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EFFECTS OF PHOSPHORUS DEFICIENCY ON ION TRANSPORT AND ITS CORRELATION WITH SUGAR CONTENT AND ANATOMICAL STRUCTURE IN CHICKPEA (*CICER ARIETINUM* L. CV. BARI CHOLA-5) SEEDLINGS

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Abstract

Phosphorus deficiency stimulated accumulation of Na^+ in the root but declined in the shoot of chickpea seedlings. K^+ content in the root and the shoot increased initially followed by a decrease. Phosphorus deficiency inhibited the accumulation of NO_3^-, PO_4^{3-} and also sugar content both in the root and shoot. It also caused a decline in the accumulation of total sugar only in the root. The interrelationship between the effect of phosphorus deficiency on ion transport and anatomical structure was discussed.

Introduction

Phosphorus (P) provides indispensable foundation to agricultural production[1]. Plant cannot survive at phosphate concentration below two parts per ten million in soil solution[2]. Phosphorus deficiency is one of the major limiting nutrition problems for plants, particularly in both acidic and calcareous soils where P retention and precipitation is maximum[3-4].

Phosphorus deficiency inhibited accumulation of K^+ in the root and shoot but enhanced that of Na^+ both in the root and shoot of lentil[5], *Pelargonium*[6], bean[7] and soybean[8]. It increased carbohydrate concentration in the root of bean[9] and maize[10]. It decreased reducing sugar content in the leaves and stem but stimulated in the root[11].

Phosphorus deficiency developed smaller radius of root and stem of spinach[12] and maize[13]. It reduced number of xylem vessels in the root of *Vigna* seedlings[14] and maize plant[13].

Chickpea (*Cicer arietinum,* 2n = 16) is a legume of the family Fabaceae, was used as a plant material because reports on the effects of phosphorus deficiency on ion transport, reducing and total sugar contents are not sufficient. In this study the effect of phosphorus deficiency on the accumulation and distribution of K^+, Na^+, NO_3^-, PO_4^{3-} and reducing and total sugars is reported.

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Materials and Methods

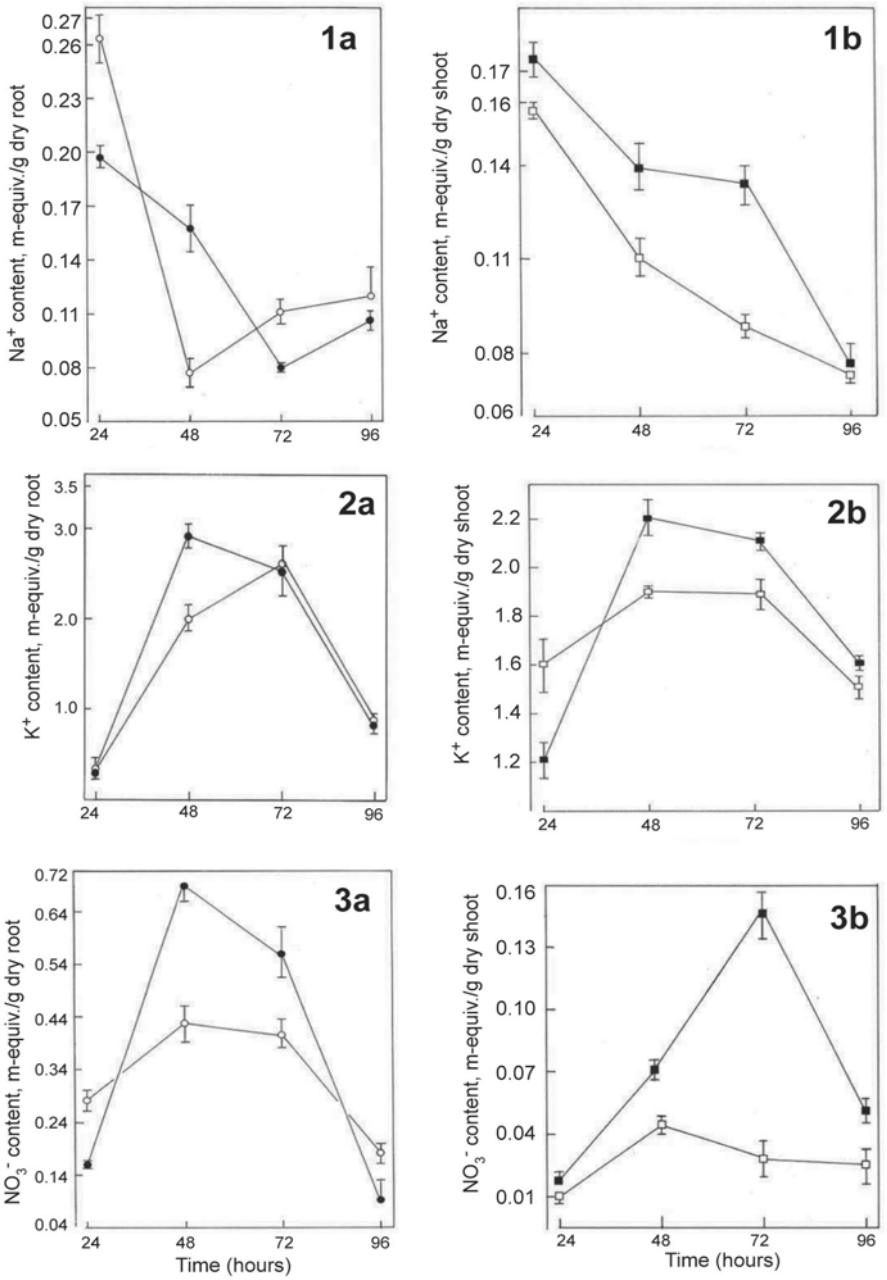
Seeds of *Cicer arietinum* L. cv. BARI Chola-5 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Chickpea seedlings were grown in a specialized nutrient solution[12]. Seeds were surface sterilized with 5.25% sodium hypochlorite solution for two min. Plastic lid covered with cotton gauze was placed upon the beaker painted block filled with nutrient solution. After 48 hrs of sowing the seeds were germinated and then the germinated seeds were transferred to light bank at a day/night temperature of 25 ± 1°C/18 ± 1°C and day/night length of 14 hrs/10 hrs and light intensity was 160 μ-einstein/m^2s. The solution was replenished every 48 hrs. The solution was continuously aerated through bubbler with the help of air compressor. These seedlings were allowed to grow for ten days. Three uniform seedlings were transferred to a dunking frame 24 hrs before the starting of the experiment. Solution containing P was used as control and solution free from P was used as P deficiency treatment and the plant samples were collected after 24, 48, 72 and 96 hrs.

K^+, Na^+ and NO_3^- in the root and shoot were extracted by water digestion and PO_4^{3-} was extracted by acid digestion. K^+ and Na^+ ions were measured using a flame analyzer (Jenway, PEP-7, UK) at wavelengths of 767 and 589 nm, respectively. NO_3^- and PO_4^{3-} were measured according to the method of Cataldo *et al.*[15] and Jackson[16]. Reducing sugar was measured following the methods of Somogyi[17] and Nelson[18] and total sugar by phenol-H_2SO_4 method of Dubois *et al.*[19].

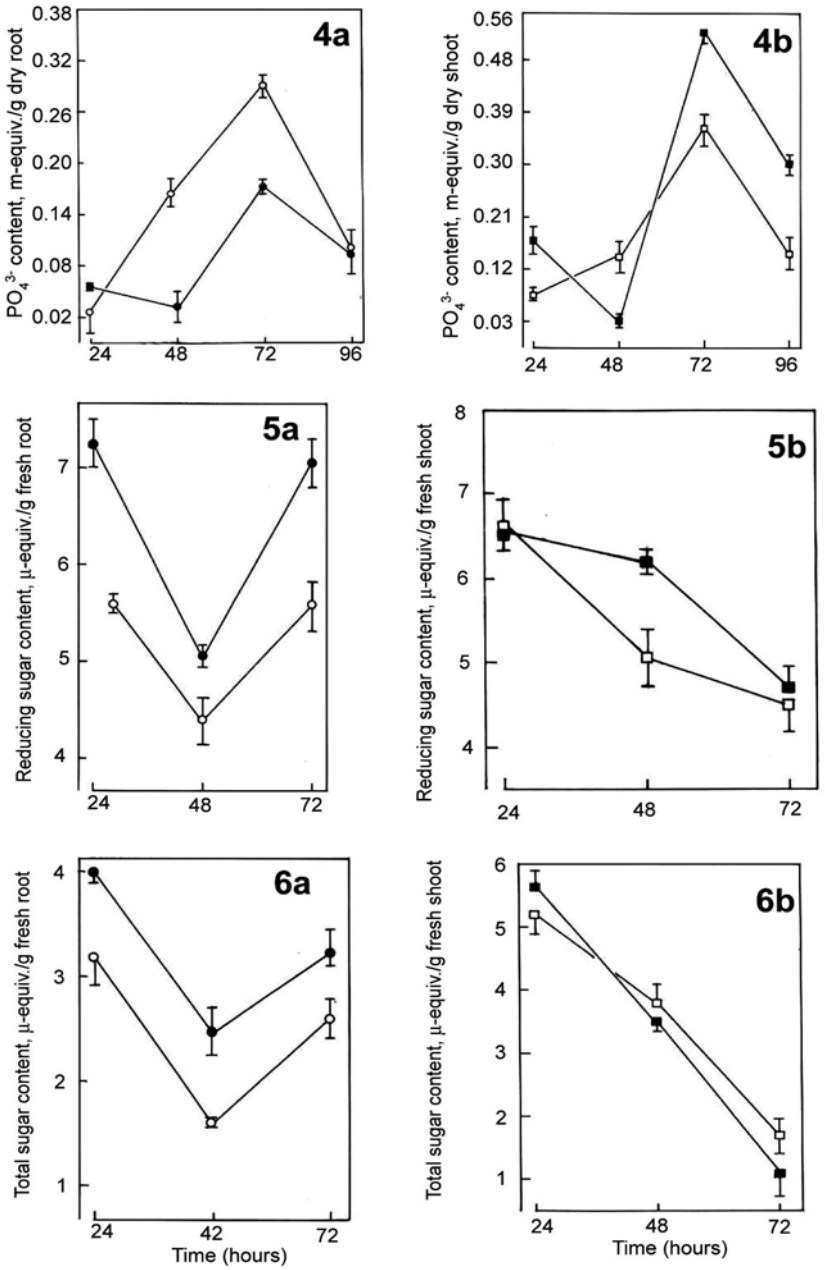
Results and Discussion

Phosphorus deficiency increased the accumulation of Na^+ from 33 to 22% in the root of chickpea seedlings at 96 hrs of treatment except a 52% inhibition at 48 hrs of treatment (Fig. 1a). But it reduced Na^+ content in the shoot gradually from 10 to 34% from 24 to 96 hrs of treatment (Fig. 1b). Initial stimulation in Na^+ accumulation may occur for compensation of the decrease in K^+ due to P deficiency[20]. Dinkelacker and Marschner[21] reported similar phenomenon in the accumulation of Na^+ in the shoot of lentil seedlings. On the contrary, P deficiency was reported to enhance Na^+ accumulation in the shoot of lentil[5].

Phosphorus deficiency accelerated K^+ content in the root by 11% at 24 hrs of treatment and this was nullified gradually within 96 hrs of treatment (Fig. 2a). In the shoot, K^+ content was stimulated by 34% initially followed by 15% inhibition over the rest of the period of treatment (Fig. 2b). Dinkelacker and Marschner[21] showed that phosphorus deficiency increased K^+ accumulation in the root but decreased in the shoot of chickpea.



Figs 1 - 3: 1. Effects of phosphorus deficiency on the accumulation of Na^+ in the root (a) and shoot (b) of chickpea seedlings. Solid symbols represent control and open symbols represent treatment. Bars represent ± standard error. 2. Effects of phosphorus deficiency on the accumulation of K^+ in the root (a) and shoot (b) of chickpea seedlings. Otherwise as Fig. 1. 3. Effects of phosphorus deficiency on the accumulation of NO_3^- in the root (a) and shoot (b) of chickpea seedlings. Otherwise as Fig. 1.



Figs 4 - 6: 4. Effects of phosphorus deficiency on the accumulation of PO_4^{3-} in the root (a) and shoot (b) of chickpea seedlings. Solid symbols represent control and open symbols represent treatment. Bars represent $\pm$ standard error. 5. Effects of phosphorus deficiency on the accumulation of reducing sugar in the root (a) and shoot (b) of chickpea seedlings. Otherwise as Fig. 4. 6. Effects of phosphorus deficiency on the accumulation of total sugar in the root (a) and shoot (b) of chickpea seedlings. Otherwise as Fig. 4.

Accumulation of NO_3^- was declined from 85 to 36% in the root from 48 to 96 hrs of treatment except an initial acceleration by 38% at 24 hrs of treatment (Fig. 3a). In the shoot, NO_3^- content showed a reduction under P-deficiency (Fig. 3b). Similarly, P-deficiency increased NO_3^- accumulation in the root but decreased that in the shoot in maize[22], bean[23] and *Ricinus communis*[24].

Phosphorus deficiency caused an increase in PO_4^{3-} content in the root up to 57% over a period of 96 hrs of treatment (Fig. 4a) with a concomitant decline in the shoot over the same time period (Fig. 4b). Similarly an inhibition in phosphate content in the root and shoot was observed by Dinkelaker and Marschner [21] in chickpea and Andreeva *et al.*[25] in mustard following P deficiency.

Phosphorus deficiency lowered reducing sugar content in the root from 24 to 72 hrs treatment (Fig. 5a) but it had no effect on shoot except a 18% inhibition at 48 hrs of treatment (Fig. 5b). Similarly, it decreased reducing sugar in the leaves and stem but stimulated that in the root[11].

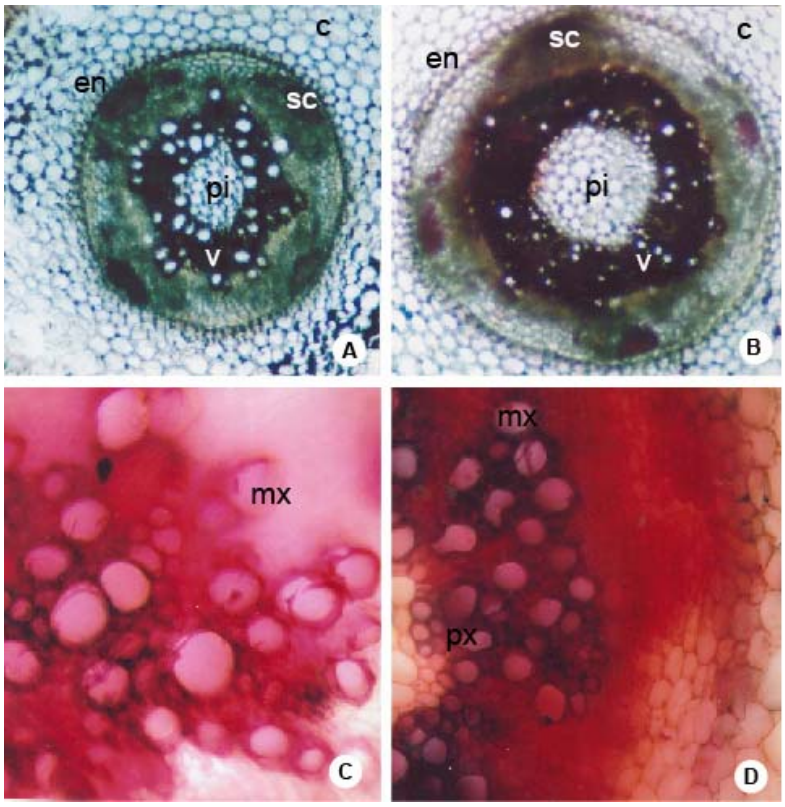


Fig. 7. TS of root of 40-day-old chickpea grown in sand culture with phosphorus (control (A,C) and without phosphorus (B,D). c = cortex; en = endodermis; mx = metaxylem; pi=pith, px = protoxylem; sc = sclerenchyma and v = vessel. (A,B= 100x, C,D=400x)

Phosphorus deficiency caused a reduction in total sugar content in the root from 21-22% from 24 to 72 hrs of treatment (Fig. 6a) but it enhanced that in the shoot by 10 and 42% at 48 and 72 hrs of treatment, respectively (Fig. 6b). On the other hand, it increased total sugar content in roots of bean[9] and maize[10].

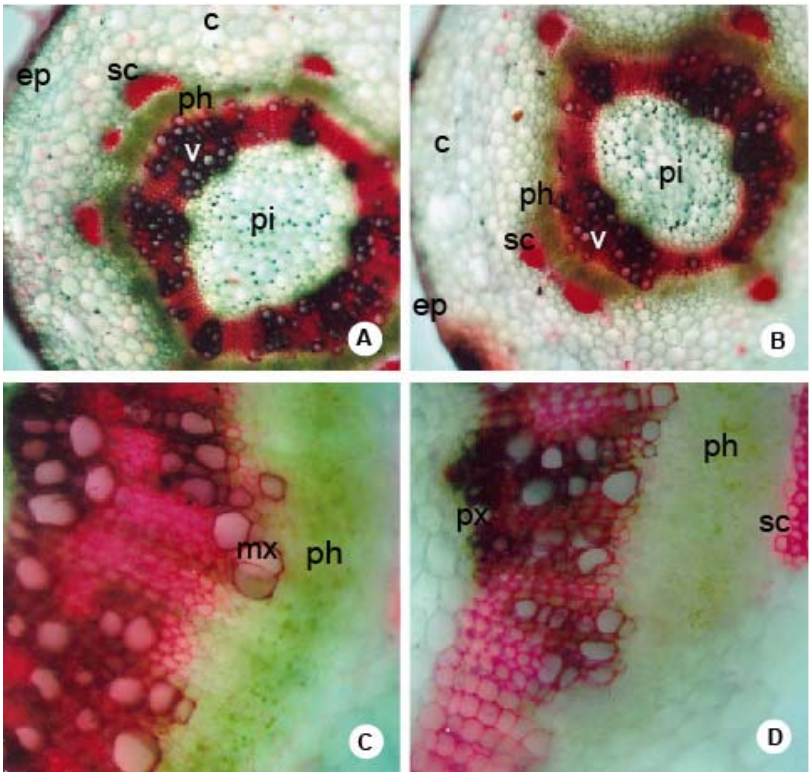


Fig. 8. TS of stem of 40-day-old chickpea grown in sand culture with phosphorus (A,C) (control) and without phosphorus (B,D). c = cortex; ep = epidermis; en = endodermis; mx = metaxylem; ph = phloem; pi=pith, px = protoxylem; sc = sclerenchyma and v = vessel. (A,B= 100×, C,D = 400×)

Layers of cortical cells were less in stem of control plant (Fig. 8A,C) and thickening of endodermis in root was observed in the phosphorus-deficient plant (Fig. 7B). Thick-walled endodermal cells were reported in maize under phosphorus deficiency[13]. Vascular bundles with less number of xylem vessels and also smaller vessel cavity were recorded in roots and shoots of plants raised under phosphorus deficiency condition (Fig. 7B, D and Fig. 8B, D) compared to control (Fig. 7A, C and Fig. 8A, C). Liu *et al.*[14] investigated anatomical structures in the seedlings of *Vigna unguiculata* ssp. *sesquipedalis* under phosphorus deficiency and also observed less number of xylem vessels. Lovelock *et al.*[26] also found that addition of phosphorus to P-deficient dwarf mangroves increased the diameter of xylem vessels and area of conductive xylem tissue.

Phosphorus deficiency induced reduction in the number of xylem vessels in vascular system and size of xylem cavity (Fig. 8B, D) may lead to the observed decrease in translocation of K^+ and NO_3^- (Fig. 2b and 3b).

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