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Original Research Article

Lai, Par and Spad values of cultivars of Indian mustard (*Brassica juncea*) as influenced phosphorus levels

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A B S T R A C T

Field investigation was carried out during *rabi* 2012-13 at Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana. Soil of the experimental field was loamy sand in texture, neutral in reaction (pH 7.8), free from salts (EC 0.10 dS/m), low in organic carbon (0.37%), nitrogen (245 kg/ha), Olsen's available phosphorus (11.7 kg/ha) and rich in potassium (165 kg/ha). The study comprised 42 treatments with three doses of phosphorus (0, 15 and 30 kg P_2O_5/ha) in the main plots and fourteen cultivars (RLC 1, PBR 210, PBR 91, RLM 619, RL 1359, PBR 357, ELM 123, NRCDR 2, NRCHB 601, Pusa Bold, Varuna, MLM 19, NPJ 79 and PLM 2) in the sub plots. Treatments were replicated thrice as per split plot design of experimentation. The study revealed that application of 30 kg/ha of P_2O_5 significantly increased LAI, PAR interception, whereas the effect of phosphorus application was non-significant on leaf chlorophyll content. Among the cultivars, NRCHB 601 performed markedly better than all other cultivars for all growth parameters.

Keywords

Cultivars, Indian mustard, LAI, Phosphorus, PAR

Introduction

Among various oilseed crops grown in India, rapeseed-mustard group of crops (*Brassica spp*. Family *Brassicaceae*). India ranks second in area after China and third in production after Canada and China contributing about 17.9 per cent of total area and 11.2 per cent of total production of rapeseed-mustard in the world (DRMR, 2013). These crops share about 22.4 per cent of total cultivated area under oilseeds (26.4 m ha) under diverse agro-ecological situations and contribute 22.6 per cent to total production of oilseeds (30.0 m t) in the country (Anonymous, 2012). Indian mustard (*Brassica juncea* L. *Czern* & *Coss*) with a share of about 80 per cent in area and production of rapeseed and mustard occupies prominent position in India. However, present productivity of rapeseed-mustard in India (1145 kg/ha) is below its average productivity in the world (1856 kg/ha). Keeping in view the acute shortage of vegetable oil in the country and stiff competition from other more remunerative crops (cereals) that reduce chances of area expansion under oilseed, there is need to improve productivity of oilseed crops by cultivating higher yielding cultivars and by reducing costs through improvement in resource use efficiency.

Deficiency of phosphorus in crop fields has been observed worldwide (Vance *et al.*, 2003, Lynch, 2007) especially in highly weathered soils of tropics and sub-tropics where formation of complexes with calcium and magnesium in alkaline soils and with some metal cations such as aluminium and iron in acid soils, reduce its availability (Holford, 1997). Worldwide about 5.7 billion hectares of land was reported to be deficient in phosphorus (Batjes, 1997). Plants fail to absorb phosphorus even from soils containing sufficient amount because of its low mobility and strong phosphate fixation in soils (Mengel and Kirby 2001).

Consequently its application in higher amounts is needed to harness optimal yields. Bolland and Gilkes (1998) reported that only 10–20 per cent of the applied phosphorus was directly used by the crop to which it was applied and even lower amount was availed by the subsequent crops. Phosphorus deficiency in cultivated soils of India is also widespread. Analysis of 9.6 million samples of Indian soils indicated that majority of them were low (49.3%) to medium (48.8%) in available phosphorus (Hasan, 1996). In Punjab, about 36 per cent soils have been found low, 32 per cent medium and only 32 per cent rich in available phosphorus (Benbi *et al.,* 2011). Application of phosphorus in higher doses is increasingly becoming uneconomical and ecologically unsound practice. Historically, almost entire amount of phosphatic fertilizers used in India is imported. High costs of imports, manufacturing and transportation of low grade P ore make it very expensive nutrient element. High P fixation and low P uptake rate make it imperative to exploit P efficient germplasm for developing P efficient cultivars (Fageria *et al.,* 2008). Selection of P efficient cultivars through exploitation of genetic variations for increased P efficiency may reduce fertilizer requirements and sustain productivity on low P soils. Plants that are efficient in P acquisition and utilization may greatly increase the efficiency of applied phosphatic fertilizers, reduce the environmental degradation and lower input cost. Keeping in view high P requirement, low uptake and purity of information about response of Indian mustard cultivars to applied P, the present investigation was planned and executed the variability in growth of Indian mustard cultivars in response to phosphorus application levels.

Materials and Methods

The field experiment was conducted at the research farm of Oilseeds Section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana during *rabi* 2012–13 (30° 56' N 75° 48' E, 247 meter above the mean sea level). The study comprised 42 treatments with three doses of phosphorus (0, 15 and 30 kg P_2O_5/ha) in the main plots and fourteen cultivars (RLC 1, PBR 210, PBR 91, RLM 619, RL 1359, PBR 357, ELM 123, NRCDR 2, NRCHB 601, Pusa Bold, Varuna, MLM 19, NPJ 79 and PLM 2) in the sub plots. The soil of the experimental field was loamy sand in texture, neutral in reaction (pH 7.8), free from salts (EC 0.10 dS/m), low in organic carbon (0.37%), nitrogen (245 kg/ha), Olsen's available phosphorus (11.7 kg/ha) and rich in potassium (165 kg/ha).

The experiment consisted of three doses of phosphorus as 0, 15 and 30 kg P_2O_5/ha in main plots and fourteen cultivars as RLC 1, PBR 210, PBR 91, RLM 619, RL 1359, PBR 357, ELM 123, NRCDR 2, NRCHB 601, Pusa Bold, Varuna, MLM 19, NPJ 79, PLM 2 in sub-plots. Treatments evaluated thrice in split plot design. The other package of practices used recommended for raising the crop.

Leaf area index (LAI) and Interception of photosynthetically active radiation (PAR)

The periodic leaf area index (LAI) and PAR interception of plants was recorded at monthly interval between 30 and 120 DAS with the Digital Plant Canopy Imager (Sun Scan Canopy Analyzer model CI-110/CI-120). The observations taken at random from three places in each plot between 11:00 am and 2:00 pm were averaged.

Soil plant analysis diagnosis (SPAD) reading

The Soil Plant Analysis Development (SPAD) unit of Minolta Camera Co., Japan has developed SPAD 502 Chlorophyll Meter as a hand held self-convenient and light weight device for non-destructive estimation of amount of chlorophyll present in the leaves. The SPAD readings were taken at 30, 60, 90 and 120 DAS. For each observation, second or third fully opened leaf from top was randomly selected from ten plants of each plot. The mean value of ten readings was reported as SPAD value. Care was taken that midrib of the leaf did not fall under the sample area (sensor) of the instrument.

The data of crop recorded in field and laboratory on different aspects were statistically analysed as per the procedure described by Cochran and Cox (1967) to test the significance of treatments. Split plot design was used and comparisons were made at 5% level of significance. Analysis of variance was conducted for various parameters using computer programme SAS (SAS, 2008).

Results and Discussion

Leaf area index (LAI)

LAI recorded periodically at 30 days interval between 30 and 120 DAS, increased up to 90 DAS and decreased thereafter (Table 1). Plants attained LAI of 0.24 at 30 DAS, which increased to 1.97 at 60 DAS and further to 3.30 at 90 DAS. The LAI at 120 DAS (1.35) was lower than that recorded at 60 DAS. Successive increments of phosphorus up to highest dose i.e. 30 kg/ha of P_2O_5 significantly increased the LAI over its lower dose at all growth stages. Proportional increase in LAI up to 90 DAS with application of 15 kg/ha of P_2O_5 over control was higher than that discerned for 30 kg/ha over 15 kg/ha of P_2O_5, whereas reverse trend was noticed at 120 DAS. Application of 15 kg/ha of P_2O_5 increased the LAI over control by 25.0, 12.5, 8.2 and 16.7 per cent in comparison to increase of 12.0, 9.6, 6.6 and 18.8 per cent with application of 30 kg/ha over 15 kg/ha of P_2O_5 at 30, 60, 90 and 120 DAS, respectively.

Leaves are photosynthetically most active tissues in the plant that determine the amount of light intercepted by crop canopy (Mandal and Sinha 2004). More leaf area of crop lead to interception of more solar radiation which aid in production of more dry matter by the crops. LAI is an indicator of the size of the assimilatory system of the crop. Phosphorus application increased the LAI by increasing the plant height and dry matter accumulation and might have increased leaf size as well. Patel and Shelke (1998), Ali *et al.*, (2000), Bhat *et al.*, (2006) also observed increase in LAI with phosphorus application. Cheema *et al.*, (2001) reported that higher levels of phosphorus have significant effect on LAI. Tomer *et al.*, (1992) reported increase in LAI with phosphorus application of 60 kg/ha of P_2O_5. Kumar and Yadav (2007) also reported that increased phosphorus application from 26.2 to 39.3 kg P/ha resulted in increased LAI. Greater increase in LAI at 120 DAS with application 30 kg/ha of P_2O_5 over 15 kg/ha of P_2O_5 in comparison to increase in LAI with 15 kg/ha of P_2O_5 over control indicates positive role of P in retention of leaves on the plant for longer duration.

Differences in LAI among cultivars were significant at all growth stages (Table 1). Cultivar NRCHB 601 attained highest LAI whereas cultivar NPJ 79 attained lowest LAI at all growth stages. At 30 DAS, cultivars RLC 1, PBR 210, PBR 91, RLM 1359, PBR 357 and PLM 2 attained statistically similar LAI with NRCHB 601 (0.28). The lowest LAI (0.21) attained by NPJ 79 was at par with RLM 619, ELM 123, NRCDR 2, Pusa Bold, Varuna and MLM 19. At 60 DAS, cultivars PBR 91, PBR 210, NRCDR 2 and Varuna attained similar LAI with NRCHB 601 (2.20) whereas the lowest LAI attained by cultivar NPJ 79 (1.73) was at par with MLM 19, RLC 1 and PBR 357 and significantly lower than rest of the cultivars.

At 90 DAS, LAI attained by NRCHB 601 (3.66) was at par with PBR 91, PBR 210, NRCDR 2 and Varuna. Lowest LAI (2.97) attained by NPJ 79 was at par with PBR 357, MLM 19, RLC 1, RLM 619, RL 1359 and ELM 123 and significantly lower than all other cultivars. At 120 DAS, NRCHB 601, NRCDR 2, and PBR 91 attained similar and higher LAI than other cultivars. The LAI attained by NPJ 79 (1.20) was at par with MLM 19, PLM 2, ELM 123, Pusa Bold, RLC 1 and RLM 619 and significantly lower than rest of cultivars. Similar results indicating significant differences in LAI among cultivars were obtained by Das (1998) and Ali *et al.*, (2000). Interactive effect of doses of phosphorus and cultivars on LAI was non-significant at all the growth stages.

Interception of photosynthetically active radiation

PAR recorded at monthly intervals between 30 and 120 DAS revealed steady increase in PAR interception from 26.4 per cent at 30 DAS to 77.1 per cent at 60 DAS and further to 83.2 per cent at 90 DAS (Table 2). The PAR interception at 120 DAS (77.7 per cent) was lower than that recorded at 90 DAS. Application of phosphorus up to the highest dose increased the PAR interception at all the growth stages and such an increase with 30 kg/ha of P_2O_5 over 15 kg/ha of P_2O_5 was significant except at 30 DAS. Similarly application of 15 kg/ha of P_2O_5 resulted in significantly higher PAR interception than without its application at 60 and 90 DAS.

The interception of photosynthetically active radiation (PAR) by a crop represents the net production of photosynthates. Increase in LAI (Table 1) that occurred from increase in leaf area with increasing dose of phosphorus provided platform for interception of greater amount of solar radiation. These results are supported by Singh and Narang (1988).

Differences among cultivars for PAR interception were significant at different growth stages except at 120 DAS (Table 2). At all growth stages, cultivar NRCHB 601 maintained its superiority than rest of the cultivars whereas cultivar NPJ 79 intercepted lowest PAR at different growth stages except at 60 DAS where RLM 619 and MLM 19 intercepted lowest PAR than NPJ 79. At 30 DAS, PAR interception by PBR 210, PBR 91, RL 1359, NRCDR 2 and Varuna was similar to NRCHB 601 (30.4%). PAR interception by PLM 2 was significantly lower than NRCHB 601. Cultivars MLM 19, PBR 357, Pusa Bold, RLC 1 and ELM 123 intercepted similar PAR to that of NPJ 79.

At 60 DAS, cultivars PBR 210, PBR 91, RL 1359, PBR 357, NRCDR 2, Varuna and PLM 2 intercepted similar PAR with that of NRCHB 601 (82.0%). At this growth stage, PAR interception by the cultivars viz. MLM 19, NPJ 79, ELM 123, RLC 1, Pusa Bold and Varuna were at par with RLM 619 which intercepted lowest PAR (72.0%). At 90 DAS, PAR intercepted by PBR 210, PBR 91, RL 1359, PBR 357, NRCDR 2 and Varuna was similar to that intercepted by NRCHB 601 (88.4%). Cultivars Pusa Bold, ELM 123, PLM 2, RLM 619, MLM 19 and RLC 1 intercepted lower PAR and were at par with NPJ 79 (78.2%). Interaction of different doses of phosphorus with cultivars showed inconspicuous response to PAR interception at all the growth stages.

SPAD values for leaf chlorophyll content

A perusal of data of leaf chlorophyll content measured with SPAD (Minolta 502) revealed marginal reduction in SPAD values at 90 (40.7) and 120 DAS growth stages (40.3) in comparison to that recorded at 60 DAS (41.7) and 30 DAS (41.2) growth stages (Table 3). Application of phosphorus resulted in consistent increase in leaf chlorophyll content at all growth stages, the differences between doses of phosphorus however, were inconspicuous (Table 3). Sah *et al.,* (2006) also reported inconspicuous increase in leaf chlorophyll content with increasing phosphorus application from 20 to 40 kg/ha of P_2O_5.

Table.1 Influence of doses of phosphorus and cultivars on leaf area index of Indian mustard at different growth stages

Treatment	**Days after sowing**			
	30	**60**	**90**	**120**
Phosphorus (kg P_2O_5/ha)				
0	0.20	1.76	3.06	1.14
15	0.25	1.98	3.31	1.33
30	0.28	2.17	3.53	1.58
LSD (p=0.05)	**0.01**	**0.09**	**0.05**	**0.09**
Cultivar				
RLC 1	0.25	1.88	3.12	1.32
PBR 210	0.26	2.11	3.54	1.39
PBR 91	0.26	2.17	3.65	1.45
RLM 619	0.22	1.93	3.23	1.34
RL 1359	0.25	1.94	3.24	1.41
PBR 357	0.26	1.80	2.99	1.35
ELM 123	0.23	1.94	3.25	1.22
NRCDR 2	0.24	2.06	3.47	1.51
NRCHB 601	0.28	2.20	3.66	1.59
Pusa Bold	0.24	1.99	3.33	1.27
Varuna	0.24	2.07	3.46	1.41
MLM 19	0.24	1.84	3.07	1.21
NPJ 79	0.21	1.73	2.97	1.20
PLM 2	0.25	1.90	3.29	1.22
LSD (p=0.05)	**0.03**	**0.16**	**0.31**	**0.14**

Table.2 Influence of doses of phosphorus and cultivars of Indian mustard on interception of photosynthetically active radiation (%) at different growth stages

Treatment	**Days after sowing**			
	30	**60**	**90**	**120**
Phosphorus (kg P_2O_5/ha)				
0	24.1	73.4	79.3	74.5
15	27.0	77.2	83.4	76.8
30	28.0	80.8	86.9	81.7
LSD (p=0.05)	**NS**	**1.6**	**3.0**	**4.3**
Cultivar				
RLC 1	25.6	75.9	81.9	77.6
PBR 210	27.2	79.4	84.3	76.1
PBR 91	27.3	79.9	84.7	75.1
RLM 619	23.9	72.0	81.9	78.6
RL 1359	27.5	79.4	85.5	79.3
PBR 357	25.1	77.6	85.1	79.5
ELM 123	26.1	75.5	81.0	79.8
NRCDR 2	28.2	79.3	86.4	81.5
NRCHB 601	30.4	82.0	88.4	81.9
Pusa Bold	25.4	76.3	79.3	79.8
Varuna	27.6	77.4	85.2	74.9
MLM 19	24.9	72.1	81.3	75.8
NPJ 79	23.0	74.4	78.2	72.7
PLM 2	27.0	78.8	81.8	75.8
LSD (p=0.05)	**3.2**	**5.6**	**5.8**	**NS**

Table.3 SPAD values of Indian mustard as influenced by doses of phosphorus and cultivars

Treatment	**Days after sowing**			
	30	**60**	**90**	**120**
Phosphorus (kg P_2O_5/ha)				
0	40.6	41.0	40.0	39.7
15	41.3	41.9	41.0	40.3
30	41.6	42.2	41.0	40.8
LSD (p=0.05)	**NS**	**NS**	**NS**	**NS**
Cultivar				
RLC 1	40.6	41.1	39.7	39.5
PBR 210	42.2	42.8	40.9	40.6
PBR 91	40.6	41.6	40.8	40.7
RLM 619	40.3	40.7	39.9	40.7
RL 1359	40.0	40.6	39.8	39.9
PBR 357	41.3	41.6	39.0	39.3
ELM 123	39.8	40.4	38.6	37.6
NRCDR 2	42.6	42.2	42.4	41.5
NRCHB 601	43.3	43.9	41.8	41.9
Pusa Bold	41.0	41.7	42.2	40.9
Varuna	41.2	42.0	41.5	40.8
MLM 19	40.1	41.9	40.6	41.0
NPJ 79	40.9	41.3	40.6	39.8
PLM 2	42.0	42.2	41.3	40.7
LSD (p=0.05)	**1.4**	**1.7**	**1.7**	**1.8**

There were significant differences in SPAD values among cultivars for leaf chlorophyll content at all the growth stages (Table 3). Cultivar NRCHB 601 registered highest SPAD values at all growth stages except at 90 DAS where NRCDR 2 resulted in highest chlorophyll content. Cultivar ELM 123 registered lowest SPAD values in all growth stages of crop. At 30 and 60 DAS, cultivars PBR 210, NRCDR 2 and PLM 2 were at par with NRCHB 601 (43.3, 43.9). Cultivar ELM 123 (39.8) registered significantly lower SPAD values than PBR 357, PLM 2, PBR 210, NRCDR 2 and NRCHB 601 at 30 DAS and PLM 2, NRCDR 2, PBR 210 and NRCHB 601 at 60 DAS. At 90 DAS, cultivars PBR 210, PBR 91, NRCHB 601, Pusa Bold, Varuna and PLM 2 were at par with NRCDR 2 (42.4) whereas cultivars RLC 1, RLM 619, RL 1359 and PBR 357 were at par with lowest SPAD values depicting cultivar ELM 123 (38.6). At 120 DAS growth stage, cultivars PBR 210, PBR 91, RLM 619, NRCDR 2, PLM 2, Pusa Bold, Varuna and MLM 19 registered similar SPAD values to that of NRCHB 601 (41.9). Cultivar PBR 357 (39.3) was at par with ELM 123 (37.6) and registered significantly lowers SPAD values than rest of the cultivars.

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