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Differential response of faba bean root components, shoot growth and phosphorus uptake to different levels of solution P concentration

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ABSTRACT

The present study was conducted in aeroponic system to examine the effect of various P concentrations on different components of root system, shoot growth and P uptake of faba bean. The results indicated that increasing P concentration from 0.02 mM to 0.2 mM, there was a significant improvement in various growth parameters. Significant increase in leaf area and photosynthetic rate was observed only up to 0.2 mM P and further increase in P concentration did not increase these parameters. Response of lateral roots to P was greater than that of tap root. The increase in tap root surface area was less than two-fold whereas increase in lateral root surface area was eight-fold at 1 mM level of P concentration. Tap root maintained higher P content than lateral roots at all the P levels tested.

Key words: Aeroponics, Faba bean, Phosphorus concentration, Photosynthetic rate, Root morphology, *Vicia faba*

Two-third of Indian soils are known to give response to phosphorus and remaining one third to heavy P feeding crops (1). The amount of phosphate present in the soil solution is very low compared to adsorbed P in the soil and therefore, P absorption depends on amount of root mass of particular plant species, which can extract P from soil. Phosphorus is known to involve in several vital metabolic processes of plant. It is also associated with development of root system. Higher root growth and development are particularly important in legume crops as they are directly related to biological nitrogen fixation (2). However, Eshel *et al.* (3) reported that removal of the distal part of the taproot of faba bean reduced its mass but hardly affected the development of other plant parts whereas removal of lateral roots above 50 % decreased growth and uptake of nutrients. Several reports showed that optimum P supply improved the root growth of cotton (4), wheat (5) and tomato (6), but in all these studies, root system was taken as a single unit and not dealt with variations among the components of root system. The present paper deals with effect of different P concentrations on responses in different components of root mass as well as shoot growth and P uptake of faba bean.

MATERIALS AND METHODS

Experiment was conducted during 1999-2000 in aeroponics to facilitate non-destructive collection of different components of root mass. Four-day old seedlings of faba bean (*Vicia faba* L.), germinated in vermiculite, were thoroughly washed with distilled water and then transferred to mini-aeroponics chambers of the 'Sarah Recine Root Laboratory' at Tel-Aviv University, Tel-Aviv, Israel (7). The experimental set-up consisted of six 100 liters aeroponics growth chambers intermittently sprayed with mist consisting of half strength Hoagland's nutrient solution (8). The chambers were sprayed for 20 seconds every minute. The sprayed solution was collected, filtered and recycled. The temperature of the growth chamber was set to 25°C during the light period (06:00-18:00h) and 19°C during the dark period (18:00-06:00h). A mixed battery of fluorescent and incandescent lamps with a PAR of 125 u mol m-2s-1 at the plants level supplied light. Three levels of P *viz.*, 0.02 mM, 0.2 mM and 1.0 mM were introduced in the solution. Each plant was taken as replication and thus 20 plants in two chambers became 40 replications for each P levels.

Ten days after exposing to different levels of P solution, plant height, leaf area and dry weights of leaf, stem, tap root and laterals were measured. The excised roots were immersed overnight in a neutral red solution (Systematic name: Toluylene red) (0.2g L^{-1}). The roots were then rinsed twice in tap water to remove the excess dye and scanned while immersed in water using an HP Scan Jet II C flatbed scanner. Leaves were scanned without staining. Leaf area, and root length and diameter distribution were determined by image analysis and their surface area and volume were calculated by the Delta-T Scan programmed (Delta-T Inc.). All plant parts were dried (80°C for 24 h) and weighed. Leaf, stem, tap root and lateral root samples were ashed at 500°C. The ash was then dissolved in 10 ml of 0.1M HCl and phosphorus content was determined by the colorimetric method (9). Phosphorus uptake in different plant parts was computed by multiplying from P content with dry matter yield. Data were analysed statistically following one way ANOVA as described by Gomez and Gomez (10).

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Table 1. Effect of P on growth parameters of faba bean (Mean±SE)

Pamameter	P concentration in aeroponic chamber		
	0.02 mM	0.2m M	1.0 mM
Plant height (cm)	6.10±41a	14.70±0.55b	15.30±0.77b
Leaf number	4.82±0.33a	8.60±0.45b	10.57±0.53b
No of branches	1.0a	1.9±0.19b	2.3±0.15c
Leaf area (cm^2 $plant^{-1}$)	21.0±2.07a	54.7±3.52b	55.8±3.09b
Photosynthetic rate (uM s^{-1})	5.68±0.42a	9.49±0.77b	9.73±0.74b
Leaf dry weight (mg $plant^{-1}$)	63±6a	180±11b	190±12b
Stem dry weight (mg $plant^{-1}$)	57±7a	160±9b	163±8b
Tap root dry weight (mg $plant^{-1}$)	49±6a	81±4b	84±5b
Lateral root dry weight (mg $plant^{-1}$)	23±3a	80±7b	95±2c
Shoot/root ratio	1.67a	2.13b	1.97b

RESULTS AND DISCUSSION

Increasing P concentration in the solution from 0.02 to 0.2 mM increased all the growth parameters significantly (Table 1). Further increase up to 1.0 mM resulted in significant increase only in leaf area, and tap and lateral root weights. Plant height increased by two and a half folds, leaf number by two-fold and leaf area by two and a half times at 0.2 mM over 0.02 mM P. Similarly, leaf and stem weights increased by about three times. Leaf area increased from 21.0±2.07 to 54.7±3.52 cm^2 $plant^{-1}$ and photosynthetic rate increased from 5.68±0.42 to 9.49±0.77 um s^{-1} at 0.2 mM P concentration. Further increase in P concentration did not affect these parameters significantly.

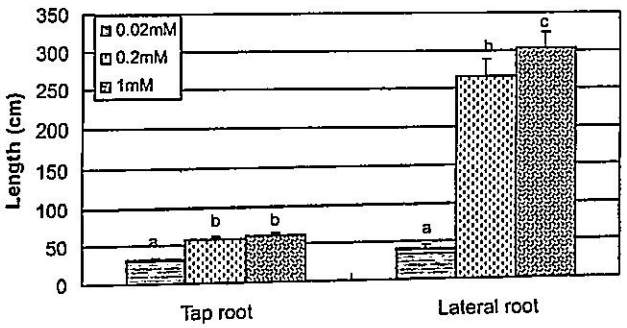

Fig. 1a : Effect of P levels on root length of faba bean

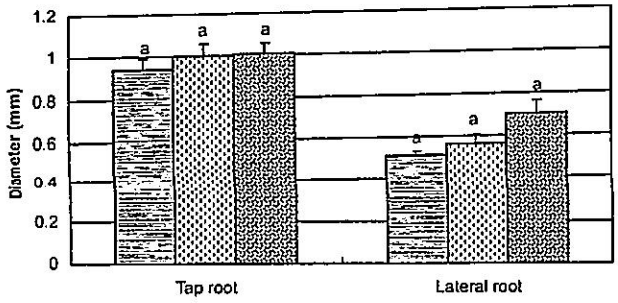

Fig. 1b: Effect of P levels on root diameter of faba bean

Diffferent letters in each indicate significant differences (5%)

Tap root dry weight increased by less than two times whereas lateral root dry weight increased by four times. This shows that tap root can sustain the growth to some extent in low P conditions whereas lateral roots needed enhanced P concentration for higher growth. Further increase in P concentration from 0.2 mM to 1.0 mM improved the tap root weight by 3 % and lateral root weight by 19 %. Overall shoot growth improved much greater than root growth due to increase in P levels. Therefore, shoot/root ratio increased with increasing P concentration. Similar increase in different plant growth parameters due to P supply was reported by Singh and Sale (11) and Rodriguez *et al.* (5). Grain yield responses to P application were also reported in mungbean (12) and chickpea (13). Such increases in growth derived from increased P supply were obviously from its contribution in the major metabolic processes related to root growth.

Tap root length increased significantly up to 0.2 mM P whereas significant increase in lateral root length was up to 1 mM P (Fig 1a and 1b). It indicates that tap root could maintain higher length at lower P concentration while lateral roots needed much higher P in solution to maintain higher growth. Tap root length was nearly doubled whereas lateral root length increased more than 7 times at 1.0 mM P concentration. There was no significant increase in diameter of both tap and lateral roots.

Volume and surface area of tap root due to different levels of P increased significantly up to 0.2 mM P whereas

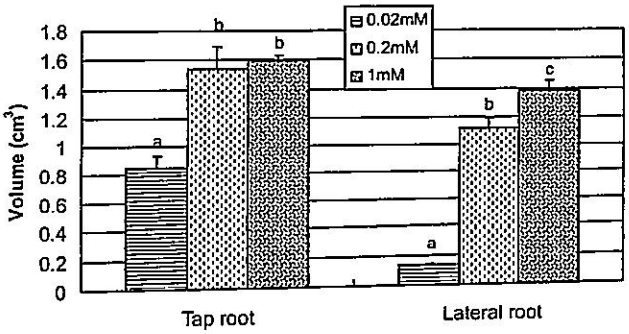

Fig.2a: Root volume of faba bean at different levels of P

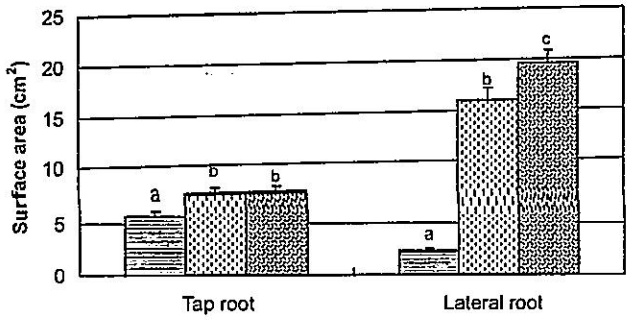

Fig. 2b: Root surface area of faba bean at different levels of P

Diffferent letters in each indicate significant differences (5%)

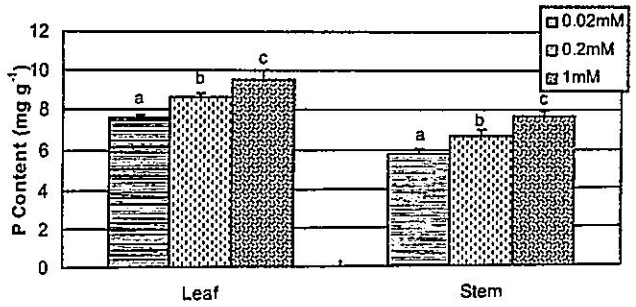

Fig. 3a: Effect of different P levels on P content of leaf and stem of faba bean

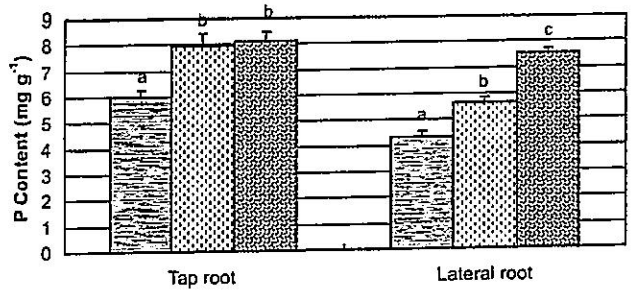

Fig. 3b: Effect of different P levels on P content in roots of faba bean

Different letters in each parameter indicate significant differences (5%)

increases in these root parameters were significant up to 1.0 mM P in case of lateral roots (Fig 2a and 2b). The increase in tap root surface area was less than two-fold and in lateral root surface area, the increase was almost eight fold at 1.0 mM P, indicating that development of lateral root affected more adversely under P deficient conditions as compared to tap root. While evaluating the performance of faba bean plants at different root pruning levels, Eshel *et al.* (3) reported that at least 50% lateral roots were needed for optimum plant growth whereas removal of distal part of tap root did not influence the plant growth. Therefore, from the present results, it is clear that in low P conditions, under development of lateral roots must have contributed greatly in the reduced shoot growth.

Tap root maintained higher P contents as compared to lateral roots at all the three levels of P concentration. This could be the possible reason that tap root responded to increasing P levels only up to 0.2 mM P whereas lateral roots responded up to 1.0 mM P. Such differences in K uptake between tap and laterals were reported by Srinivasarao *et al.* (14) and indicated that tap root maintained higher K uptake over laterals. Among plant parts, leaves showed the highest P content followed by tap root, stem and lateral roots. Significant increase in P content of leaf, stem and lateral roots was observed up to 1.0 mM P while the increase was significant only up to 0.2 mM P in tap root P content. Total P uptake of the plant increased from 1.203 mg plant^{-1} at 0.02 mM P to 4.458 mg plant^{-1} at 1.0 mM P.

The above results suggest that different components of root system responded differently to P supply. Lateral roots are much sensitive to P nutrition than tap root. Thus, contribution of different root types to functional system varies with different environments.

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