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# Productivity and profitability of Indian mustard (*Brassica juncea* L.) genotypes as influenced by N and S fertilization under irrigated conditions of eastern Uttar Pradesh

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## Abstract

A field experiment was conducted with combinations of three nitrogen levels (90, 120 and 150 kg ha$^{-1}$) and two genotypes of Indian mustard (Pusa Bold and RH- 749) as main plot treatments and three sulphur levels (0, 25 and 50 kg ha$^{-1}$) as sub-plot treatments and replicated thricely in split-plot design during *Rabi* 2016-17. Yield attributes and yield parameters *viz.* siliquae on main shoot, siliquae plant$^{-1}$, siliqua length, seeds siliqua$^{-1}$, 1000-seed weight, seed yield and stover yield and quality parameters such as seed protein content, protein and oil yield were positively correlated with increasing rates of N and S up to 150 and 50 kg ha$^{-1}$, respectively. Similar trend was also observed in yield and quality of mustard genotypes. However, decrease in seed oil content was noticed with higher dose of N. Application of 120 and 150 kg N ha$^{-1}$ produced 6.0% and 14.1% higher seed and 8.7% and 14.1% higher stover yield, respectively over 90 kg N ha$^{-1}$. Similarly, application of 50 kg S ha$^{-1}$ recorded 1.2% and 7.2% higher seed yield over 25 kg S ha$^{-1}$ and control, respectively. Between the two genotypes, 'RH-749' produced distinctly higher seed (16.9 q ha$^{-1}$) and stover (57.8 q ha$^{-1}$) yield over 'Pusa Bold'. The maximum net returns and B:C ratio were obtained with 'RH-749' fertilized with 150 kg N and 25 kg S ha$^{-1}$.

***Keywords:*** *Genotypes, Indian mustard, nitrogen, productivity, sulphur.*

## Introduction

Expeditious population growth with improved standard of living and changing dietary habit has put immense pressure on Indian agriculture. To meet the food demand of the increased population, India is spending billions of dollars in importing food grains, out of which edible oil accounts the major share. As per estimation, the projected per capita edible oil consumption will reach 24 kg by 2027 with an annual per capita consumption growth of 3.1% (OECD/FAO, 2018). Thus, it is the need of the hour to intensify oilseed production through adoption of improved agronomic practices to meet the future requirement. Oilseeds, being the backbone of various agricultural economies play an important role in agro industries and trades throughout the globe. India is the 4th largest oilseed producing economy after China, USA and Brazil contributing 10% of global oilseed production, 6-7% of world vegetable oil production and roughly 7% of protein meal (Reddy and Immanuelraj, 2017). Among seven edible oilseed crops cultivated in India, rapeseed-mustard rank second and contributes nearly 27.8% in the Indian oilseed's economy and 80% of *rabi* oilseed production. It is cultivated in an area of 5.96 million ha with a production of 8.32 million tonnes with 1397 kg ha$^{-1}$ productivity (GOI, 2018). However, national productivity of the crop is much less than global average productivity of 2144 kg ha$^{-1}$ as the crop is mostly grown in marginal and sub marginal areas, either mixed or intercropped with wheat, gram, pea, sugarcane and lentil under rainfed conditions. Besides, use of traditional and/or local varieties, intensive agriculture with imbalanced and irrational application of inorganic high analysis S-free fertilizers leading to widespread S deficiency in Indian soils could be other reasons for poor productivity (Ram *et al.*, 2016; Rana *et al.*, 2020).

It is well documented that no two cultivars of any crop can be expected to show comparable or superior performance in every location due to variations in their genetic makeup and eco-physiological responses to different habitats (Dubey, 2007). Experimenting with three different cultivars of Indian mustard (Varuna, Vardan and Ashirwad), Kumar *et al.* (2015) found distinctly superior growth and yield in the variety 'Varuna' at Faizabad, Uttar Pradesh. Hence, the necessity for selection of suitable varieties is utmost important to achieve maximum production potential. Among essential plant nutrients, both N and S play pivotal role in realizing the higher yield of seed and oil in mustard (Singh and Meena, 2004). Nitrogen imparts dark green to plant and promotes vegetative growth and development. Being a constituent of structural proteins and protoplasm, it not only regulates plant metabolism but also helps in greater partitioning of photosynthates. Similarly, S is known to improve oil and protein synthesis, especially synthesis of amino acid *viz.* cystein, cystine and methionine. Several researchers have found enhancement in growth, yield, oil and protein content of mustard with increased application of N and S to mustard (Mohiuddin *et al.*, 2011). The assimilatory pathways of S and N have been believed to be functionally integrated and well-coordinated as the availability of one regulates other (Kabdal *et al.*, 2018). N metabolism is greatly influenced by S status of the soil (Janzen and Bettany, 1984; Duke and Reisenauer, 1986). Addition of S maximizes the efficiency of applied nitrogenous fertilizer. Therefore, accurate balancing of N and S levels and their possible coordination in action could be a convincing strategy for better growth and productivity of Indian mustard. Keeping all the above facts in view, the present investigation was undertaken to evaluate the relative performance of Indian mustard genotypes fertilized with different doses of nitrogen and sulphur nutrients.

## Materials and Methods

The research experiment was conducted during winter (*rabi)* season of 2016-17 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh under irrigated condition. The site was geographically located in the subtropical zone of Northern Gangetic Alluvial plain at 25°18' North latitudes, 83°03' East longitude and at an altitude of 80.71 meter AMSL. The region has sub-tropical climate characterized by hot summer and cool winter with a mean annual rainfall and mean annual potential evapotranspiration of about 1100 mm and 1525 mm, respectively. The weekly average maximum and minimum temperature ranged between 20.1ºC to 38.5ºC and 8.2ºC to 20.1ºC, respectively. The soil of experimental site was Gangetic alluvium having sandy clay loam texture with an initial fertility status of 0.38% organic carbon, 138.48 kg $ha^{-1}$ of available N, 23.31 kg $ha^{-1}$ of available phosphorus, 172.10 kg $ha^{-1}$ of available potassium, 20.73 kg $ha^{-1}$ of available S, pH of 7.8 and EC of 0.18 dS $m^{-1}$. Initial soil properties of Agricultural Research Farm are presented in Table 1.

The design of experiment was split plot having 18 treatment combinations with three replications. Main plots comprised of combinations of 3 N levels (90, 120 and 150 kg $ha^{-1}$) and two varieties (Pusa Bold and RH-749), whereas three levels of S (0, 25 and 50 kg $ha^{-1}$) were allocated to sub-plots. A pre sowing irrigation was given and when the soil reached desired moisture level seedbed was prepared. The experimental plot of size 4.4m × 3.6m was separated by using 0.30m buffer rows. Seed @ 5 kg $ha^{-1}$ was sown manually with 40 cm row spacing and an inter plant distance of 15 cm was maintained by thinning at 4-6 leaf stage. The rate of application of fertilizer was done as per the treatments using urea, DAP, MOP and elemental S as the source of N, phosphorus, potassium and S, respectively. Half dose of N and full doses of phosphorus, potassium and S as per treatment were applied in furrows after mixing with moist soil. The rest half of the N was top dressed using urea after first irrigation at pre bloom stage. The test crop was raised with the recommended package of practices of weed management *viz.*, pre-emergence application of pendimethalin @ 1 kg *a.i.* $ha^{-1}$ followed by 1 mechanical weeding at 30 DAS. To keep the crop free from insect pests and diseases Rogor + Dithane M-45 was sprayed twice at one week interval during flowering to pod formation stage. All the data pertaining to yield attributes and yield were recorded at 40, 70, 100 DAS and at harvest by selecting and labeling four individual plants from each net plot area from the middle rows to avoid border effect. Fully matured crop was harvested and threshed manually after sun drying. Seed and biomass yield from each net plot area was measured and converted into q $ha^{-1}$. Harvest index (HI) was calculated using the formula below given by Donald and Hamblin (1976).

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Quality parameter such as seed oil content was estimated with the help of Soxhlet apparatus using petroleum ether as the extractant (Sankaran, 1966) whereas the seed protein content was calculated by determining the percentage of N in seed using micro Kjeldahl method (Jackson, 1973)

Table 1: chemical properties of initial soil sample of experimental site during 2016-17

| Parameters | Values |
|---|---|
| pH | 7.8 |
| EC (dS/m) at 25p C | 0.18 |
| Organic carbon (%) | 0.38 |
| Available nitrogen (kg $ha^{-1}$) | 138.48 |
| Available $P_2O_5$ (kg $ha^{-1}$) | 23.48 |
| Available $K_2O$ (kg $ha^{-1}$) | 172.10 |
| Available S (mg $ha^{-1}$) | 20.73 |
| Available B (mg $ha^{-1}$) | 0.75 |
| Available Zn (mg $ha^{-1}$) | 0.53 |

and multiplying it by the factor 6.25.

$$\text{Oil content (\%)} = \frac{\text{Weight of oil}}{\text{Weight of seed sample}} \times 100$$

Oil yield and protein yield were calculated by multiplying seed yield with seed oil content and seed protein content, respectively and expressed in kg ha$^{-1}$

$$\text{Oil yield (kg ha}^{-1}) = \frac{\text{Oil content in seed (\%)} \times \text{seed yield (kg ha}^{-1})}{100}$$

$$\text{Protein yield (kg ha}^{-1}) = \frac{\text{Seed protein content (\%)} \times \text{seed yield (kg ha}^{-1})}{100}$$

All the data obtained were statistically analyzed by applying the techniques of analysis of variance (ANOVA) and the significance of variance was tested by 'error mean square' method of Fishers Snedecor's F-Test at the probability level of 0.05 at appropriate level of degree of freedom (P=0.05).

## Results and Discussion

### Yield attributes and yield

Each increment in N levels from 90 kg N ha$^{-1}$ to 150 N kg ha$^{-1}$ brought about significant increase in production of yield attributing characters *viz.* siliquae on main shoot, siliqua plant$^{-1}$, seeds siliqua$^{-1}$ and 1000 seed weight (Table 2). However, the difference between 120 kg N ha$^{-1}$ and 150 kg N ha$^{-1}$ remained comparable. The increase in N levels though increased siliqua length of mustard but the differences did not differ significantly. It is well observed that distinct improvement in various vegetative attributes and overall effective vegetative growth performance under adequate N supply acts as a principal factor for improving yield attributes. The basic vegetative phase has a crucial role in shaping the reproductive organs, which is most important from point of view of obtaining high yield. In addition, under adequate N more efficient mobilization of nutrients to reproductive attributes is bound to occur. Increase in siliqua and seeds plant$^{-1}$ as well as test weight could be ascribed to this phenomenon. These findings are in consonance to result reported by Keivanrad and Zandi (2014). Increased N doses enhanced the seed and stover yields lucidly up to 150 kg N ha$^{-1}$. The highest increase in mustard seed yield was recorded with application of 150 kg N ha$^{-1}$ followed by 120 kg N ha$^{-1}$. Nevertheless, harvest index was not affected by application of different N doses. Higher yields associated with higher levels of fertility were consistently observed because of enhanced growth and yield attributes. Positive response of mustard to applied N was also reported by Rajput (2012).

Genotypes of mustard used in experiment exerted pronounced effect on yield and yield attributes. Among the two genotypes, 'RH-749' produced significantly higher siliquae on main shoot (42.7) and siliquae plant$^{-1}$

Table 2: Effect of N and S levels on yield attributes and yield of Indian mustard genotypes

| Treatment | Siliquae on main shoot | Siliquae plant$^{-1}$ | Siliqua length (cm) | Seeds siliqua$^{-1}$ | 1000-seed weight (g) | Seed yield (q ha$^{-1}$) | Stover yield (q ha$^{-1}$) | Harvest Index (%) |
|---|---|---|---|---|---|---|---|---|
| N levels (kg N ha$^{-1}$) | | | | | | | | |
| 90 | 38.6 | 229.0 | 5.37 | 11.80 | 5.3 | 14.9 | 51.9 | 22.3 |
| 120 | 41.5 | 255.7 | 5.49 | 12.16 | 5.5 | 15.8 | 56.4 | 21.9 |
| 150 | 42.4 | 263.9 | 5.56 | 12.50 | 5.6 | 17.0 | 60.4 | 22.0 |
| SEm± | 0.89 | 6.39 | 0.11 | 0.12 | 0.06 | 0.40 | 1.01 | 0.39 |
| CD(P=0.05) | 2.80 | 20.14 | NS | 0.38 | 0.18 | 1.27 | 3.18 | NS |
| Genotypes | | | | | | | | |
| Pusa Bold | 38.9 | 232.2 | 5.60 | 12.29 | 5.7 | 14.8 | 54.7 | 21.3 |
| RH-749 | 42.7 | 266.9 | 5.35 | 12.02 | 5.3 | 16.9 | 57.8 | 22.7 |
| SEm± | 0.73 | 5.22 | 0.09 | 0.10 | 0.05 | 0.33 | 0.82 | 0.32 |
| CD (P=0.05) | 2.29 | 16.44 | NS | 0.31 | 0.15 | 1.04 | 2.60 | 1.01 |
| S levels (kg S ha$^{-1}$) | | | | | | | | |
| 0 | 39.4 | 226.7 | 5.42 | 11.85 | 5.3 | 15.2 | 53.6 | 22.2 |
| 25 | 40.4 | 251.4 | 5.39 | 12.23 | 5.5 | 16.1 | 56.6 | 22.2 |
| 50 | 42.6 | 270.6 | 5.61 | 12.38 | 5.7 | 16.3 | 58.5 | 21.7 |
| SEm± | 0.84 | 6.47 | 0.08 | 0.15 | 0.05 | 0.15 | 0.90 | 0.31 |
| CD (P=0.05) | 2.45 | 18.88 | 0.24 | 0.43 | 0.16 | 0.43 | 2.62 | NS |

(266.9), seed yield (16.9 q ha$^{-1}$) and stover yield (57.8 q ha$^{-1}$) over 'Pusa Bold' (Table 2). However, no significant effect was found in case of siliqua length and seeds siliqua$^{-1}$ between the two varieties. However, 1000-seed weight was recorded higher in 'Pusa Bold' (5.7g) over the 'RH-749' (5.3g) due to its bolder seed. Higher seed and stover yield in 'RH-749' may be due to better vegetative growth and superior yield attributing character of the genotype over 'Pusa Bold'. The relationship of yield with growth parameters and yield attributes in the present study is in accordance with the findings of Bansal *et al.* (2000). Mutant genotype 'RH-749' recorded significantly higher harvest index as compared to 'Pusa Bold' which may be attributed to efficient utilization of photosynthates by 'RH-749' than the other.

Yield components and yield of mustard were positively impacted by increasing S levels from 0 to 50 kg ha$^{-1}$ (Table 2). Application of 50 kg S ha$^{-1}$ resulted maximum siliquae on main shoot (42.6), siliqua plant$^{-1}$ (270.6), siliqua length (5.61 cm), seeds siliqua$^{-1}$ (12.38) and test weight (5.7g) compared to 25 kg S ha$^{-1}$ and control. Notwithstanding, the differences could not touch the level of significance between any two levels in case of siliqua length and seeds siliqua$^{-1}$. The higher number of siliquae on main shoot at higher rates of S application is attributed to the longer central axis owing to taller plants and that of the siliquae plant$^{-1}$ to the enhanced primary and secondary branching. Similar trend was also observed by Parihar *et al.* (2014).

Application of S @ 50 kg ha$^{-1}$ produced significantly higher seed (16.3 q ha$^{-1}$) and stover (58. 5 q ha$^{-1}$) yield over control, but it remained comparable to application of 25 kg S ha$^{-1}$ (Table 2). The highest seed yield obtained with the application of S might be due to increased formation of reproductive structure for sink strength and increased production of assimilates to fill the economically important sink. These findings are also in line with those recorded by Ray *et al.* (2015) and Islam *et al.* (2018). On the other hand, decline in harvest index was noticed with the application of S @ 50 kg ha$^{-1}$. However, the difference failed to touch the level of significance. This shows that both the seed and stover utilized the applied nutrients at the same level of efficiency.

## Quality parameters

Increasing levels of N from 90 to 150 kg ha$^{-1}$ showed decline trend in oil content of mustard (Table 3). The maximum percentage of oil was recorded with 90 kg N ha$^{-1}$ (32.7%), but the differences among the levels remained statistically at par. Whereas, increasing trend of protein content was noticed with each increment of N doses from 90 to 150 kg ha$^{-1}$. This may be ascribed to rapid conversion of carbohydrate to protein due to increased availability of N at higher rates of application as N being part of amino acids improves protein content. Such inverse relationship between protein and oil content has also been reported by Premi and Kumar (2004). Oil and protein yield of mustard increased with increasing rates of N up

Table 3: Effect of N and S levels on quality and economics of Indian mustard cultivars

| Treatment | Seed oil content (%) | Oil yield (kg ha$^{-1}$) | Seed protein content (%) | Protein yield (kg ha$^{-1}$) | Gross returns (Rs. $10^3$ ha$^{-1}$) | Net returns (Rs. $10^3$ ha$^{-1}$) | B:C ratio |
|---|---|---|---|---|---|---|---|
| N levels (kg N ha$^{-1}$) | | | | | | | |
| 90 | 32.7 | 487 | 17.5 | 262 | 64.7 | 30.8 | 0.91 |
| 120 | 32.3 | 511 | 18.4 | 292 | 68.8 | 34.4 | 1.00 |
| 150 | 32.0 | 544 | 19.0 | 323 | 74.0 | 39.2 | 1.13 |
| SEm± | 0.39 | 13.3 | 0.24 | 10.4 | 1.7 | 1.7 | 0.04 |
| CD (P=0.05) | NS | 42.0 | 0.74 | 32.7 | 5.3 | 5.3 | 0.12 |
| Genotypes | | | | | | | |
| Pusa Bold | 31.8 | 472 | 18.0 | 268 | 64.8 | 30.4 | 0.88 |
| RH- 749 | 32.8 | 556 | 18.6 | 316 | 73.6 | 39.2 | 1.14 |
| SEm± | 0.32 | 10.9 | 0.19 | 8.5 | 1.36 | 1.36 | 0.04 |
| CD (P=0.05) | NS | 34.3 | 0.60 | 26.7 | 4.30 | 4.30 | 0.13 |
| Sulphur levels (kg S ha$^{-1}$) | | | | | | | |
| 0 | 31.4 | 479 | 17.8 | 272 | 66.4 | 33.6 | 1.02 |
| 25 | 32.1 | 518 | 18.3 | 297 | 70.2 | 35.8 | 1.04 |
| 50 | 33.5 | 545 | 18.8 | 307 | 70.9 | 35.0 | 0.97 |
| SEm± | 0.29 | 6.3 | 0.18 | 3.7 | 0.61 | 0.61 | 0.02 |
| CD (P=0.05) | 0.85 | 18.3 | 0.54 | 10.9 | 1.77 | 1.77 | 0.05 |

to 150 kg ha$^{-1}$. However, significant difference was found only between 90 and 150 kg N ha$^{-1}$. Both oil and protein yield are directly related to seed yield of the mustard. Hence higher oil and protein yield with higher level of nutrient is justified. These results are confirmed by Saleem *et al.* (2001) who concluded that expanding N fertilizer rate had a significant positive impact on the protein content of canola seed.

Due to differential genetic makeup the mutant genotype 'RH-749' produced approximately 3.14% and 3.33% higher oil and protein content, respectively compared to 'Pusa Bold', however in case of seed oil content the differences failed to touch the level of Significance (Table 3). Similarly, oil and protein yield were found to be distinctly superior in 'RH-749' over 'Pusa bold' due to its higher seed yield. The results are in close conformity with Roop *et al.* (2014).

With respect to different levels of S application, it was observed that increasing rates of S application from 0 to 50 kg ha$^{-1}$ resulted in obvious improvement in oil and protein content. Nevertheless, the significant difference was noticed only between lowest and highest level of S application. Maximum oil yield of 545 kg ha$^{-1}$ was obtained with 50 kg S ha$^{-1}$ which recorded 5.26% and 13.98% higher oil yield than 25 kg S ha$^{-1}$ and control, respectively (Table 3). In case protein yield, increasing trend was shown with increasing levels of S from 0 to 50 kg ha$^{-1}$. Nevertheless, the differences between 25 and 50 kg S ha$^{-1}$ did not turn significant. The improvement in seed oil content with increasing levels of S might be due to its role in the formation of Acetyl Co- A, a precursor compound for synthesis of long chain fatty acids. Since S is an integral component of a multi enzyme complex 'fatty acid synthatase' as well as various amino acids viz., cysteine, cysteine and methionine, its application enhanced quantity of oil and protein, respectively. The results are in concurrence with those reported by Basumatary and Talukdar (2011).

## Economics

The result pertaining to economic analysis as influenced by N levels indicated that application of 150 kg N ha$^{-1}$ recorded significantly higher gross returns (Rs. 74019 ha$^{-1}$) and net returns (Rs. 39196 ha$^{-1}$) with a B:C ratio of 1.13 over application of 90 kg N ha$^{-1}$ (Table 3). This could be attributed to significantly higher seed yield with higher N rates. Varietal difference influenced markedly gross and net returns and RH-749 recorded significantly higher gross (Rs. 73559 ha$^{-1}$) and net returns (Rs. 39191 ha$^{-1}$) over 'Pusa Bold' because of higher seed and stover yield. B:C ratio also followed the similar trend. Sulphur @ 25 kg ha$^{-1}$ recorded the highest net returns of Rs. 35835 with the highest B:C ratio of 1.04, while the highest gross returns was found with 50 kg S ha$^{-1}$. The higher net profit could be attributed to lucid increase in seed yield as compared to control and saving of extra cost of S fertilizer as compared to 50 kg S ha$^{-1}$. The results are in agreement with the findings of Sipai *et al.* (2015).

## Conclusion

It is concluded that application of 150 kg N ha$^{-1}$ resulted highest seed yield and obtained higher net returns and B:C ratio over other levels of N. Recently released genotype 'RH-749' recorded higher yield, quality and net returns as compared to traditionally grown cultivar 'Pusa Bold'. Sulphur level of 25 kg ha$^{-1}$ seems to be optimum for getting higher monetary returns. Therefore, on the basis of economic analysis of experimental findings, 150 kg N and 25 kg S ha$^{-1}$ could be applied to mustard var. 'RH-749' to obtain higher yield and economical realization under irrigated conditions of Eastern Uttar Pradesh.

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