased by 12.9% at 96 hrs of treatment (Fig. 2a) and decreased that in the shoot except an initial increase by 24.12% at 24 hrs of treatment (Fig. 2b). Dinkelaker and Marschner (1992) reported similar decrease in the accumulation of Na^+ in the shoot of lentil seedlings. On the other hand, it was observed that phosphorus deficiency increased Na^+ accumulation in the shoot of lentil (Sarker and Karmoker 2011).

Accumulation of NO_3^- was increased up to 78.2% in the root over a period of 72 hrs and the stimulatory effect was maintained up to 96 hrs of treatment (Fig. 3a). In the shoot, NO_3^- uptake showed an increase under P-deficient stress (Fig. 3b). Similarly it increased NO_3^- accumulation in the root but decreased that in the shoot (Sarker and Karmoker 2011). Dinkelaker and Marschner (1992) indicated that phosphorus deficiency plays an important role in stimulation of N-uptake.

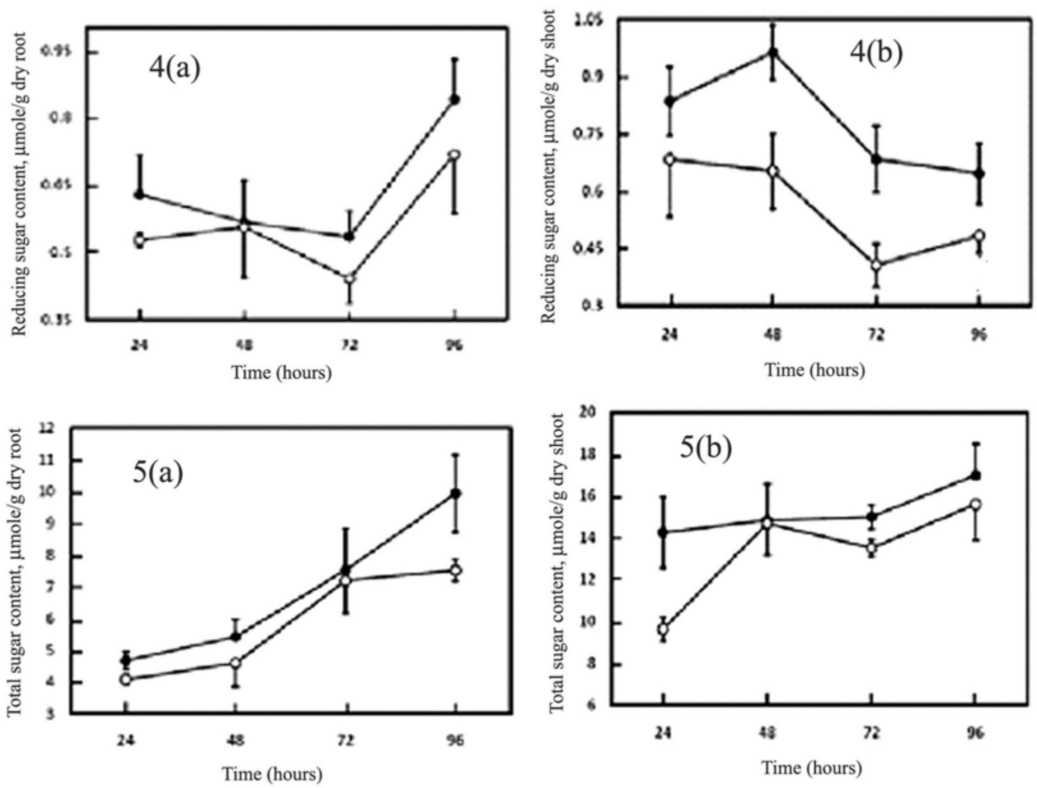
Reducing sugar content was decreased by 16.2 to 14.63% in the root (Fig. 4a) and by 18.1 to 40.6% in the shoot from 24 to 96 hrs of treatment (Fig. 4b). P-deficiency decreased concentration of sugars in roots of tomato plants (Khavari-Nejad *et al.* 2013). Sarker and Karmoker (2011) found that P-deficiency decreased reducing sugar in the leaves and stem but increased that in the root of lentil.

Phosphorus deficiency caused a decrease in the total sugar content both in the root and shoot of wheat (Fig. 5a, b). On the other hand, phosphorus deficiency increased total sugar content in the root of bean (Ciereszko *et al.* 1996) and maize (Khamis *et al.* 1990).



Figs 1-3**.** Effects of phosphorus deficiency on the accumulation of K^+ (Figs 1a, b), Na^+ (Figs 2a, b) and NO_3^- (Figs. 3a, b) in the root and stem of 14-day-old wheat seedlings. Solid symbols (●) represent +P and open symbols (o) represent –P. Each value is the mean of three replicates; the vertical bars represents ± standard error of mean.

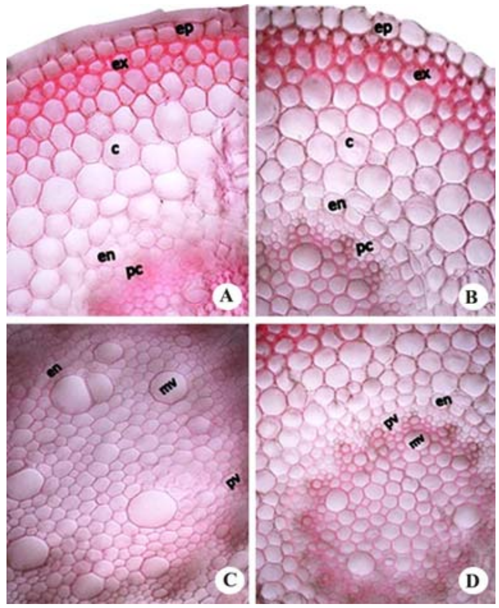
Effects of phosphorus deficiency on anatomy of root: The epidermal cells became thick walled in phosphorus deficient plant (Fig. 6B). Thick walled epidermis in root was reported in maize under phosphorus deficiency (Sarker *et al.* 2010). Similar results was found in lentil (Sarker *et al*. 2015). The endodermal cells are thick walled in plant grown under phosphorus deficient condition (Fig. 6D). Thick walled endodermal cells were found in maize plant under P-deficient condition (Sarker *et al.* 2010). Drastic change in vascular area was noticed in P-deficient plant root. Vascular area was found to decrease and occupy less area with less number of xylem vessels. The metaxylem vessel's cavity of phosphorus deficient plant were smaller in size than those of control plant (Fig. 6D). In phosphorus deficient plant, phloem elements were decreased in size compared to that of control (Fig. 6D). Liu *et al.* (2004) observed that phosphorus deficiency decreased number of xylem vessels with smaller area in *Vigna* seedlings. Amatun *et al.* (2014) and Sarker *et al*. (2015) also found same result in chickpea and lentil.



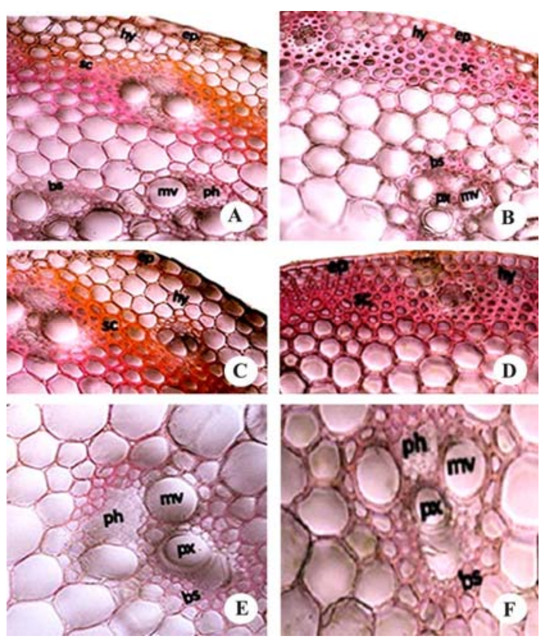
Figs 4-5. Effects of phosphorus deficiency on the accumulation of reducing sugar in the root and shoot (Figs 4a, b) and total sugar in the root and shoot (Figs 5a, b) of 14-day-old wheat seedlings. Otherwise as in Figs 1-3.

Effects of phosphorus deficiency on anatomy of stem: Phosphorus deficiency resulted in thickening of epidermal cells of the stem compared to that of control (Fig. 7B). Similar results was also recorded in maize under phosphorus deficient condition (Sarker *et al.* 2010).

Hypodermal layer of stem was only one in P-deficient plants while it was 3 in control plant (Fig. 7B). Mechanically strong sclerenchymatous tissues were found in both P-deficient and control stem. Number of sclerenchymatous layers were four to five (4 - 5) in P-deficient plant while there were only two in control plant. There are concentric rings of vascular bundles. Smaller vascular bundles occur in this tissue. In phosphorus deficient plant, vascular bundles in the ground tissue were reduced in size with smaller size and cavity of the metaxylem vessels. Size of phloem tissue decreased as compared to that of control (Fig. 7D). Similar effect was found in maize (Sarker *et al.* 2010).



Figs 6(A-D). Transverse sections of root of 45-day-old wheat grown in sand culture with phosphorus, (A, C) control and (B, D) without phosphorus, c = cortex, en = endodermis, ep = epidermis, ex = exodermis, mv = metaxylem vessel, pc = pericycle, pv = protoxylem vessel, (A-D = 400x).



Figs 7(A-F). Transverse sections of shoot of 45day-old wheat grown in sand culture with phosphorus, (A, C, E) control and (B, D, F) without phosphorus, bs = bundle sheath, ep = epidermis, hy = hypodermis, mv = metaxylem vessel, ph = phloem, px = protoxylem , sc = sclerenchyma, (A-F = 400x).

Wheat plant showed different degree of anatomical changes in the root and stem under phosphorus deficient condition (Figs 6B, D, 7D) which may be related observed changes in ion transport (Figs 1B, 2B, 3B). For example, phosphorus deficiency, the epidermal cells of the root and shoot were thicker (Figs 6B, 7B) and it may be suggested that the thickening of epidermal cell may lead to a decrease in accumulation of Na^+ in the root (Fig. 2B). The root of wheat showed thick-walled endodermis. Thickened endodermis lead to the decrease transport of K^+ into the xylem (Fig. 1B). P-deficiency reduced the size of xylem cavity (Figs 6D, 7D) and these changes may lead to the decrease in translocation of K^+ in shoot (Fig. 1B).

References

Cataldo DA, Haaron M, Schrader LF and Youngs VL 1975. Rapid colorimetric determination of nitrate in plant tissue by titration of salicylic acid.Commun. Soil Sci. Plant Anal. **6**: 71-81.

Ciereszko I, Gniazdowska A, Mikulska M and Rychter AM 1996. Assimilate translocation in bean plants (*Phaseolus vulgaris* L.) during phosphate deficiency. J. Plant Physiol. **149**: 343-348.

Cui JY, Wang JG, Zhang FS, Cui JY, Wang JG and Zhang FS 2003. Effect of phlogopite on plant growth under phosphorus deficiency.Commun.Soil Sci. and Plant Analysis.**34**: 7-8.

Das BK and Sen SP 1981. Effect of nitrogen, phosphorus and potassium deficiency on the uptake and mobilization of ions in Bengal gram (*Cicer arietinum*). J. Biosci. **3**: 249-258

Dinkelaker B and Marschner H 1992. Excretion of citrate and malate in the rhizosphere of chickpea (*Cicer arietinum*): Influence of phosphorus supply and N source. Ph.D. thesis.Institute of Plant Nutrition, University of Hohenheim, Germany.

Dubois M,Gilles KA, Hemilton JK, Rebers PA and Smith F 1956. Colorimetric method for determination of sugars and related substances. Ann. Chem. **28**: 350-356.

Fohse D, Ciassen, N and Jungk A 1991. Phosphorus efficiency of plants 11.Significance of root radius, root hairs and cation-anion balance for phosphorus influx in seven plant species.Plant Soil.**132**: 261-272.

Hewitt EJ 1966. Sand and water culture methods used in the study of plant nutrition. 2nd ed. Agricultural Bureau, Farnham Royal, England, pp. 547.

Karim A, Rashid P, Samad R and Karmoker JL 2014. Effect of phosphorus deficiency on ion transport and its correlation with sugar content and anatomical structure in Chickpea (*Cicer arietinum* L. CV. BARICHOLA-5) seedlings. Dhaka Univ. J. Biol. Sci. **23**: 157-164.

Khamis S, Chaillou S and Lamaze T 1990. CO_2 assimilation and partitioning of carbon in maize plants deprived of orthophosphate. J. Expt. Bot. **41**: 1619-1625.

Khavari-Nejad RA, Najafi F and Tofighi C 2013. The effects of nitrate and phosphate deficiencies on certain biochemical metabolites in tomato (*Lycopersicon esculentum* Mill. c.v. Urbana V.F.) plant. J. Stress Physiol. Biochem. **9**: 64-73.

Liu HC, GJ Chen, RY Chen, YH Kuang and XY Wu 2004. Anatomical structures of seedlings of *Vigna unguiculata* ssp. *sesquipedalis* cultivars under phosphorus deficiency stress. J. Plant Resour. Environ. **3**: 48-52.

Nagarjan VK, Jain A, Poling MD, Lewis AJ, Raghothama KG and Smith AP 2011. *Arabidopsis* Pht 1:5 mobilizes phosphates between source and sink organs and influences. The interaction between phosphate homeostasis and ethylene signaling. Plant Physiol. **156**: 1149-1163.

Nelson N 1944. A photometric adaptation of the somogyi method for determination of glucose. J. Biol. Chem. **153**: 375-380.

Rufty TW, Israel DW, Volk RJ, Qiu J and Sa T. 1993. Phosphate regulation of nitrate assimilation in soybean. J. Expt. Bot. **44**: 879-891.

Sarker BC and Karmoker JL 2011. Effect of phosphorus deficiency on growth and transport of K^+, Na^+, Cl^-, NO_3^- in lentil seedling (*Lens culinaris* Medik. var. Barimasur-4). Dhaka Univ. J. Biol. Sci. **20**: 103-108.

Sarker BC, Karmoker JL and Rashid P 2010. Effects of phosphorus deficiency on anatomical structures in maize (*Zea mays* L.). Bangladesh J. Bot. **39**: 57-60.

Sarker BC, Rashid P and Karmoker JL 2015. Anatomical changes of lentil (*Lens culinaris* Medik.) under phosphorus deficiency stress. Bangladesh J. Bot. **44**: 73-78.

Somogyi M 1952. Notes on sugar determination. J. Biol. Chem. B. **195**: 19-23.

Taylor MD, Nelson PV, Frantz JM and Rufty TW 2010. Phosphorus deficiency in *Pelargonium* : Effects on nitrate and ammonium uptake and acidity generation. J. Plant Nutr. **33**: 701-712.

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