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Genetic variation in fenugreek (*Trigonella foenum-graecum* L.) for phosphorus utilization under Aridisol

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Abstract

An experiment was conducted at Ajmer (Rajasthan) to investigate the genetic variation of seven fenugreek (*Trigonella foenum-graecum*) genotypes for phosphorus utilization under typical Aridisol. The result showed that cv. Rajendra Kranti was superior and could utilize about 71% of the rhizosphere phosphorus. A strong positive correlation between plant phosphorus concentration and alkaline phosphatase ($r = 0.51$, $P < 0.05$) as well as dehydrogenase activity ($r = 0.62$, $P < 0.01$) in the rhizosphere was observed. Labile phosphorus showed a strong negative correlation with plant phosphorus concentration ($r = -0.70$, $P < 0.01$) and total phosphorus uptake ($r = -0.62$, $P < 0.01$). Higher phosphorus concentration (3.36 mg g^{-1}), total phosphorus uptake (87.4 mg plant $^{-1}$) and dry biomass (26.0 g plant^{-1}) at critical growth stage was observed in Rajendra Kranti. A strong correlation ($r = 0.98$, $P < 0.001$) was also found with dry biomass and total phosphorus uptake.

Key words: fenugreek, phosphorus accumulation, *Trigonella foenum-graecum*.

As a leguminous plant, the phosphorus requirement of fenugreek (*Trigonella foenum graecum* L.) is very high. But the crop is grown under arid and semi-arid areas where available phosphorus content in the soil is very low and varies between 0.7% and 1.8% of the total P (Tarafdar *et al*. 2006). Therefore, there is a need to select a cultivar which influences microbial and phosphorus mobilizing enzyme activities in the rhizosphere so that more phosphorus can be converted to available form and taken up by the plant. Since no information is available on this aspect, a study was conducted with seven genotypes of fenugreek to see the microbial (dehydrogenase) and enzymatic (phosphatase and phytase) build up in the rhizosphere during the critical growth period and identify the best genotype which can accumulate and transport more phosphorus into the plant for better growth and development.

The field experiment was conducted during *rabi* season of 2007 at Tabiji Farm, Ajmer, Rajasthan, with seven diverse fenugreek

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genotypes (RMT-1, RMT-305, UM-351, Rajendra Kranti, NDM, NRCSS AM-1, NRCSS AM-2). Each genotype was sown in 3 m × 3 m plot with 30 cm inter-row spacing. A basal dose of N @ 20 kg ha^{-1} and P_2O_5 @ 15 kg ha^{-1} was applied. Irrigation was given once at the time of sowing. Three plants of each cultivar with intact roots were carefully freed from soil at critical growth stage (35 days after planting). The roots were thoroughly washed free of soil in tap water followed by deionized water. Shoots and roots were dried at 60°C to a constant weight, and dry weight was taken. The rhizosphere soil was collected and refrigerated before being analyzed. Phosphatase (acid and alkaline) activity was estimated by the method of Tabatabai & Bremner (1969) using acetate buffer (pH 5.4) and borax-NaOH buffer (pH 9.4), respectively. Dehydrogenase activity, a measure of microbial activity, was assayed by the method of Tabatabai (1982). Labile phosphorus was estimated by the method of Sibbesen (1978) after using a strongly basic anion exchange resin INDION® GS 400 (Indira 2008). Available phosphorus was estimated (Olsen's method) as described by Jackson (1967). Plant phosphorus was measured colorimetrically as molybdovanadophosphoric acid (Kitson & Mellon 1944) after wet ashing. Statistical analysis was carried out as described by Sokal & Rohlf (1981).

A wide variation in microbial activity (dehydrogenase activity) was observed among the genotypes which was higher in NRCSS AM-1 closely followed by RMT-1 and Rajendra Kranti (Table 1). A wide variation in acid and alkaline phosphatase activity among the genotypes was also observed. Higher acid phosphatase was noticed under UM-351 and alkaline phosphatase under Rajendra Kranti. In general, a strong correlation between dehydrogenase activity with plant phosphorus concentration ($r = 0.62$, $P < 0.01$) and alkaline phosphatase activity with plant phosphorus concentration ($r = 0.51$, $P < 0.05$) was observed. Labile phoshorus showed strong negative correlation with phosphorus concentration ($r = -0.70$, $P < 0.01$) and total phoshorus uptake ($r = -0.62$, $P < 0.01$). This indicates that, the phosphorus accumulated in the rhizosphere is immediately taken up by the plant. Plant roots may influence the availability and uptake of mineral nutrients by mechanisms such as the release of root exudates, protons, bicarbonate ions and ectoenzymes. These mechanisms are of particular importance under conditions of low nutrient availability. Differences in enzyme and microbial activity could be related to rhizosphere chemical mobilization, root exudation or root hair density. Foehse *et al*. (1991) found that a higher concentration of P at the root hair surface caused a higher influx.

Table 1. Dehydrogenase, acid phosphatase and alkaline phosphatase activities of fenugreek genotypes

Genotype	Enzyme activity		
	Dehydrogenase (p kat g^{-1})	Acid phosphatase (EU 10^{-5})	Alkaline phosphatase (EU 10^{-5})
RMT-1	5.62 0.27	2.91 0.24	6.45 0.03
RMT-305	3.82 0.17	2.80 0.08	6.51 0.23
UM-351	3.49 0.13	4.30 0.14	10.19 0.06
Rajendra Kranti	5.41 0.07	3.46 0.18	12.88 0.05
NDM	5.19 0.09	2.40 0.07	7.77 0.48
NRCSS AM-1	6.10 0.018	3.55 0.25	9.26 0.32
NRCSS AM-2	4.97 0.16	2.48 0.31	9.32 0.42

Labile phosphorus concentration (estimated after using ion exchange resin) in fenugreek genotypes showed a strong depletion of labile phosphorus content in the rhizosphere soil, which varied between 42.1% and 71.6% (Table 2). Maximum utilization of native phosphorus was noticed in Rajendra Kranti where the ion exchange resin-phosphorus

Table 2. Labile phosphorus concentration in fenugreek genotypes

Genotype	Resin-P (mg kg^{-1})	Per cent decrease over control
RMT-1	10.30 ± 0.14	57.92
RMT-305	7.58 ± 0.32	69.04
UM-351	14.17 ± 0.27	42.12
Rajendra Kranti	6.95 ± 0.13	71.61
NDM	9.30 ± 0.11	62.01
NRCSS AM-1	7.35 ± 0.19	69.98
NRCSS AM-2	13.80 ± 0.23	43.63
Control soil (without plant)	24.48 ± 0.78	

was reduced from 24.48 (control) to 6.95, resulting in a reduction of 71.6% of available phosphorus, which may be taken up by the plants during their growth period. Least reduction was observed in the genotype UM-351. Phosphorus adsorption by ion exchange resin showed wide genotypic differences in phosphorus accumulation. Ion adsorption by the resin is affected by competition both biologically and chemically when resin is placed in soils. Nutrient conversion by native organisms will affect supply of nutrient to the resin for adsorption (Subler *et al*. 1995). Therefore, ion exchange resins behave in a similar manner to a plant root in their ion uptake capacity (Sibbesen 1978).

Maximum utilization of native phosphorus by the genotype Rajendra Kranti was confirmed further when the phosphorus concentration and total phosphorus uptake by the plant was analyzed (Table 3). The results showed higher concentration of phosphorus in Rajendra Kranti (3.36 mg g^{-1}), and maximum phosphorus depletion from labile sources (71.6%) among the genotypes. The total phosphorus uptake was also more (87.4 mg $count^{-1}$) in Rajendra Kranti. The results clearly demonstrated that Rajendra Kranti is the best phosphorus utilizer among the seven genotypes tested. The genotype UM-351 showed lowest phosphorus concentration (2.63 mg g^{-1}) and total phosphorus uptake (21.3 mg $plant^{-1}$) and has least labile phosphorus depletion in the rhizosphere (42.1%) than the other genotypes tested. The dry biomass (g $plant^{-1}$) was also maximum in Rajendra Kranti (26.0) and least in UM-351 (8.1). A strong correlation was also found between dry biomass and total phosphorus uptake ($r = 0.98$, $P < 0.001$) as well as plant phosphorus concentration ($r = 0.55$, $P < 0.01$).

Enzyme activities in the soil environment are considered to be a major factor contributing

Table 3. Plant biomass, phosphorus concentration and total phosphorus uptake of fenugreek genotypes during critical period

Genotype	Plant P content (%)	Total P uptake (mg $plant^{-1}$)	Dry biomass (g $plant^{-1}$)
RMT-1	0.274	53.4	19.5
RMT-305	0.289	49.7	17.2
UM-351	0.263	21.3	8.1
Rajendra Kranti	0.336	87.4	26.0
NDM	0.311	51.4	16.5
NRCSS AM-1	0.321	38.7	12.1
NRCSS AM-2	0.295	44.8	15.2
CD (P = 0.05)	0.012	0.83	2.12

to overall soil microbial activity and soil quality. The evidence available (Tarafdar & Claassen 2005) indicates that under suitable conditions enzymes readily attached with different P compounds. The rate of phosphorus mineralization depends on microbial activity (Tarafdar *et al*. 1988) and the activity of free phosphatases, which is controlled by the solution phosphorus concentration (Yadav & Tarafdar 2001). Plant species differ in their ability to obtain phosphorus from soil and adopt different physiological strategies (Lajtha & Harison 1995). The present result clearly demonstrated that Rajendra Kranti is the most efficient fenugreek cultivar for phosphorus utilization and accumulation.

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