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Effect of nitrogen on growth, yield and quality of Indian mustard (*Brassica juncea* L.) genotypes

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Abstract
The field experiment entitled "Effect of nitrogen on growth, yield and quality of Indian mustard (*Brassica juncea* L.) genotypes" was conducted at Sanskriti University, Mathura, during the rabi season of 2018-19 on loamy sand, neutral in reaction, low in available N, rich in available P and K soil. The study was conducted in split plot design in three replications with four doses of nitrogen (0, 50, 100 and 150 kg/ha) in the main plots and five genotypes (RLC 1, RLC 11, RLC 12, PBR 210 and PBR 91) in the sub plots. Application of N significantly increased plant height, dry matter accumulation (DMA), leaf area index (LAI), photosynthetically active radiation (PAR) interception and chlorophyll content up to 100 kg/ha though such an increase, except plant height continued upto 150 kg/ha of N. Nitrogen application delayed initiation of flowering and significantly increased number of the secondary branches and siliquae per plant and, seeds per siliqua over control. Seed yield increased by 65.7 and 12.0 per cent with 100 kg/ha of N over control and 50 kg/ha of N, respectively. There was consistent reduction in seed oil content and significant increase in oil yield with N application of 50 kg/ha over control. Nitrogen, protein and linoleic acid content increased with increase in N levels. Among genotypes, PBR 91 and PBR 210 exhibited significantly better growth in terms of plant height, DMA and LAI with higher PAR as compared to RLC 11 and RLC. RLC 12 produced significant higher number of primary and secondary branches per plant, RLC 11 produced higher number of seeds per siliqua. Genotypes PBR 91, RLC 1 and PBR 210 registered significantly higher 1000-seed weight than RLC 11 and RLC 12. Differences in seed yield among genotypes were non-significant. Genotype RLC 11 registered significantly higher oil content but lowest seed protein content. Genotype RLC 12 contained significantly higher seed protein content than rest of the genotypes.

Keywords: Indian mustard, nitrogen dose, growth, yield, quality, N uptake

Introduction
Among various oilseed crops grown in India, rapeseed-mustard group of crops (Brassica spp., Family Brassicaceae) comprising Indian rape (toria), Indian mustard (raya), oilseed rape (Gobhi Sarson), Ethopian mustard (African sarson), yellow sarson, brown sarson and taramira, are next to soybean in terms of area and production. Cultivation of these crops in 28 states of the country under diverse agro-ecological situations over an area of 7.49 million hectares to produce 6.7 million tonnes signifies its importance in vegetable oil scenario of the country. Rapeseed-mustard group of crops occupies 33.8 per cent of total cultivated area under oilseeds (27.2 mha) and contributes 16 percent to total production of oilseeds (32.5 mt) in the country. Among these Brassica species, Indian mustard (*Brassica juncea* L. Czern & Coss) with a share of about 80 per cent in area and production, occupies prominent position in India.

Crop production largely depends on cultivation of high yielding cultivars and need based application of nutrients. Nitrogen (N) is the most important nutrient, and being a constituent of protoplasm and protein, it is involved in several metabolic processes that strongly influence growth, productivity and quality of crops (Reddy and Reddy 1998, Kumar *et al*. 2000) [1, 2]. The N fertilizer application accounts for significant crop production cost. Rapeseed-mustard group of crops have relatively high demand for N than many other crops owing to larger N content in seeds and plant tissues (Laine *et al*. 1993, Pasricha and Tandon 1993, Malagoli *et al* 2005) [3, 4, 5]. Yield increases in Indian mustard at various locations in India have been reported with application of N as high as 150 kg/ha or more (Singh and Rathi 1984, Tomar *et al* 1997, Deekshitulu *et al* 1998, Singh and Brar 1999, Singh *et al*. 2010) [8]. Brassicas are known to remove higher amount of N until flowering with relatively lower amount taken up during reproductive growth phase (Rathke *et al* 2006). Poor translocation of N from vegetative parts to seed during reproductive growth results in low nitrogen use efficiency. A significant part of the unused N is lost to environment causing pollution and contamination of water bodies

(Malagoli *et al*. 2005) [5] or gets converted to greenhouse gases such as oxides of N. Increasing N application also reduces oil content (Singh *et al*. 1994, Dubey *et al*. 1994, Singh and Singh 2005 and Singh *et al*. 2008) [8, 14, 12, 13]. Since N fertilizers are costly, poor NUE is of great concern and therefore, attempts are needed to improve the contribution of applied N to production of grain and this approach will reduce the environmental and production costs in agriculture. Differences in N concentration in various plant parts of oilseed rape (*Brassica napus* L.) suggest that N uptake and distribution is an inherited character (Grami and La Croix 1977) [16]. Spring oilseed rape cultivars producing lowest yields at lowest level of N application generally responded more markedly to increased N application rates than cultivars with higher yield at high N application (Yau and Thurling 1987a, b) [17-18].

The quality of oil primarily depends on its fatty acid composition. Traditional cultivars of rapeseed-mustard contain high proportion of long chain fatty acids such as eicosenoic and erucic acid (more than 45%) and low proportion of oleic acid (15-20%) in oil. These long chain fatty acids are reported to cause thickening of arteries and increase blood cholesterol leading to heart ailments in human beings (Zhao *et al*. 1993) [19]. Traditional cultivars of rapeseed-mustard also contain high levels of sulphur rich glucosinolates (more than 100 μ mole/g) in defatted seed meal which is used as a protein rich feed for dairy animals and birds. Such a high level of glucosinolates in seed meal leads to reduced appetite and reproduction and, increased thyroid associated problems in animals.

Materials and Methods

The field experiment was conducted at the Agronomical Experimental Site of Sanskriti University, Mathura (U.P.), India during rabi season of 2018-19. Mathura is characterized by Sub-tropical, Humid type of climate with hot and dry summer during April to June followed by hot and humid period during July to September and cold winter during December and January. The mean maximum and minimum temperatures show considerable variations during different months of the year. Temperature often exceeds 38oC during summer and sometimes touches 45oC with dry spells during May and June. Minimum temperature falls below 0.5oC with some frosty spells during the winter months of December and January. The average annual rainfall of the Mathura is 650 mm, about three-fourth of which is contributed by the south-west monsoon during July to September. Winter rains received in the months of December, January and February are scanty. The soil texture of experimental plot was loamy sand with pH of 7.60 which was slightly alkaline in nature, EC was 0.15, organic carbon in the plot was 0.24% and the initial N: P_2O_5: K_2O was 206 kg N/ha: 26.2 kg P_2O_5/ha: 150.5 kg K_2O/ha respectively. In addition to basal application of recommended dose of phosphorus and potassium, 50 per cent of N as per treatments was also applied at time of field preparation before last planking. The remaining dose of N as per treatments was applied after first irrigation. Nitrogen, phosphorus and potassium were applied through urea (46% N), single super phosphate (16% P2O5) and muriate of potash (60% K2O), respectively.

The experiment was laid out in split plot design with 4 doses of nitrogen that were 0, 50, 100 and 150 kg N/ha in the main plots and 5 genotypes in the sub plots were RLC 1, RLC 11, RLC 12, PBR 210 and PBR 91. Treatments were replicated thrice. The test genotypes RLC 1, RLC 11, RLC 12 (quality oil/seed meal) and PBR 210 and PBR 91 (conventional) were sown on November 16, 2011 with manually operated seed drill at row spacing of 30 cm using seed rate of 3.75 kg/ha.

Plants growth parameters such as emergence count, plant height, dry matter accumulation, leaf area index (LAI) and photosynthetically Active Radiation (PAR) were observed over the period of time at 30, 60, 90 and 120 DAS. The average of 5 plants were considered for final observation for all growth parameters. Yield attributes such as Number of siliquae, Number of seeds per silique, 1000-Seed weight, seed yield and stover yield were observed individually from each plots after harvest. Nitrogen uptake in seed and straw was estimated using modified micro-Kjeldahl method proposed by Subbiah and Asija (1956). Seed quality analysis such as Oil content in seed was determined with NIRS (Model FOSS 6500) by using non-destructive method of oil estimation as suggested by Alexander *et al*. (1967) [21], Oil yield was calculated by multiplying the oil content in the seed sample of each treatment with its respective seed yield and expressed in kg per ha, Protein content in seed was determined directly by NIRS (Model FOSS 6500) using mustard equation, Protein yield under each treatment was obtained by multiplying the seed protein content with seed yield of that particular treatment, Fatty acids in oil were trans-esterified and analyzed by gas liquid chromatography (GLC) using standard method of trans-esterification developed by Appleqvist (1968) [22] and Glucosinolates in the de-oiled seed meal i.e. in seed after oil extraction were estimated non-destructively on NIRS (Model Foss 6500).

Results and Discussion

The result of different genotypes and different doses of nitrogen on growth characteristics such as emergence count, plant height, dry matter accumulation, leaf area index (LAI) and photosynthetically Active Radiation (PAR) was found significant and given in table 1 and it was observed that application of 150 kg N/ha produced taller plants and maximum dry matter accumulation, LAI and PAR which was at par with 100 kg N/ha, among genotypes PBR 210 and PBR 91 produced taller plant, maximum dry matter accumulation and LAI than any other genotypes. But in case of PAR the maximum was recorded with genotypes PBR 210, PBR 91 and RLC 12 which were statistically at par with each other. This results are in tally with that of Kumbhare *et al*. (2007) [23], Kumar *et al*. (1997) [24], Dubey *et al*. (1992) [13] and Sandhu (2010) [25]

The key factors of a crop's eventual yield are yield characteristics such as Number of siliquae, Number of seeds per silique, 1000-Seed weight, seed yield and stover yield was found significant and given in table 2. Increase in dose of N up to 150 kg/ha increased the number of siliquae on main shoot as well as the total number of siliquae per plant followed by 100 kg N/ha, this results are in tally with Kumar and Yadav (2007) [26]. All the test genotypes produced statistically similar number of siliquae on main shoot as well as the total number of siliquae per plant. Number of seeds per siliqua increased with application of N up to 100 kg/ha followed by application 150 kg N/ha. Genotype RLC 11 produced significantly higher number of seeds per siliqua than rest of the test genotypes *viz*. RLC 1, RLC 12, PBR 210 and PBR 91 which were statistically at par with each other. Application of 150 kg N/ha produced highest 1000 grain weight which is at par with 100 kg N/ha. Genotype PBR 91 registered the highest 1000 seed weight) and RLC 12 produced the lowest 1000 seed weight. Application of 100 kg/ha of N increased the seed yield which was at par with 150 kg N/ha. All the test genotypes produced statistically similar seed yields. Genotype RLC 11 produced the lowest seed yield, whereas, the highest seed yield was produced by PBR 91. This results are in tally with Yadav *et al*. (2007) [27] and Panda *et al*. (2004) [28].

Interaction effect of nitrogen and genotypes on seed yield was significant and presented in table 3. Seed yield increased with application of N up to 100 kg/ha in case of RLC 1 and RLC 12, whereas the increasing trend continued up to 150 kg/ha of N in RLC 11, PBR 210 and PBR 91. Genotype PBR 210 responded most favourably to N application as is evident from the fact that it produced lowest seed yield (1098 kg/ha) in the absence of applied N and highest (102% higher) seed yield (2217 kg/ha) with application of highest dose of N i.e. 150 kg/ha. Application of 100 kg/ha of N increased the seed yield by 41.1% in RLC 12, 47.3% in RLC 1, 76.7% in PBR 91, 77.8% in RLC 11 and 96.4% in PBR 210 over without application of N. Similarly increase in seed yield with 100 kg over 50 kg/ha of N was 4.1% in PBR 91, 11.0% in RLC 1, 14.4% in PBR 210, 15.1% in RLC 11 and 16.2% in RLC 12.

The result of different genotypes and different doses of nitrogen on quality of seeds such as Oil content, Oil yield, protein content, Fatty acid composition of oil and Glucosinolate content in deoiled seed meal are presented in table 4. The oil content decreased with each increasing dose of N up to the highest level. Application of 150 kg/ha of N caused significant reduction in oil content (36.9%) over 100 kg/ha (38.2%) of N. Genotype RLC 11 (40.3%) registered significantly higher and RLC 1 (36.7%) significantly lower oil content than rest of the test genotypes. This results are in tally with Singh and Singh (2005) [14] and Singh *et al*. (2008) [15]. Application of 100 kg/ha of N increased oil yield by 8.8 per cent over 50 kg N/ha and by 59.4 per cent over control. Differences in oil yield among genotypes were also significant. Genotypes PBR, RLC 11 and PBR 210 produced statistically similar oil yields and out yielded RLC 1 by significant margin this result is in tally with Shukla and Kumar (1994) [29]. Increase in dose of N up to 150 kg/ha resulted in consistent increase in seed protein content followed by application of 100 kg N/ha. This results are in tally with Ghatak *et al*. (1992). Genotype RLC 12 contained significantly higher protein content (24.4%) than all other genotypes. Genotypes RLC 1, PBR 91 and PBR 210 contained statistically similar (23.3%) but significantly higher seed protein than RLC 11 (22.3%). Nitrogen application failed to markedly influence the fatty acid composition of oil except linoleic acid. Linoleic acid increased with N application up to 150 kg/ha and such an increase with 150 kg/ha (26.93%) over 50 kg/ha (24.71%) and 100 kg/ha (26.13%) over control (23.96%). Similarly, application of N up to 150 kg/ha resulted in consistent increase in palmitic acid (3.95-4.17%) and linolenic acid (19.57- 19.89%) content, whereas, stearic acid and eicosenoic acid increased up to 100 kg /ha. Oleic acid (25.17-24.17%) and erucic acid (23.31-21.09%) decreased consistently with increasing N application up to the highest dose. Differences among genotypes for various fatty acids except palmitic acid (3.98- 4.31%) were significant. Oleic acid content in RLC 1 (40.12%) and RLC 12 (40.2%) were significantly higher than RLC 11, PBR 210 and PBR 91 (14.70-15.82%). Genotype RLC 12 registered significantly higher linolenic acid (21.28%) and RLC 1 registered significantly higher linoleic acid (32.74%) than rest of the genotypes this result is in tally with Siddiqui and Mohammad (2004) [30].

The result of different genotypes and different doses of nitrogen on nitrogen content and nitrogen uptake are given in table 5. N application significantly increased the N concentration up to 100 kg N/ha. Significant differences were recorded among genotypes for N concentration at all the growth stages. Genotype PBR 210 contained highest N concentration at 30, 60 (except in stems) and 90 DAS. At 60 (stems) and 120 DAS, PBR 91 contained highest N concentration. Both PBR 210 and PBR 91 contained statistically similar N concentration at all growth stages and in all plant parts except at 30 DAS. Nitrogen concentration in seeds of RLC 12 was significantly higher than all other genotypes. Both RLC 1 and RLC 11 contained statistically similar N concentration in all growth stages which were significantly lower than N concentration in PBR 210 and PBR 91. This result is in tally with Singh and Prasad (2003b). Increase in N uptake was significant up to 100 kg/ha over lower doses of N, significant increase in N uptake was observed up to 150 kg/ha of applied N. Genotype PBR 210 accumulated highest N uptake whereas PBR 91 accumulated highest N uptake in leaves and in seeds at harvest. Genotype PBR 210 and PBR 91 accumulated statistically similar N uptake at all growth stages. This result is in tally with Ahmad *et al*. (2008) [32].

Table 1: plant height (cm), dry matter accumulation (DM), LAI and PAR of Indian mustard as influenced by doses of nitrogen and genotypes.

Treatments	Plant Height (cm)				DM (kg/ha)				LAI				PAR			
	Days After Sowing (DAS)															
	30	60	90	120	30	60	90	120	30	60	90	120	30	60	90	120
Doses of nitrogen (kg/ha)																
0	12.4	48.4	149.1	180	74	673	4650	7052	0.24	1.3	2.3	1.21	20.6	61	82.1	68.2
50	13.5	53	173.9	198.2	84	852	5380	7714	0.26	2.07	3.65	1.76	23.8	76.1	90.9	81
100	14.3	54	179	200.2	103	1013	6748	8545	0.34	2.62	4.55	2.02	29.7	84.4	94.6	85.2
150	14.5	53	178.5	203.7	97	1009	7677	9240	0.35	2.96	5.47	2.19	30.4	85.9	96.4	87.4
CD (p=0.05)	0.8	1.9	5.3	7.8	19	172	532	659	0.06	0.31	0.6	0.15	4.5	3.8	2.2	3.9
Genotype																
RLC 1	14.7	46.1	169.8	195.3	86	875	5627	8073	0.27	2.02	3.83	1.56	25.7	75.9	89.6	78.4
RLC 11	11.2	58.2	170.2	194.8	80	740	5622	7911	0.3	2.05	3.88	1.71	24.8	75.5	90.3	79.1
RLC 12	12.7	52.1	166	194.9	72	906	5686	7880	0.29	2.2	4.06	1.79	25.5	75.2	92	80.3
PBR 210	14.8	52.3	173.4	192.9	110	1001	6877	8409	0.32	2.25	4.08	1.91	25.8	75.6	90.1	83.4
PBR 91	15.1	51.8	171.1	199.7	99	913	6758	8416	0.33	2.66	4.11	2.01	29	82.1	93	81.1
CD (p=0.05)	0.6	4.3	3.7	NS	20	159	835	364	NS	0.34	NS	0.25	NS	3.6	NS	NS

DM= Dry Matter Accumulation, LAI= Leaf Area Index, PAR= Photosynthetically Active Radiation.

Table 2: Number of siliquae, Number of seeds per silique, 1000-Seed weight, seed yield and stover yield of Indian mustard as influenced by doses of nitrogen and genotypes

Treatments	Number of siliquae per plant	Number of seeds per silique	1000-Seed weight (g)	seed yield (kg/ha)	stover yield (kg/ha)
Doses of nitrogen (kg/ha)					
0	301	11.8	3.51	1271	4917
50	354	13.2	3.61	1881	6924
100	368	13.4	3.69	2106	7916
150	383	13.2	3.75	2102	8137
CD (p=0.05)	32	1	NS	211	611
Genotypes					
RLC 1	369	12.5	3.88	1826	6785
RLC 11	357	15	3.4	1800	6332
RLC 12	372	12.6	2.9	1833	7119
PBR 210	321	12.2	3.89	1840	7191
PBR 91	338	12.2	4.14	1902	7452
CD (p=0.05)	NS	0.8	0.15	NS	338

Table 3: Interaction effect of nitrogen and genotypes on seed yield of Indian mustard as influenced by doses of nitrogen and genotypes

Doses of nitrogen (kg/ha)	Genotypes				
	RLC 1	RLC 11	RLC 12	PBR 210	PBR 91
0	1400	1177	1463	1098	1217
50	1858	1818	1777	1886	2066
100	2062	2093	2065	2157	2151
150	1984	2109	2025	2217	2175
CD (p=0.05)	213				

Table 4: Oil content, Oil yield, protein content, Fatty acid composition of oil and Glucosinolate content in deoiled seed meal of Indian mustard as influenced by doses of nitrogen and genotypes

Treatments	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Fatty acid composition (%)				Glucosinolate content (µ mole/ 100g defatted meal)
				palmitic	stearic	oleic	linoleic	
Doses of nitrogen								
0	39.9	505.5	22.4	3.95	1.06	25.51	23.96	60.06
50	39.4	740.5	22.7	4.15	1.11	25.31	24.71	63.20
100	38.2	805.7	23.7	4.02	1.13	24.60	26.13	62.37
150	36.9	776.8	24.7	4.17	1.11	24.17	26.93	61.91
CD (p=0.05)	1.0	901	0.7	NS	NS	NS	1.56	NS
Genotypes								
RLC 1	36.7	668.5	23.4	3.98	1.57	40.12	32.74	75.28
RLC 11	40.3	721.1	22.3	4.28	0.97	15.82	24.23	26.84
RLC 12	37.8	689.5	24.4	4.31	1.22	40.20	29.43	44.11
PBR 210	39.1	714.4	23.4	4.00	1.01	14.70	19.80	80.89
PBR 91	39.2	742.1	23.4	3.78	0.73	14.96	21.57	8229
CD (p=0.05)	0.9	43.8	0.8	NS	0.32	2.31	1.54	1.66

Table 5: Effect of nitrogen application and genotypes on the nitrogen uptake (kg/ha) by different plant parts at different growth stages of Indian mustard.

Treatments	Nitrogen uptake in seed (kg/ha)	Nitrogen uptake in stover (kg/ha)	Total nitrogen uptake (kg/ha)
Doses of nitrogen			
0	45.85	24.29	70.14
50	68.44	36.39	104.83
100	79.93	49.05	128.98
150	83.06	57.97	141.03
CD (p=0.05)	9.34	4.48	12.43
Genotypes			
RLC 1	68.59	37.92	106.51
RLC 11	64.60	39.94	99.55
RLC 12	71.93	40.57	112.50
PBR 210	69.58	49.41	118.99
PBR 91	71.89	49.76	118.68
CD (p=0.05)	NS	4.08	7.71

Conclusion

Nitrogen application favourably influenced the growth, yield attributes, seed yield and oil yield of Indian mustard up to 100 kg/ha nitrogen content and uptake at all the growth stages including seed and stover at harvest, stover yield and protein yield increased up to 150 kg/ha of N. Increase in seed, stover and protein yields with application of N up to 100 kg/ha and oil yield up to 50 kg/ha of N was significant. Differences among genotypes for seed yield and protein yield were non significant. Genotypes RLC 11, PBR 210 and PBR 91 produced significantly higher oil yield as compared to RLC 1. Genotypes RLC 12 and RLC 1 with low erucic acid content in oil qualify as quality mustard genotypes. Similarly, RLC 11 and RLC 12 with low glucosinolate content offer better quality of seed meal. The study indicates that under same agro-climatic conditions, quality mustard genotypes produced similar seed yields and required similar dose of N to that of conventional mustard genotypes.

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