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Impact of nitrogen-sulphur fertilizers on quality and economics in Indian mustard productivity

PHOOL CHANDRA SINGH AND RAJESH KUMAR SINGH
Deptt. Of Agronomy, Sri Durga Ji P.G. College, Chandeshwar, Azamgarh (U.P.)

Abstract

Nitrogen and sulphur are yield limiting factors for Indian mustard production in the sandy loam soil of the Agriculture farm of Sri Durga Ji Post Graduate College Chandeshwar, Azamgarh during rabi *seasons of 2015-16 and 2016-17. The field trial consisted four levels of nitrogen (0, 30, 60 and 90 Kg N/ha) and four levels of sulphur (0, 20, 40 and 60 kg S/ha) making sixteen treatment combinations and was laid out in randomized block design with three replications. The highest yield was obtained from 90 kg N ha^{-1} as compared to the control (N_1). Seed yield and seed oil content of the mustard significantly increased with the sulphur level. Application of 60 kg S ha^{-1} produced the highest yield. Similarly, 60 kg S ha^{-1} produced the highest oil content compared to the control (S_0). The interaction effect of nitrogen and sulphur at the rate of 90 kg N ha^{-1} and 60 kg S ha^{-1} produced significantly highest yield than control. The seed oil content of the mustard was also significantly influenced by the combined application of nitrogen and sulphur. The highest oil content was observed from the plot with 60 kg N ha^{-1} and 60 kg S ha^{-1} which was at par with 90 kg N ha^{-1} and 40 kg S ha^{-1} compared to the control plot which has the minimum oil content in the seed. There was increase in incremental yield and marginal profit with the increasing dose of N as the highest B:C ratio was obtained from 90 kg N ha^{-1} which was significantly greater than 60 kg N ha^{-1} and control.*

Keywords: Sulphur, oil content, Seed yield, oil content, B:C ratio

Introduction

Mustard (*Brassica juncea* L.) belongs to the family *cruciferae* popularly known as rai and is an important *rabi* season oilseed crop of north India. Mustard is second most important edible oilseed crop after groundnut, accounts nearly 30% of the total oilseeds produced in India. India is one of the largest rapeseed mustard growing countries in the world, occupying the first rank in area and second in production next to China. Total area under rapeseed and mustard in India is 5.92 million hectares with a production of 6.78 million tonnes and productivity of 1145 kg ha^{-1}. The area under mustard in Bihar is 0.82 lakh hectares with production of 0.76 lakh tonnes and productivity of 926 kg ha^{-1} (FAI, 2017).

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). 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). 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 (Tomar *et al.,* 1997, Deekshutulu *et al.,* 1998, Singh and Brar 1999, Singh *et al.,* 2010). 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) or gets converted to greenhouse gases such as oxides of N. Furthermore, N efficiency decreases with increase in N application (Chamoro *et al.,* 2002). Increasing N application also reduces oil content (Singh *et al.,* 2008). 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.

Sulphur deficiencies in India are widespread and scattered. Deficiency of sulphur in Indian soils is on increase due to intensification of agriculture with high yielding varieties and multiple cropping coupled with the use of high analysis sulphur free fertilizers along with the restricted or no use of organic manures have accrued in depletion of the soil sulphur reserve. Crops generally absorb sulphur and phosphorus in similar amounts. On average, the sulphur absorbed per tonne of grain production is 3-4 kilograms in cereals, 8 kilograms in pulses, and 12 kilograms in oilseeds. Soils, which are deficient in sulphur, cannot on their own provide adequate sulphur to meet crop demand resulting in sulphur deficient crops and sub-optimal yields (Chattopaddhyay *et al.,* 2012).

Material and Methods

A field research was conducted at Crop Research Farm, Department of Agronomy, Shri Durga Ji Post Graduate College, Chandesar, Azamgarh with two factors, Nitrogen with four levels (0, 30, 60 & 90 kg N ha-1) and Sulphur with four levels (0, 20, 40 & 60 kg S ha-1) were arranged in factorial randomized complete block design. Sixteen treatments combination (N_1S_0, N_1S_1, N_1S_2, N_1S_3, N_2S_0, N_2S_1, N_2S_2, N_2S_3, N_3S_0, N_3S_1, N_3S_2, N_3S_3, N_4S_0, N_4S_1, N_4S_2 and N_4S_3) were replicated thrice. Observations were recorded on plant height (cm), number of branches, leaf area index (LAI), dry matter accumulation per plant, number of siliquae per plant, length of siliquae, number of seeds per siliquae, seed yield per plant (g), 1000-seed weight (g), grain yield (q/ha), stover yield (q/ha) and harvest index (%) along with quality traits such as protein content (%), oil content (%), nitrogen uptake by crop and Sulphur uptake by crop as well as soil properties such as soil pH, nitrogen (%), available phosphorus (ppm), available potassium (meq/100 g soil) and available sulphur (ppm). The data were subjected to statistical analysis to obtain information on the mean performance and to assess the association between yield and its components. Benefit-Cost ratio was calculated on the basis of standard procedure and all the cost related with labor, inputs, and farm cost are included. Total benefit was calculated on the basis of grain yield value.

Results and Discussion

Grain yield and Stover yield (q/ha)

Data pertaining to grain yield and stover yield by different level of nitrogen and sulphur levels presented in Table 1. There was significant variation due to all experimental variables on grain yield and stover yield during both the years of experimentation. Grain yield and stover yield significantly increased with progressive increase in nitrogen levels. The significantly highest grain yield and stover yield was recorded under plot fertilized with 90 kg N/ha (N_4) followed by 60 kg N/ha (N_3) and 30 kg N/ha (N_2). The lowest grain yield and stover yield was recorded in control (N_0).

Sulphur application brought about significant effect on grain yield and stover yield production during both years. Increasing level of sulphur significant increase in grain yield as well as stover yield. Accordingly, application of 60 kg S/ha (S_3) produced maximum grain yield and stover yield and showed its significant superiority over 40 kg S/ha (S_2) and 20 kg S/ha (S_0).

The interaction effect of different levels of nitrogen with sulphur levels on grain yield and stover yield has significantly influenced the performance. The maximum grain yield and stover yield was observed at 90 kg N/ha (N_4) in combination with 60 kg S/ha (S_3), during both the years 2015-16 and 2016-17.

Quality studies

Protein content in grains (%)

Protein content in grains were significantly influenced by different levels of nitrogen and sulphur fertilization during both the years (Table 1). With successive increase in nitrogen rates, the protein content in grains increased significantly and the maximum value was observed with 90 kg N/ha (N_4) followed by 60 kg N/ha (N_3) and 30 kg N/ha (N_2) during both the years. The lowest protein content in grains was recorded in control (N_0).

Levels of sulphur fertilization on protein content in grains proved significant result during both the years. The protein content in grains was increased significantly with increasing level of sulphur. The significantly highest protein content in grains recorded with application of 60 kg S/ha (S_3) followed by 40 kg S/ha (S_2) and 20 kg S/ha (S_1).

The interaction effect between different levels of nitrogen and sulphur fertilization on protein content in grains was found to be significant during both the

Table 1: Effect of different levels of nitrogen and sulphur on grain & stover yield, protein content in grain and oil content in grain during 2015-16 and 2016-17.

Treatment	Grain yield (q/ha)		Stover yield (q/ha)		Protein content in grain (%)		Oil content in grain (%)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Nitrogen level								
N_1	18.31	18.51	79.08	79.92	18.54	18.74	40.60	41.03
N_2	21.67	22.08	85.30	86.93	20.90	21.30	39.28	40.03
N_3	23.21	23.53	87.87	89.09	22.68	22.99	38.81	39.35
N_4	24.17	24.56	90.44	91.89	23.64	24.02	38.30	38.91
S.Em (±)	0.39	0.34	2.07	1.33	0.54	0.34	0.72	0.61
C.D. at 5%	1.14	0.98	5.97	3.83	1.56	0.97	2.08	1.76
Sulphur level								
S_0	19.85	20.08	79.49	80.43	21.24	21.49	37.68	38.12
S_1	21.38	21.77	84.76	86.28	21.26	21.65	38.52	39.20
S_2	22.88	23.23	88.01	89.33	21.51	21.83	39.76	40.36
S_3	23.24	23.59	90.44	91.78	21.76	22.08	41.04	41.64
S.Em (±)	0.39	0.34	2.07	1.33	0.54	0.34	0.72	0.61
C.D. at 5%	1.14	0.98	5.97	3.83	1.56	0.97	2.08	1.76

years. The data indicates that increase of nitrogen levels has increased the protein content in grains at all the level of sulphur application in both the years. The maximum protein content in grains was observed at 90 kg N/ha (N_4) in combination with 60 kg S/ha (S_3), during both the years 2015-16 and 2016-17.

Oil content in grains (%)

Data pertaining to oil content in grains by different level of nitrogen and sulphur levels presented in Table 1. The oil content in grains during second year was comparatively higher than that of first year. Oil content in grains significantly increased with progressive increase in nitrogen levels. The significantly highest oil content in grains was recorded under plot fertilized with 90 kg N/ha (N_4) followed by 60 kg N/ha (N_3) and 30 kg N/ha (N_2). The lowest oil content in grains was recorded in control (N_0).

Sulphur application brought about significant effect on oil content in grains production during both years. Increasing level of sulphur significant increase in oil content in grains. Accordingly, application of 60 kg S/ha (S_3) produced maximum oil content in grains and showed its significant superiority over 40 kg S/ha (S_2) and 20 kg S/ha (S_0).

The effect of interaction of different levels of nitrogen with sulphur levels on oil content in grains has significantly influenced the performance. Overall interaction of these four nitrogen levels under four sulphur levels indicated superiority in oil content. The higher oil content in grains was observed at 90 kg N/ha (N_4) in combination with 60 kg S/ha (S_3), during both the years 2015-16 and 2016-17.

Nitrogen uptake by crop (kg/ha)

Nitrogen uptake by crop were significantly influenced by different levels of nitrogen and sulphur fertilization during both the years (Table 2).

With successive increase in nitrogen rates, the nitrogen uptake by crop increased significantly and the maximum value was observed with 90 kg N/ha (N_4) followed by 60 kg N/ha (N_3) and 30 kg N/ha (N_2) during both the years. The lowest nitrogen uptake by crop was recorded in control (N_0).

Levels of sulphur fertilization on nitrogen uptake by crop proved significant result during both the years. The nitrogen uptake by crop was increased significantly with increasing level of sulphur. The significantly highest nitrogen uptake by crop recorded with application of 60 kg S/ha (S_3) followed by 40 kg S/ha (S_2) and 20 kg S/ha (S_1).

The interaction effect between different levels of nitrogen and sulphur fertilization on nitrogen uptake by crop was found to be significant during both the years. The maximum nitrogen uptake by crop was observed at 90 kg N/ha (N_4) in combination with 60 kg S/ha (S_3), during both the years 2015-16 and 2016-17 (Table 2).

Sulphur uptake by crop (kg/ha)

Sulphur uptake by crop were significantly influenced by different levels of nitrogen and sulphur fertilization during both the years (Table.2).

With successive increase in nitrogen rates, the sulphur uptake by crop increased significantly and the maximum value was observed with 90 kg N/ha followed by 60 kg N/ha and 30 kg N/ha during both the years. The lowest sulphur uptake by crop was recorded in control.

Levels of sulphur fertilization on sulphur uptake by crop proved significant result during both the years. The sulphur uptake by crop was increased significantly with increasing level of sulphur. The significantly highest sulphur uptake by crop recorded with application of 60 kg S/ha followed by 40 kg S/ha and 20 kg S/ha.

The interaction effect between different levels of nitrogen and sulphur fertilization on sulphur uptake by crop was found to be significant during both the years. The maximum sulphur uptake by crop was observed at 90 kg N/ha in combination with 60 kg S/ha, during both the years 2015-16 and 2016-17.

Economics

Different levels of nitrogen and sulphur fertilization influenced the cost of cultivation, additional benefit over control, net return and benefit cost ratio during both the years are presented in Table 2. Maximum cost of cultivation was recorded at 90 kg N/ha (N_4) followed by 60, 30 and 0 kg N/ha (N_0), respectively in both the years.

However, higher net returns were obtained at 90 kg N/ha during 2015-16 and 2016-17 resulting in higher returns during both the years. The BCR at 90 kg N/ha over control was 1.27 and 1.27, respectively during 2015-16 and 2016-17.

With successive increase in sulphur application the cost of cultivation and gross returns increased and the maximum increase was up to 60 kg S/ha during both the years. However, higher net returns were obtained when sulphur was applied @ 60 kg/ha during both the years. The BCR at 60 kg S/ha over control was 1.26 and 1.25, respectively during 2015-16 and 2016-17.

Nitrogen fertilization

The seed yield was higher during 2016-17 as compared to 2015-16 mainly because of prevalence of higher temperature at maturity leading to poor seed development and lack of rainfall during initial stages of crop growth in 2016-17. The increase in yield of mustard due to nitrogen application may be because of the fact that nitrogen played an important role in the synthesis of chlorophyll and amino acid which constitute building blocks of proteins. The more harvest index with the application of nitrogen indicated the corresponding increase in seed yield rather than stover yield.

Nitrogen influenced the seed yield through a source-sink relationship and addition to higher production of photosynthates it lead to increased translocation to reproductive parts. Nitrogen being most important plant nutrient is needed for growth and development of plant and is known to increase the yield of *Brassica species* (Kumar and Gangwar, 1985).

Table 2: Effect of different levels of nitrogen and sulphur on total nitrogen uptake & total sulphur uptake by crop and BCR during 2015-16 and 2016-17.

Treatment	Total nitrogen uptake by crop (kg/ha)		Total sulphur uptake by crop (kg/ha)		BCR	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Nitrogen level						
N_1	34.81	35.18	34.81	35.18	1.23	1.22
N_2	41.34	42.12	41.34	42.12	1.23	1.23
N_3	48.13	48.80	48.13	48.80	1.23	1.23
N_4	51.97	52.81	51.97	52.81	1.27	1.27
S.Em (±)	1.14	0.70	1.14	0.70		
C.D. at 5%	3.30	2.03	3.30	2.03		
Sulphur level						
S_0	38.63	39.09	38.63	39.09	1.24	1.23
S_1	40.74	41.48	40.74	41.48	1.25	1.24
S_2	47.12	47.83	47.12	47.83	1.25	1.24
S_3	49.76	50.51	49.76	50.51	1.26	1.25
S.Em (±)	1.14	0.70	1.14	0.70		
C.D. at 5%	3.30	2.03	3.30	2.03		

The higher levels of nitrogen fertilization decreased the oil content significantly but increased the oil yield per hectare. This may be due to the fact that more availability of nitrogen increased the proportion of protenious substance in seeds. As per pathway of degradation, carbohydrates are degraded to acetyl Co-A. In case of insufficient supply of nitrogen acetyl Co-A is used for the synthesis of fatty acids by using acetyl carrying proteins (ACP) resulting in higher oil content in seeds although, nitrogen application resulted in reduced oil percent in seeds but it increased the oil yield per hectare significantly. Since, oil yield per hectare is the resultant of seed yield and oil percent, the oil yield per hectare also increased due to nitrogen application up to 90 kg/ha because of increase in seed yield. These findings are in agreement with Bishnoi and Singh (1979), Singh (1989) khan (1990). and Jayan *et al.* (1997).

The protein content was significantly more with the application of higher levels of nitrogen during both the years. Nitrogen is a basic constituent of protein and with the increase in the rates of nitrogen application, the nitrogen availability increased which resulted in increased protein content in seeds. Increase in protein content and seed yield with 90 Kg N/ha resulted an increase in the protein yield. A highly negative correlation between oil content and protein yield but positive correlation between nitrogen rates and protein yield was also reported by many workers like Singh and Sharma (1993).

Nitrogen application at 90 kg/ha produced the higher net returns and maximum BCR during both the years of experimentation.

Sulphur fertilization

Application of sulphur brought about a significant variation in seed yield of mustard during both the years. Although, with the application of sulphur @60 Kg/ha the yield increased but 40 and 20 Kg S/ha levels were at par. Seed yield of mustard is chiefly a product of yield attributing character viz. number of siliquae/plant, number of seeds/siliquae, seed weight/ plant and 1000-seed weight. Higher stover yield and harvest index was also recorded at 60 Kg S/ha which may be due to increased supply of sulphur and better translocation of photosynthesis from stover to seed leading to more accumulation of photosynthesis in seeds and thus increased harvest index. Khanpara *et al.* (1993) and Lallu *et al.* (1995) also emphasized that increasing levels of sulphur increased the seed yield of mustard.

Application of sulphur increased nitrogen content and their uptake in plants as well as in seeds. However, the maximum response was at 40 or 60 Kg S/ha, at different stages of the crop growth in different parts of the plant. The increase in nitrogen content may be attributed to the increased supply of sulphur to plants, which in turn resulted into profuse vegetative and root growth, thereby activating greater absorption of nitrogen from soil (Ahmad *et al.* 1998), Similarly the total uptake of nitrogen by the crop plant at different parts and seeds at harvest was also increased significantly with sulphur fertilization in comparison to no sulphur application during both the years. This increase in total uptake of nitrogen might be the outcome of increased nitrogen content and dry matter yields of different parts as well as increased seed and stover yields as a result of sulphur application. Similar findings were also reported by Aulakh *et al.* (1984) Rathore (1988) and Singh and Sharma (1993) in mustard.

The uptake of sulphur increased significantly at higher doses of sulphur fertilization i.e. upto 60 kg S/ha during both the years. The higher sulphur content in different plant parts at different stages and in seed and stover yield might have resulted in greater uptake of sulphur. Similarly, the total sulphur uptake in different plant parts and seeds at harvest increased mainly because of more sulphur content. Jhosi *et al.* (1991) in mustard also obtained similar results.

Oil content and oil yield of mustard increased significantly due to sulphur application. The percent increase in oil yield at 60 kg S/ha over control during 2015-16 and 2016-17. The increase in oil content might be attributed in increased availability of sulphur. The maximum percentage contribution in terms of oil yield was from primary branches during both the years. This was primarily because of more seed weight on primary branches, which showed maximum percent contribution in terms of oil yield also. Contrary to it oil content (%) in seeds present on main shoot had slightly higher value on account of longer period available for the development of seeds. Similarly, protein yield also increased with higher levels of sulphur fertilization. It may be noted that sulphur is an integral parts of mustard oil and therefore, it played a significant role in the synthesis of oil. Sulphur supply seems to be involved in an increased conversion of primary fatty acid metabolites to end product of fatty acid. Similarly, increased oil and protein yield were due to higher seed yield and oil content on account of increased sulphur supply Singh and Singh (1983) Tripathi and Sharma (1997) also reported significant increase in oil content and oil yield of mustard with the application of sulphur ranged between 3-5 percent.

The net returns and BCR increased with the increasing rates of sulphur application and the highest net returns and benefit cost ratio was obtained when sulphur was applied at 60 kg S/ha during both the years.

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