



Re-visiting of nitrogen and sulphur requirements in Indian mustard (*Brassica juncea*) under irrigated conditions

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ABSTRACT

Present study was carried out during 2018–19 and 2019–20 at ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan to evaluate the effect of nitrogen (N) and sulphur (S) nutrition on production efficiency, water productivity, and economics of Indian mustard [*Brassica juncea* (L.) Czern & Coss.] under irrigated conditions. The experiment was conducted in a split plot design with 5 nitrogen levels (0, 60, 80, 100 and 120 kg/ha) as the main plot treatment and 4 sulphur levels (0, 20, 40, and 60 kg/ha) as subplot treatment with 3 replications. Results revealed that the application of 120 kg N/ha recorded the highest plant height (205 cm), leaf area index (5.4), number of leaves/plant (47.3), primary branches/plant (6.8), secondary branches/plant (18.9), SCMR (46.5), number of siliques/plant (382), number of seeds/silique (18), stem girth (6.65 cm), test weight (5.79 g) and seed yield (3.04 t/ha). Among the different S levels, the maximum values of growth and physiological parameters, yield attributes and seed yield were recorded at 60 kg S/ha (2.71 t/ha). Similarly, production efficiency (22.1 kg/ha/day) and water productivity (1.53 kg seed/m³) were found higher than 120 kg N/ha and 60 kg S/ha. The highest net monetary returns and Benefit cost (B:C) ratio were recorded with 120 kg N/ha and 60 kg S/ha. Thus, the application of N and S may be revised to 120 and 60 kg/ha, respectively for Indian mustard in the irrigated semi-arid climates to achieve higher productivity, efficiency and profitability.

Keywords: Indian mustard, Nitrogen, Production efficiency, Profitability, Sulphur, Water productivity

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is a winter (*rabi*) season crop which thrives best in light to heavy loam soils in semi-arid climates. Indian mustard ranks third most important oilseed crop after soybean and groundnut in India in terms of oil production. India is the third largest producer (11.3%) of rapeseed and mustard in the world, after Canada and China and contributes about 6–7% of the world's oilseed production (Rathore *et al.* 2022). Being an oilseed crop, Indian mustard is a high energy requiring crop. But, due to cultivation in semi-arid climates and poor fertility soils, the production levels are still far behind the world level.

The role of nitrogen in plants is considered as most important for the crop to activate many physiological activities and energy transformation. It also play an important role in plant nutrient uptake and helps in the better assimilation and partitioning of photosynthesis to the reproductive parts (Singh and Meena 2004). Sulphur deficiency in soils is another reason for the low productivity

of Indian mustard in rainfed areas (Rego *et al.* 2007). Asia is having the largest Sulphur deficient soils with maximum area in India (40%) followed by China (30%) (Messick 2014). Sulphur application in deficient soils have been studied and found to significantly be increased the crop yield in a number of on-farm trials conducted across the different climates (Gupta and Jain 2008). Nitrogen along with sulphur are essential nutrients required as primary source of nutrition for the growth and development of oilseed crops (Fazili *et al.* 2008). Cultivation of oilseed crops, especially brassicas have high demand of nitrogen and sulphur in increasing the seed yield and oil content (Jamal *et al.* 2010). The present level of recommended N and S in Indian mustard is 80 and 40 kg/ha, respectively which needs to be revised in the present context of decreasing soil fertility, nutrient factor productivity and climate change. Therefore, the present investigation was undertaken to study the response of graded levels of N and S on productivity and profitability of Indian mustard.

MATERIALS AND METHODS

Experimental site and climate characteristics: An experiment was conducted during 2018–19 and 2019–20 at the research farm of ICAR-Directorate of Rapeseed-Mustard

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Research, Bharatpur (77°30' E, 27°15' N and at an altitude of 178.37 meter amsl), Rajasthan. The climate of this zone is typically semi-arid, characterized with wide range of temperature between summer and winter. The average rainfall of the locality is around 650 mm of which 85% is contributed by south-west monsoon during July to August. The mean monthly maximum and minimum temperature during the crop growing seasons fluctuated between 17.3–34.5 and 5.2–20.1°C. The mean monthly evaporation from USWB class a pan evaporimeter ranged from 1.1 to 5.1 mm. The average relative humidity fluctuated between 56.1 to 79.% at noon. Rainfall received during 2018–19 and 2019–20 was 74.3 mm and 83.0 mm.

Soil characteristics: The soil samples were collected from surface soil (0–15 cm) and analyzed for soil physico-chemical properties with the help of standard methods. The experimental site was silty clay loam in texture (21.9% sand, 50.1% silt and 28.0% clay), and pH (1:2 soil water suspension) 8.3, bulk density 1.52 g/cm³, field capacity (by weight) 12.5% and permanent wilting point 2.35% were observed. The nutrient concentration in soil was also measured 0.27%, 127.2 kg/ha, 16.7 kg/ha, 163.9 kg/ha of organic C, available N, available P and available K, respectively.

Treatment details and preparation of field: The experiment was conducted in split plot design with 5 nitrogen levels i.e., 0, 60, 80, 100 and 120 kg/ha as main plot treatments, and 4 sulphur levels i.e., 0, 20, 40 and 60 kg/ha as subplot treatments with 3 replications. To eliminate weeds in experimental area, one hoeing was done at 25 DAS (Days after sowing). The crop was harvested when 75% silique turned down yellowish brown. Thereafter, plants from each net plot area (5.5 m × 5 m) were harvested carefully and seed yield from each plot was recorded. Dates of sowing of Indian mustard were 15th October 2018 and 19th October 2019 and harvested during 1st March 2019 and 3rd March 2020. Variety DRMRIJ-31 was used for sowing purpose with row to row distance 45 cm and plant to plant 10–15 cm.

Observation recorded: Observations on physiological parameters, yield and yield attributing characters were recorded. The SCMR (SPAD chlorophyll meter reading) was measured after 45, 60 and 90 DAS. SCMR data were recorded on top, middle and bottom leaf of each representative plant during morning hours. The total biomass harvested from each plot was threshed and cleaned. The seeds obtained were weighed and then converted in to t/ha. The leaf area index was calculated on the basis of leaf area to ground area. It is used to find out the assimilatory surface area occupied by the plants.

$$LAI = \frac{A}{P}$$

where A, Leaf area (cm²) and P, ground area (cm²).

Production efficiency was calculated by dividing seed yield into the crop's duration (137 days). The input water productivity was computed as the ratio of grain yield to

the total water input (irrigation + rainfall) from sowing to harvesting of the crop and expressed as kg seed/m³.

The economics of different treatments was worked out in terms of cost of cultivation, net monetary returns (NMR) and benefit-cost ratio (B:C) on per hectare area basis to ascertain the economic viability of the treatments.

Net monetary returns = Gross monetary returns - Total cost of cultivation

To estimate the benefits treatments from different treatment for each rupee of expenditure incurred, B: C ratio of each treatment was calculated as:

$$B:C \text{ ratio} = \frac{\text{Net monetary returns}}{\text{Total cost of cultivation}}$$

The data obtained on various observations were tabulated and analyzed in split plot design with 3 replications by using the techniques of the analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967) and the treatment was tested by F test shown their significance where critical difference (CD) at 5% level of significance was determined for each character to compared the differences among treatment means.

RESULTS AND DISCUSSION

Growth and physiological parameters: The data pertaining to plant height at different stages of plant growth as influenced by various nitrogen (N) and sulphur (S) levels are presented in Table 1. It is evident from the data, the plant height increased with the advancement of the plant growth stages and the highest plant height was recorded at 90 days after sowing (DAS) in all treatments. In N levels; the significantly higher plant height was recorded at the treatment 120 kg/ha (204.8 cm) followed by 100 kg/ha (200.4 cm). Among the different S levels, the highest plant height was recorded at 90 DAS with the treatment 60 kg/ha (203.3 cm) which was closely followed by 40 kg/ha (200.6 cm). Increasing the plant height with the increasing nitrogen and sulphur levels was also observed by Singh and Singh (2018).

The maximum leaf area index was recorded at 60 DAS and marginally reduction in LAI was recorded at 90 DAS in all treatments (Table 1). Among different N treatments, 120 kg/ha recorded highest leaf area index ((5.39) followed by 100 kg/ha (4.95). Sulphur @60 kg/ha recorded maximum leaf area index (5.0) which was closely followed by 40 kg/ha (4.83). Similar findings were also reported by Begum *et al.* (2012).

The highest number of leaves was recorded with the treatment 120 kg N/ha (47.31) which was at par with 100 kg N/ha (45.28) (Table 1). Treatment 60 kg S/ha recorded maximum number of leaves/plant (45.75) while control treatment recorded least leaves/plant. Similar findings were also reported by Begum *et al.* (2012).

SCMR increased till 60 DAS and marginally reduction was observed at 90 DAS in all the treatments (Table 1). The highest SCMR was recorded at 60 DAS and marginal

Table 1 Effect of different N and S levels on growth and physiological parameters of Indian mustard (mean of 2-year data)

Treatment	Plant height (cm)			Leaf area index			Number of leaves/plant			SCMR reading		
	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS
<i>N levels</i>												
Control	57.7	129.7	197.0	2.47	4.37	3.36	13.40	30.61	43.23	36.5	43.9	41.7
60 kg/ha	58.8	131.8	197.6	2.51	4.48	3.40	13.53	31.17	43.38	37.1	44.6	42.0
80 kg/ha	60.3	134.4	198.9	2.54	4.73	3.47	13.95	32.05	44.17	38.2	45.1	42.3
100 kg/ha	62.5	144.5	200.4	2.78	4.95	3.61	14.71	33.24	45.28	39.8	45.8	43.4
120 kg/ha	67.0	169.1	204.8	3.35	5.39	4.01	15.51	34.51	47.31	42.7	47.8	46.5
SEm±	0.59	1.78	0.73	0.05	0.03	0.04	0.04	0.12	0.23	0.28	0.44	0.28
CD (P=0.05)	1.94	5.81	2.37	0.17	0.09	0.13	0.12	0.40	0.75	0.92	1.44	0.92
<i>S levels</i>												
Control	58.9	136.6	196.9	2.57	4.58	3.34	13.76	31.41	43.54	37.8	44.3	42.3
20 kg/ha	59.4	141.0	198.2	2.68	4.73	3.54	14.13	31.85	44.36	38.6	45.2	43.0
40 kg/ha	61.5	142.5	200.6	2.75	4.83	3.63	14.37	32.72	45.04	39.0	45.6	43.3
60 kg/ha	65.2	147.6	203.3	2.91	5.00	3.78	14.61	33.28	45.75	39.9	46.6	44.1
SEm±	0.65	1.54	0.69	0.04	0.02	0.03	0.04	0.16	0.22	0.26	0.33	0.28
CD (P=0.05)	1.88	4.44	1.99	0.11	0.06	0.09	0.12	0.46	0.63	0.74	0.96	0.79
<i>Interaction (N × S)</i>												
CD (P=0.05)	NS	NS	2.41	0.25	0.13	NS	0.27	1.04	1.40	1.34	1.69	1.23

reduction was recorded at 90 DAS due to shrinkage in leaves. Nitrogen treatment 120 kg/ha recorded highest SCMR (47.8) followed by 100 kg/ha (45.8). Among the different S levels, the highest SCMR reading was recorded in 60 kg/ha (46.6) and least was recorded in control treatment. Interaction between nitrogen and sulphur levels on SCMR was found significant. The present work is supported by the reports of earlier work done by Begum *et al.* (2012).

Post-harvest observations in Indian mustard: The maximum primary branches/plant were recorded with 120 kg N/ha (6.81) followed by 100 kg N/ha (6.04) (Table 2). Among the different S levels, the maximum primary branches/plant were recorded with the treatment 60 kg/ha (6.13) which was closely followed by 40 kg/ha (5.91). Interaction between nitrogen and sulphur levels on primary branches/plant was found significant. The present work is supported by the reports of earlier work done by Singh and Singh (2018). The highest number of secondary branches was recorded with 120 kg N/ha (18.91) and 60 kg S/ha (17.55) which was followed by 100 kg N/ha (17.04) and 40 kg S/ha (16.81) (Table 2). Interaction between nitrogen and sulphur levels on secondary branches/plant was found significant. Rajput *et al.* (2018) reported that number of primary and secondary branches were maximum at 120 kg N/ha with 60 kg S/ha.

The application of 120 kg N/ha recorded highest number of siliquae/plant (382) followed by 100 kg N/ha (347) (Table 2). The 60 kg S/ha recorded more number of siliquae/plant (340) followed by 40 kg S/ha and 20 kg S/ha. Similar results were also reported by Ray *et al.* (2015). The length of silique was significantly ($P=0.05$) higher under 120 kg N/ha treatment (5.63 cm) as compared to other treatments

(Table 2). 60 kg S/ha recorded highest silique length (5.03 cm) followed by 40 kg S/ha and 20 kg S/ha. Similar results were also reported by Ray *et al.* (2015) and Singh (2017). The number of seeds/silique was significantly ($P=0.05$) higher under 120 kg N/ha treatment (18.01) (Table 2). In S levels, 60 kg/ha recorded highest number of seeds/silique (16.93) whereas control treatment recorded least number of seeds/siliquae (15.53). Similar results were also reported by Ray *et al.* (2015).

The maximum stem girth was recorded in the treatment 120 kg N/ha (6.65), however least stem girth was recorded in control treatment (5.68). In S level treatments, 60 kg/ha recorded more stem girth (6.25) which was closely followed by 40 kg S/ha (6.05) and 20 kg S/ha (5.94). Interaction between N levels and S levels on stem girth was found significant. Similar results were also reported by Ray *et al.* (2015).

Significantly higher 1000-seeds weight of Indian mustard was recorded in 120 kg N/ha treatment (5.79) which was followed by 100 kg N/ha (5.21) (Table 2). Treatment 60 kg S/ha recorded highest test weight (5.38) followed by 40 kg S/ha (5.16) and 20 kg S/ha (4.97). Ray *et al.* (2015) reported that yield attributes and yield of Indian mustard crop was highest with 60 kg S/ha, mostly at par with 45 kg S/ha.

Seed, stover and biological yield: The highest seed yield (3.04 t/ha), stover yield (5.97 t/ha) and biological yield (9 t/ha) was recorded under the treatment 120 kg N/ha which was at par with treatment 100 kg N/ha (Table 3). Among the different S levels, 60 kg S/ha recorded the highest seed yield (2.71 t/ha), stover yield (5.11 t/ha) and biological yield (7.82 t/ha) which was followed by 40 kg S/ha > 20 kg S/ha

Table 2 Effect of different N and S levels on post-harvest observations of Indian mustard (mean of 2-year data)

Treatment	Primary branches/plant	Secondary branches/plant	Number of siliquae/plant	Length of silique (cm)	Number of seeds/silique	Stem girth (cm)	Test weight (g)
<i>N levels</i>							
Control	5.42	15.77	244	4.42	15.04	5.68	4.62
60 kg/ha	5.47	15.90	263	4.47	15.40	5.73	4.76
80 kg/ha	5.66	16.28	294	4.70	16.12	5.84	5.01
100 kg/ha	6.04	17.04	347	5.11	16.81	6.14	5.21
120 kg/ha	6.81	18.97	382	5.63	18.01	6.65	5.79
SEm±	0.03	0.11	4.94	0.06	0.05	0.04	0.07
CD (P=0.05)	0.10	0.35	16.12	0.20	0.16	0.12	0.22
<i>S levels</i>							
Control	5.68	16.25	280	4.67	15.53	5.79	4.81
20 kg/ha	5.79	16.56	289	4.77	16.19	5.94	4.97
40 kg/ha	5.91	16.81	314	4.99	16.45	6.05	5.16
60 kg/ha	6.13	17.55	340	5.03	16.93	6.25	5.38
SEm±	0.04	0.10	4.19	0.05	0.07	0.04	0.05
CD (P=0.05)	0.12	0.30	12.09	0.15	0.19	0.11	0.14
<i>Interaction (N×S)</i>							
CD (P=0.05)	0.27	0.62	NS	NS	0.43	0.25	0.31

and control treatment. Interaction between N and S levels was found significant. Combined application of 120 kg N/ha and 60 kg S/ha resulted in the maximum seed yield of Indian mustard. Maximum seed and biological yield were recorded under 120 kg N/ha with 60 kg S/ha (Singh and Singh 2005, Rajput *et al.* 2018).

Water productivity (WP): WP recorded highest in the treatment 120 kg N/ha (1.53) while least was recorded in the control treatment (Table 3). Among S level, the highest WP was recorded with treatment 60 kg/ha (1.37) which was closely followed by 40 kg/ha (1.31) and 20 kg/ha (1.27). The Similar results were also reported by Chaudhary *et al.* (2021).

Production efficiency (kg/ha/day): Production efficiency (PE) was recorded highest in the treatment at 120 kg N/ha (22.1). Among S level, the highest production efficiency was recorded with treatment 60 kg/ha (19.77) which was closely followed by 40 kg/ha (19) and 20 kg/ha (18.4).

Partial factor productivity: The partial factor productivity of applied N (PFP_N) decreased with the increase in N levels from 60 to 120 kg/ha, though it was improved substantially with increase in S levels (Fig 1). Application of N @60 kg/ha along with S @60 kg/ha resulted in the maximum PFP_N (44.29 kg seed/kg N) which was reduced to the minimum at 120 kg N/ha under the 0 kg S/ha by -45.83%.

Similarly, the partial factor productivity of applied S (PFP_S) decreased with the increase in S levels from 20 to 60 kg/ha, though it was improved substantially with increase in N levels from 0 to 120 kg/ha (Fig 2). Application of S @20 kg/ha along with N @120 kg/ha resulted the maximum PFP_S (151.28 kg seed/kg S) which was reduced to the minimum at 60 kg S/ha under the 0 kg N/ha by -78.58%.

Economics: The highest NMR was accrued in the treatment 120 kg N/ha (97980 ₹/ha) while, least NMR was calculated in the control treatment (47620 ₹/ha). The B:C ratio was maximum (3.3) under the treatment 120 kg N/ha while the least was recorded in control (1.6). Among the S levels, the highest NMR (84100 ₹/ha) and B:C ratio (2.8)

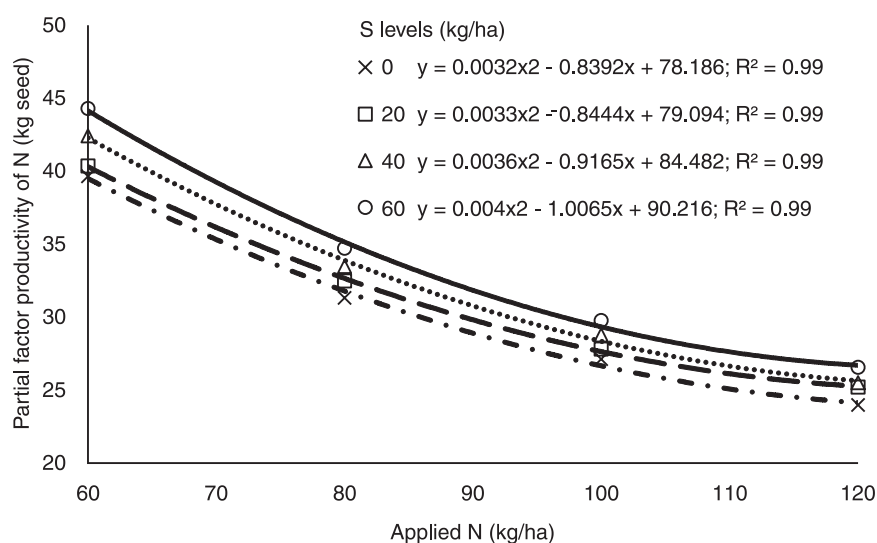


Fig 1 Effect of different N and S levels on partial factor productivity of applied N.

Table 3 Effect of different N and S levels on yield and economics of Indian mustard (mean of 2-year data)

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Water productivity (kg seed/m ³)	Production efficiency (kg/ha/day)	NMR (₹/ha)	B:C ratio
<i>N levels</i>							
Control	1.81	3.80	5.61	0.91	13.2	47620	1.6
60 kg/ha	2.50	4.11	6.61	1.26	18.2	76080	2.6
80 kg/ha	2.64	4.42	7.06	1.33	19.2	81700	2.8
100 kg/ha	2.84	5.39	8.22	1.43	20.7	89840	3.0
120 kg/ha	3.04	5.97	9.00	1.53	22.1	97980	3.3
SEm±	0.02	0.04	0.04	0.01	0.13	-	-
CD (P=0.05)	0.06	0.12	0.12	0.03	0.41	-	-
<i>S levels</i>							
Control	2.43	4.44	6.87	1.23	17.7	73660	2.5
20 kg/ha	2.52	4.60	7.12	1.27	18.4	77000	2.6
40 kg/ha	2.60	4.79	7.40	1.31	19.0	79920	2.7
60 kg/ha	2.71	5.11	7.82	1.37	19.77	84100	2.8
SEm±	0.02	0.04	0.04	0.01	0.15	-	-
CD (P=0.05)	0.06	0.11	0.13	0.03	0.44	-	-
<i>Interaction (N × S)</i>							
CD (P=0.05)	0.11	0.22	0.26	0.05	0.82		

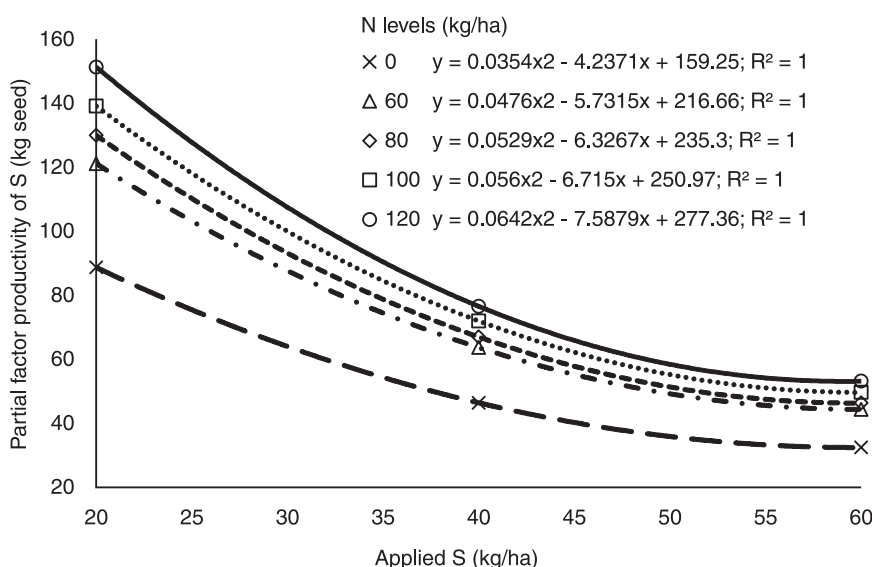


Fig 2 Effect of different N and S levels on partial factor productivity of applied S.

was recorded with treatment 60 kg/ha. Application of 120 kg N/ha with 60 kg S/ha has been reported economically most profitable. Similar results were also reported by Kumar *et al.* (2009) and Chaudhary *et al.* (2021).

This study represents contrasting results to the earlier recommendations for N (80 kg/ha) and S (40 kg/ha) for Indian mustard. Thus, the present recommendation of N and S may be revised to 120 and 60 kg/ha, respectively to achieve maximum seed yield, water productivity, production efficiency and profitability of Indian mustard under irrigated semi-arid climates.

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