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Response of Indian mustard (*Brassica juncea*) germplasm grown under low nitrogen conditions

SURENDER SINGH[1], RASHMI YADAV[2]*, NALEENI RAMAWAT[1]*, J C RANA[2], H L RAIGER[2], RAKESH BHARDWAJ[2], J K RANJAN[3], HARINDER VISHWAKARMA[2] and B L MEENA[2]

Amity Institute of Organic Agriculture, Amity University, Noida, Uttar Pradesh 201 313, India

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ABSTRACT

Brassicas are highly responsive to N application and require relatively high rates of mineral N fertilizers for optimum seed yields. Present study was carried out at the Experimental Farm of ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi, India during 2015–16 and 2016–17. Forty five accessions of Indian mustard were tested under three different nitrogen fertilizer rates i.e. Control (0 kg/ha), moderate (40 kg/ha) and optimal (80 kg/ha) to determine the performance of Indian mustard (*Brassica juncea* (L.) Czern.). The results showed that with increase in nitrogen fertilizer rate seed test weight, oil content, stover yield, seed nitrogen uptake, total nitrogen uptake, seed uptake efficiency, nitrogen use efficiency and seed yield also increased. However, some accessions performed better under low nitrogen condition. For example, IC267538, IC311819 showed more plant height under zero N-fertilizer application as compared to high N dose. Out of 45 accessions, 36 showed more no. of branches at zero N dose. Accession IC571402 was the best performer under zero N dose as it showed superiority for 8 different traits, viz. no. of branches/plant, test weight, oil content, N% in plants, N% in seed, total N%, grain uptake efficiency and Nitrogen Harvest Index. Similarly, accessions IC424415 and IC571654 performed well for 7 different traits. A set of *Brassica juncea* germplasm which performed better under low N fertilizer conditions were identified. These nitrogen use efficient accessions would be useful for breeders/researchers to develop varieties of mustard for low nitrogen usages.

Keywords: *Brassica juncea* L., Genotype × nitrogen interactions, Mustard, Nitrogen use efficiency, Yield improvement

Rapeseed and mustard is second biggest oilseed crop out of all other nine oilseeds grown in India. India contributes about 30% in area and 20% production to world, individually of oilseed brassicas (National Food Security Mission 2018). According to Food and Agriculture Organization statistics (FAOSTAT 2018), the production of rapeseed stands second after soybeans around the world. Globally, the production of rapeseed was assessed to be 75 million tonnes (MT) during 2017–18. India produces 7.92 MT on an area of 6.07 MH with a productivity of 1304 kg/ha while Uttar Pradesh leads by producing 0.84 MT on 0.66 MH with a productivity of 1080 Kg/ha .

Brassica is considered as heavy feeder of nitrogen as accessible nitrogen is the most restricting source (Rossato *et al.* 2001) thus, application of nitrogen is an essential to harvest good crop (Rathke and Schuster 2001, Abdallah *et al*. 2010). However, nitrogen requirement depends upon soil type, agronomic practices, timing, source and rate of nitrogen application, cultivars etc. (Kafkafi *et al.* 1998). High nitrogen efficiency may increase yield by influencing growth parameters such as number of branches per plant, number of pods per plant and number of siliques in main branch. Also, it increases the number and weight of pods, seeds and flowers per plant and overall crop assimilation (Wright *et al.* 1988 and Al-Barrak 2006). On the contrary, although high nitrogen application increases the yield but at the same time cost of Nitrogen fertilizer production is high (Rothstein 2007) and heavy application leads to environmental pollution (Goulding 2004). Therefore, using appropriate N rate and improving nitrogen use efficiency (NUE) to get higher production per unit area at lower N supply becomes very important. Further, the quantification of genotype and nitrogen interaction is crucial for better understanding of the genotypic responses to various N stress conditions. Here, we studied the performance of Indian mustard (*Brassica juncea* L.) germplasm under different nitrogen conditions for growth, yield contributing traits and N uptake.

Present address: [1]Amity Institute of Organic Agriculture, Amity University, Noida, Uttar Pradesh; [2]ICAR-National Bureau of Plant Genetic Resources, New Delhi; [3]ICAR-Indian Agricultural Research Institute, New Delhi. *Corresponding author e-mail: rashmi.yadav1@icar.gov.in, nramawat@amity.edu

MATERIALS AND METHODS

Plant Material and Field Trials: Under the study, 45 accessions (40 accessions of germplasm and 5 released varieties) of Indian mustard were evaluated for seed yield at high, moderate and low nitrogen supply during 2015–16 and 2016–17 at Experimental Farm, ICAR – National Bureau of Plant Genetic Resources, New Delhi, India located at 28°35'N latitude and 77°12'E longitude at an altitude of about 228.61 m amsl. The experimental soil was sandy loam in texture [67% sand, 14% silt and 19% clay (hydrometer method, Bouyoucos, 1962)] with 7.8 *p*H (1:2.5 soil : water, Jackson 1973), organic carbon 0.40% (Walkey and Black method, Jackson 1973). At the start of experiment, the values of soil sample were $KMnO_4$-oxidizable N 143.5 Kg/ha, 0.5 N $NaHCO_3$ extractable P 17.3 kg/ha (Olsen *et al.* 1956), 1.0 N NH_4OAc- exchangable K 223.5 kg/ha (Jackson 1973).

Three different nitrogen levels i.e. control = 0 Kg/ha (F1), moderate= 40 Kg/ha (F2) and optimal= 80 kg/ha (F3) were used in two factor randomized block design with three replications. The plant spacing was 60 cm × 10 cm and three rows of 3 m row length. Recommended agronomic practices were followed for growing the crop. The accessions were evaluated for 16 agronomic traits, viz. plant height (cm), number of branches per plant, number of siliques in main branch, 1000 seed weight (g), oil content (%), stover yield (q/ha), nitrogen content in plant (%), nitrogen content in seed (%), total nitrogen content (%), seed nitrogen uptake (N Kg/ha), stover nitrogen uptake (N Kg/ha), total nitrogen uptake (N Kg/ha), seed uptake efficiency, nitrogen harvest index, nitrogen uptake efficiency and seed yield (Kg/ha). The data was recorded as per minimal descriptors for *Brassica* spp.

Quality Analysis for Nitrogen content: Nitrogen content was determined by the Kjeldahl method with various modifications, accuracy was improved using Kjeltic Auto Analyser 2300, Scrubber unit with Exhaust manifold (Model 1013 from Tecator, Sweden) and Digestion system (Model 2020 from Tecator, Sweden). For nitrogen content analysis, an oven-dried sample of plant/seed/stover composite was milled to particle sizes of 0.2 mm or 0.5–1.0 g.

Estimation of Nitrogen Related Parameters: Seed nitrogen uptake was calculated on the basis of seed dry matter yield and nitrogen content in the seeds. Total Plant nitrogen uptake was calculated on the basis of plant dry matter yield and nitrogen content in the plant (%) while stover nitrogen yield was calculated as the product of stover dry matter yield and nitrogen content in the stover. Seed uptake efficiency at maturity was estimated as the sum of nitrogen in stover and seeds. The nitrogen harvest index (NHI) was estimated by dividing seed nitrogen yield to total nitrogen yield at maturity.

Nitrogen use efficiency (NUE) is defined as seed production per unit of nitrogen available in the soil and nitrogen uptake efficiency and nitrogen utilization efficiency were calculated according to Moll *et al*. (1982) as:

Nitrogen use efficiency = Seed yield / N_s, Nitrogen uptake efficiency $= N_t / N_s$, N utilization efficiency = Seed yield / N_t

where, N_s is the total nitrogen supply and N_t is the total nitrogen uptake (above ground) of a genotype at maturity. The nitrogen supply in the unfertilized control treatment was defined in each replication by the highest amount of total nitrogen taken up by a genotype at maturity. So, the total nitrogen supply (Ns) of the fertilized treatment was the sum of the highest amount of total nitrogen taken up by a genotype in unfertilized replications and the amount of nitrogen fertilizer. The N_s and N_t are expressed in the same units as the seed yield (Kg/ha). The relative contribution of nitrogen uptake and utilization efficiency to the total genetic variance in nitrogen use efficiency were calculated as described by Moll *et al.* (1982).

Statistical Analysis: Combined statistical analysis of variance (ANOVA) was done for the obtained data of two studied seasons after applying the assumptions of analysis of variance.

RESULTS AND DISUCUSSION

The performance of accessions under three different nitrogen fertilizer doses (0, 40 and 80 kg/ha) for all the traits were studied (Fig 1). The plant height ranged from 112.38-165.55 cm (N at 0 Kg/ha); 127.53-207.90 cm (N at 40 Kg/ha) and 131.28-195.53 cm at optimum N dose (80 kg/ha). We found that two accessions IC267538, IC311819 showed more plant height under 0 kg N-fertilizer application as compared to two higher N doses (Fig 1). Higher number of branches (6.65-14.9) was found under N at 0 kg/ha as compared to 7.30-11.38 and 7.38-11.30 N at 40 Kg/ha and N at 80 Kg/ha, respectively. There were 36 accessions out of 45 that produced more no. of branches at 0 kg N as compared to other two N doses. It revealed that under low N conditions some accessions produced more branches instead of increase in plant height (Fig 1). The no. of siliques on the main branch was in the range of 40.96-75.09, 56.05-79.73, 51.71–68.76 with 0, 40, and 80 kg/ha of N fertilizer doses, respectively. Accessions IC267693 and IC311819 produced higher no. of siliques under 0 kg N compared to higher doses. The 1000 seed weight ranged from 1.99 to 5.89 g at 0 kg N, 2.11 to 5.15 g at 40 kg N and 2.26 to 5.57 g at 80 N Kg/ha. Accessions, viz. IC265385, IC267693, IC296746, IC339953, IC401571, IC571402, IC571654 showed higher seed weight at 0 kg N as compared to high N fertilizer dose (Fig 1). The oil content ranged from 32.95–37.50% at 0 kg N while at 40 and 80 kg/ha N it was in the range of 29.43-37.59% and 31.83-37.61% respectively. Accessions such as IC267538, IC275106, IC335855, IC338494, IC339605, IC491209, IC538665, IC546946, IC571402, IC571669 performed well under control (0 N Kg/ha) conditions.

We found that effect of N dose has increased the grain yield in general. Under 0 kg N, the grain yield was in the range of 1296.00 (IC571629) to 3232.50 (IC338494) Kg/ha while at 40 N Kg/ha and 80 N Kg/ha the seed yield were in the range of 1482.39 (IC265385) to 3385.00 kg/ha (IC338494) and 1951.25 (RH-30) to 3517.5 (IC267693) Kg/ha. Similarly, there was an increase in stover yield as the N dose was increased. However, few accessions IC267538,

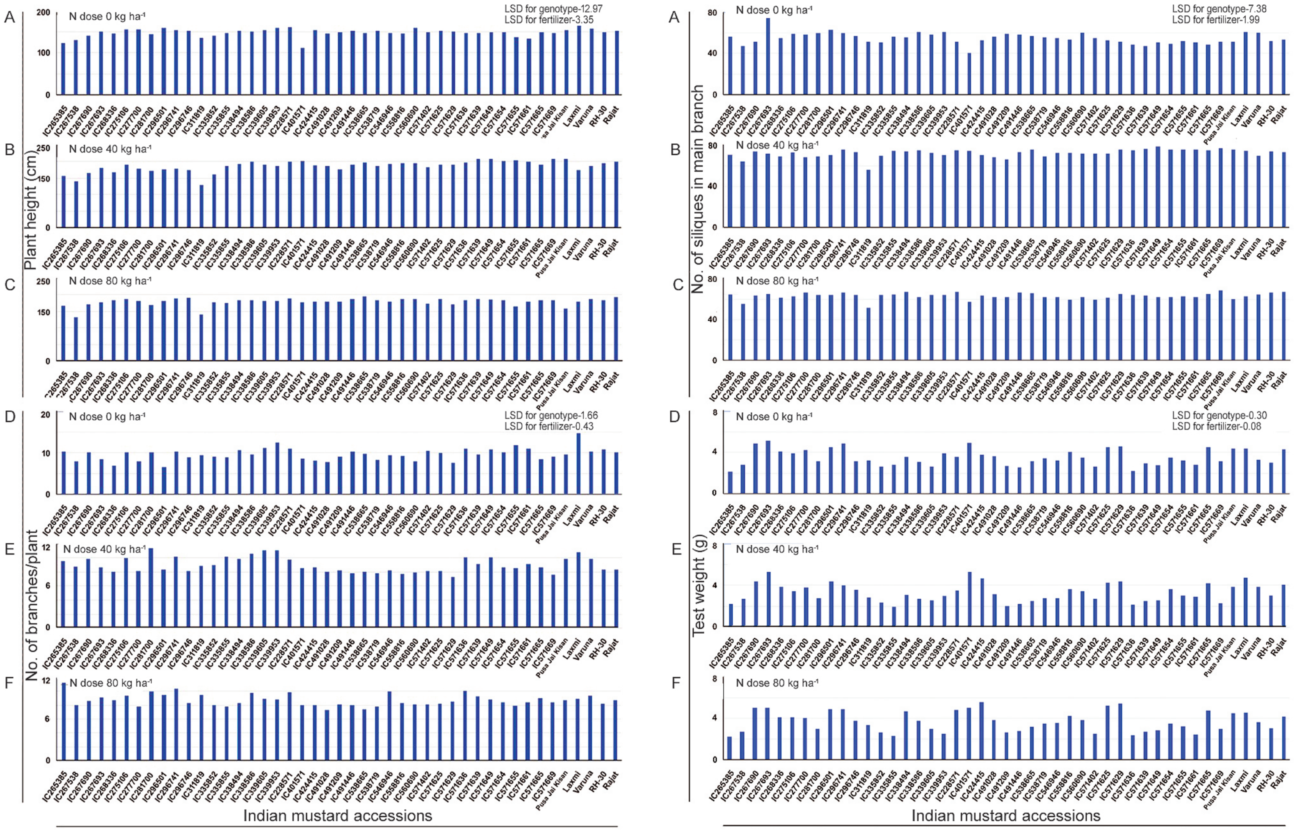

Fig 1 Plant height (cm); number of primary branches/plant; number of siliques on main branch) and test weight (g) in different accessions of Indian mustard germplasm at different nitrogen levels.

IC277700, IC296501, IC491209 and IC571669 performed better under 0 N Kg/ha as compared to higher doses. It is observed that if stover is not harvested in mustard as it is done in oliferous rapeseed, it is a dead sink for fertilized nutrients and assimilates that are left in the field, might lead to nitrogen leaching after harvest (Bouchet *et al.* 2016). The N% in seed revealed that out of 45 accessions 29 performed better under 0 N Kg/ha. Total N% present in the plant was ranged from 4.78-6.02% and 4.93-5.91% at 40 and 80 N Kg/ha fertilizer dosage respectively. Ten 10 accessions performed better under low N conditions (IC267690, IC267693, IC281700, IC424415, IC558816, IC571402, IC571629, IC571654, IC571655, IC571665) for trait total N% in plants. It is assumed that there is always a transfer of assimilates/nutrients from source (straw) to sink (grain) at the time of grain formation. In this study, it was reflected through the nitrogen uptake by grain and straw. Nitrogen Harvest Index (NHI) is an important criterion and directly associated with the grain yield. A total of 37 accessions (few most promising e.g. IC265385, IC267538, IC267690, IC267693, IC268336) out of 45 showed high NHI at 0 kg N as compared to higher N fertilizer doses.

While analysing the results across traits, it was observed that many accessions were found superior for multiple traits. Out of all the accessions IC571402 performed best for eight different traits, viz. no. of branches/plant, test weight, oil content, N% in plants, N% in seed, total N%, seed uptake efficiency and NHI at 0 kg N fertilizer dose. Similarly accession IC424415 for no. of branches/plant, N% in plants, N% in seed, Total N%, straw N uptake, seed uptake efficiency, NHI and IC571654 for no. of branches/plant, test weight, N% in plants, N% in seed, seed N uptake, straw N uptake, total N uptake. Accessions IC267693, IC338494 and IC546946 performed better for 6 different traits, 11 accessions IC267538, IC267690, IC311819, IC335855, IC339605, IC339953, IC401571, IC538665, IC571629, IC571655, IC571665 for 5 different traits and 6 accessions IC538719, IC560690, IC571625, IC571636, IC571639, and IC571649 for 4 different traits at 0 kg N (Table 1). We assumed that these accessions would be further utilized by breeders/researchers for yield enhancement of mustard under low nitrogen fertilizer usage.

It was observed that total nitrogen uptake was in the range of 87.30-208.38 under low N conditions, while it was 104.63-238.46 and 146.62–236.15 under 40 and 80 N Kg/ha N doses, respectively (Fig 2). Two accessions IC571654, IC571665 performed better for total N uptake at 0 N fertilizers as compared to high N dose. Seed uptake efficiency was in the range of 10.63–17.35, 9.93–16.81 and 11.88–17.41 at 0, 40 and 80 N Kg/ha of N fertilizer doses, respectively. A total of 36 accessions performed well under 0 N dose for trait grain uptake efficiency. Also, it was observed that NUE was increased as the N fertilizer doses increased from 0 to 40 and then to 80 N Kg/ha. It

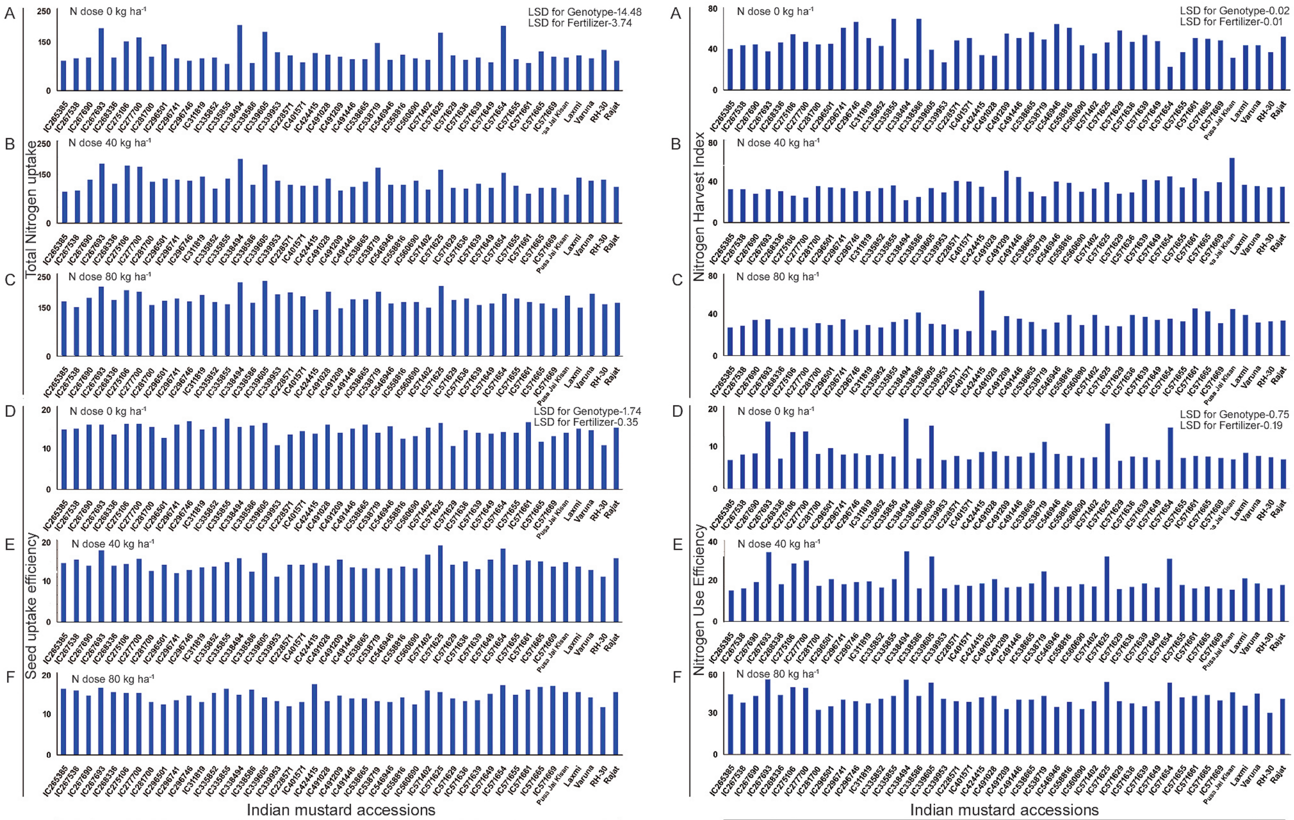

Fig 2 Total nitrogen uptake efficiency; Seed uptake efficiency; Nitrogen Harvest Index (NHI) and Nitrogen Use efficiency (NUE) in Indian mustard germplasm at different nitrogen levels. LSD stands for Least Significance Difference.

Table 1 *Brassica juncea* germplasm accessions showing superior for multiple trait under low N condition

Accession	Trait associated with	Total trait
IC571402	No. of branches/plant, test weight, oil content, N % in plants, N % in seed, Total N%, seed uptake efficiency, NHI	8
IC424415	No. of branches/plant, N % in plants, N % in seed, Total N%, Straw N uptake, seed uptake efficiency, NHI	7
IC571654	No. of branches/plant, test weight, N% in plants, N% in seed, Seed N uptake, Straw N uptake, Total N uptake	7
IC267693	Siliques on the main branch, test weight, N % in plant, N % in seed , Total N %, NHI	6
IC338494	No. of branches/plant, oil content, N % in plant, Straw N uptake, Seed uptake efficiency, NHI	6
IC546946	No. of branches/plant, oil content, N% in seed, Seed N uptake, Seed uptake efficiency, NHI	6
IC267538	Plant height, no. of branches/plant, oil content, seed uptake efficiency, NHI	5
IC267690	No. of branches/plant, N % in seed, total N %, seed uptake efficiency, NHI	5
IC311819	Plant height, no. of branches/plant, Siliques on the main branch, seed uptake efficiency, NHI	5
IC335855	No. of branches/plant, oil content, N % in seed, seed uptake efficiency, NHI	5
IC339605	No. of branches/plant, test weight, oil content, seed uptake efficiency, NHI	5
IC339953	No. of branches/plant, test weight, N % in plants, seed uptake efficiency, NHI	5
IC401571	No. of branches/plant, test weight, N % in seed, seed uptake efficiency, NHI	5
IC538665	No. of branches/plant, oil content, N% in seed, seed uptake efficiency, NHI	5
IC571629	N% in seed, Total N %, seed N uptake, seed uptake efficiency, NHI	5
IC571655	No. of branches/plant, N% in seed, Total N%, seed uptake efficiency, NHI	5
IC571665	N% in seed, Total N%, Seed N uptake, Total N uptake, NHI	5

shows that these accessions proved to leave less nitrogen in stover in the field after harvest and had a higher nitrogen use efficiency and nitrogen harvest index. Thus, they were better adapted to low nitrogen fertilizer conditions.

In mustard germplasm with such a significant differences for traits plant height, number of branches per plant, number of siliques in main branch, 1000 seed weight, stover yield and seed yield might be due to the differences in their genetic background (Yadav *et al*. 2018). On the other hand genetic and environment interaction also affect performance of accessions under various doses of nitrogen fertilizer (Khoshanazar *et al*. 2000, Kolte *et al.* 2000, Stringam *et al.* 2000). Certain cultivars may be sensitive to environmental factors while others may be tolerant, thus lead to variation in plant height, 1000 seed weight and number of siliques on main branch (Sana *et al.* 2003). Similar findings were also reported by Munir and McNeilly (1992), Hashem *et al*. (1998) and Om *et al.* (1999) among different mustard varieties.

We observed high variations for all the morphological and biochemical nitrogen related traits. Accessions such as IC571402, IC424415, IC571654, IC267693 and IC338494 performed better for multiple traits under low N conditions as compared to high N fertilizer doses. These accessions will used by breeders/researchers for developing varieties for low nitrogen use conditions not only to reduce the N fertilizer application cost but will also reduce the soil and water pollution.

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REFERENCES

Abdallah L D, Meuriot F, Etienne P Avice J C and Ourry A. 2010. Effect of mineral sulphur availability on nitrogen and sulphur uptake and remobilization during the vegetative growth of *Brassica napus* L. *Journal of Experimental Botany* **61**(10): 2635–46.

Al- Barrak K M. 2006. Irrigation interval and nitrogen level effects on growth and yield of canola (*Brassica napus* L.), *Scientific Journal of King Faisal University* (Basic and Applied Sciences) **7**(1): 87–103.

Bouchet A, Laperche A, Bussuel-Belaygue C, Snowdon R, Nesi N and Stahl A. 2016. Nitrogen use efficiency in rapeseed. A review, *Agronomy for Sustainable Development* **36**:38 Doi: 10.1007/s13593-016-0371-0.

Bouyocos G J. 1962. Hydrometer method improved for making particle size analyses of soils. *Agronomy journal* https://doi.org/10.2134/*agronj1962*.00021962005400050028x.

FAO STAT. 2018. FAO Crops. Food and Agriculture Organization of the United Nations. http://www.*fao.org/faostat/*en/#data/QC/visualize.

Goulding K W T. 2004. Minimising losses of nitrogen from UK agriculture. *Journal of Royal Agricultural Society of England* **165**: 1–11.

Jham G N, Moser B R and Shah S N. 2009. "Wild Brazilian mustard (*Brassica juncea*L.) seed oil methyl esters as biodiesel fuel," *JAOCS: Journal of the American Oil Chemists' Society* **86**(9): 917–26.

Hashem A, Majumdar M N A, Hamid A and Hossain M M.1998. Drought stress effects on seed yield, yield attributes, growth, cell membrane stability and gas exchange of synthesized *Brassica napus* L., *Journal of Agronomy and Crop Science*. **180**: 129–36.

Jackson M L.1973. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 498.

Kafkafi U, Yamaguchi I, Sugimoto Y and Inanaga S. 1998. Response of oilseed rape plant to low root temperature and Nitrate: Ammonium ratios. *Journal of Plant Nutrition* **21**(7): 1463–81.

Khoshanazar P R, Ahmadi M R and Ghanndha M R.2000. A study of adaptation and yield capacity of rapeseed (*Brassica napus* L.) cultivars and tines, *Iranian Journal of Science and Technology* **31**: 341–52.

Rathke G W, Behrens T and Diepenbrock W. 2006. Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassica napus* L.): a review. *Agriculture, Ecosystems and Environment* **117**(2-3): 80–108.

Kolte S J, Awasthi R P and Vishwanath R. 2000. Divya mustard: a useful source to create Alternaria black spot tolerant dwarf varieties of oilseed Brassica, *Plant Varieties and Seeds* **13**: 107–11.

Rathke G W and Schuster C. 2001.Yield and quality of winter oilseed rape related to nitrogen supply," in *Plant Nutrition: Food Security and Sustainability of Agro-Ecosystems Through Basic and Applied Research*, W J Horst (Eds) pp. 798–99, Kluwer Academic Publishers, Dordrecht, The Netherland,.

Rossato L, Laine P and Ourry A. 2001. Nitrogen storage and remobilization in *Brassica napus* L. during the growth cycle: nitrogen fluxes within the plant and changes in soluble protein patterns. *Journal of Experimental Botany* **52**(361): 1655–63.

Moll R H, Kamprath E J and Jackson W A. 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen- utilization. *Agronomy Journal* **74**: 562–64.

Munir M and McNeilly T. 1992. Comparison of variation in yield and yield components in forage and winter oilseed rape, *Pakistan Journal of Agricultural Research* **13**: 289–92.

Nanjundan J, Radhamani J, Thakur A K, Berliner J, Manjunatha C, Sindhu A, Aravind J and Songh K H.2020. Utilization of Rapeseed-Mustard Genetic Resources for Brassica Improvement: A Retrospective Approach. Brassica Improvement: Molecular, Genetics and Genomic Perspectives, *Springer Nature Switzerland*. https://doi.org/10.1007/978-3-030-34694-2_1.

National Food Security Mission. 2018. Present Status of Oilseed crops and vegetable oils in India. https://www.nfsm.gov.in/StatusPaper/NMOOP2018.pdf.

Om P, Das T K, Singh H B and Singh N.1999. Performance of three Brassica species as affected by time of sowing and nitrogen, I. Yield attributes and yield, Annals *of* Agricultural *Sciences* **20**: 448–54.

Rothstein S. 2007. Returning to our roots: making plant biology research relevant to future challenges in agriculture. *Plant Cell* **19**: 2695–99.

Sana M A, Ali M, Malik , Saleem M F and Rafiq M.2003. Comparative yield potential and oil contents of different canola cultivars (*Brassica napus* L.), *Pakistan Journal of Agronomy* **2**(1): 1–7.

Stringam G R, Degenhardt D F, Thalgarajah M R, Bansal V K and Hawklns G P.2002. Kelsey summer rape, *Canadian Journal of Plant Sci*ence **82**: 559–60.

Yadav R, Prasad L, Nanjundan J, Tewari A K, Singh P, Sandhu P S, Pant U, Avtar R, Radhamani J, Kumar S, Rao M and Rana J C.2018. Identification and evaluation of the Indian mustard genotypes for white rust and resistance and agronomic performance. *Indian Journal of Genetics and plant breeding* **78**(1): 81–89

Walkley A and Black A.1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method, *Soil Science* **37**(1): 29–38.

Wright G C, Smith C J and Woodroffe M R. 1988. The effect of irrigation and nitrogen fertilizer on rapeseed (*Brassica napus*) production in South- Eastern Australia, I. Growth and seed yield. *Irrigation Science*. **9**: 1–13.