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Productivity, nutrients uptake and profitability of rapeseed (*Brassica napus* L.) as influenced by application of nitrogen and Sulphur in Mid-hills of Himachal Pradesh

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Abstract
A field experiment was conducted during *Rabi* season of 2021-22 at Chamelti Agriculture Farm, Shoolini University of Biotechnology and Management Sciences Solan (H.P.). Results of the experimental field were revealed that treatment N_4 was increased in seed, stover and biological yield to the tune of 12.66 and 25.20%, 9.48 and 21.5%, 10.18 and 22.36% as compared to N_3 and N_2, respectively. Besides S_4 was exhibited 4.32 and 11.05%, 6.70 and 10.61% and 6.14 and 10.71% increase in seed yield, stover yield and biological yield, respectively as compared to S_3 and S_2. Treatments N_4 and S_4 were recorded maximum oil content and oil yield followed by N_3 and S_3. Treatment S_4 was recorded to the tune of 0.24 and 20.45% more oil yield as compared to S_3 and S_2. The maximum gross returns, net returns and B:C ratio was recorded under treatments N_4 and S_4.

Keywords: Rapeseed, yield, uptake, nitrogen, sulphur

Introduction
Rapeseed (*Brassica napus* L.) is one of the most widely used oilseed crop and it belongs to the family of Brassicaceae or Cruciferae. Young plant leaves are used as green vegetables because they provide sulphur and nutrients to the diet. They are not only extraordinary in energy and fat-soluble vitamins A, D, E and K, but they also appear in meals and flavors, cosmetics and condiments, soap and detergents, lubricants, laxatives and are used in medicinal and therapeutic applications. Mostly Rapeseed is cultivated for edible oils but used as condiments, spices, leafy vegetables and as fodder for livestock and it's by product is used as feed for farm animals and as an organic manure in crop production. In the other hand, rapeseed oil contains 50% erucic acid and high levels of glucosinolates, lowering the nutritional value of rapeseed press cakes for animal feed.

The total area, production and productivity of rapeseed-mustard in world during 2019-20 was 35.95 m ha, 71.49 m t and 1990 kg ha^{-1}, respectively. India has attained a record food grain production of 305.44 mt during 2020-21. The total oilseeds production is expected to be 36.57 mt during 2020-21. Globally, India continues to be rank 2nd after Canada in acreage (19.81%) and 4th rank after Canada, European Union and China in production (10.37%). In India, states like Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, West Bengal, and Assam states are major grower of Rapeseed and accounts 86.72% of area and 89.53% of production in the country. Rajasthan alone contribute 41.44% to the total area and 45.03% to the production (Anonymous 2020-21) [3]. Rapeseed is responsive to plant nutrients especially for Nitrogen and Sulphur. Nitrogen is considered to be the most important nutrient for Rapeseed to activate the metabolic activity and transformation of energy, chlorophyll and synthesis of protein. Application of Sulphur is expressed in yield, oil content per cent and oil yield. It involved in the synthesis of essential amino acids like Cysteine, Cystine and Methionine (Piri and Sharma 2006 and Kumar and Yadav 2007) [17, 10].

Materials and Methods

The experiment was conducted at Chamelti Agriculture farm Shoolini University of Biotechnology and Management Sciences Solan (H.P). The experiment was laid out in Split Plot Design (SPD) with three replications, four Nitrogen levels *viz.*, N_1- Control, N_2- Nitrogen @ 40 kg ha^{-1}, N_3- Nitrogen @ 60 kg ha^{-1}, N_4- Nitrogen @ 80 kg ha^{-1}, four Sulphur levels *viz.*, S_1-Control, S_2- Sulphur @ 25 kg ha^{-1}, S_3- Sulphur @ 35 kg ha^{-1}, S_4- Sulphur @ 45 kg ha^{-1} and one Variety of Rapeseed Him Sarson-1 were tested.

Yield attributing characters

Total number of siliquae $plant^{-1}$ was recorded from five tagged plants at harvest. Mean of five plants was recorded as the number of siliquae $plant^{-1}$. Seeds of ten siliquae $plant^{-1}$ from randomly five tagged plants were recorded at harvest. Mean number of seeds of ten siliquae $plant^{-1}$ of five tagged plants was recorded as number of seeds $siliqua^{-1}$. Length of 10 randomly selected siliquae from main shoot, primary and secondary branches were measured and average length of siliquae was measured in cm. The weight of thousand seeds (g) was recorded from the seed samples drawn from the produce obtained from each of the net plot. From these, 1000-seeds were counted and weighed on an electric top pan balance and expressed in g.

Yield (kg ha^{-1})

At maturity all plants from each net plot were harvested. Seeds were separated, air dried, cleaned and weighed, seed yield ha^{-1} was worked out and expressed in q ha^{-1}. After threshing weight of stem and chaff $plot^{-1}$ was recorded and added treatment wise. These were converted to kg ha^{-1} by multiplying with appropriate conversion factor. The above ground portion of plants of net plot area after harvest were sun dried for about one week than weighed to work out the biological yield and expressed in terms of q ha^{-1}. Harvest index is the ratio of economic yield to the biological yield (harvest index) was computed using the following formula given by (Nichiporovich, 1967) [14].

$$\text{Harvest index (\%)} = \frac{\text{Economic Yield (Seed)}}{\text{Biological Yield (Seed + Stover)}} \times 100$$

Oil content of oven dried seeds was estimated by Soxhlet method against a standard reference sample (AOAC, 1990) [1]. 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 ha^{-1}.

Plant analysis

Method suggested by Piper, 1966 [16] (Modified Kjeldahl method) was used for estimation of Nitrogen content (%) in seed samples. The Vanadomolybdo phosphoric acid yellow color method as suggested by Jackson (1973) [6] was used for estimation of Phosphorus in digested plant samples obtained from crop. Potassium content (%) was estimated by Flame photometer method as suggested by Jackson (1973) [6]. Sulphur content (%) was estimated by turbidimetrically colorimetric method as suggested by Tabatabai and Brenner (1970) [24].

Nutrient uptake in both seed and stover samples were calculated by multiplying per cent nutrient content with their respective yield as per the formula given below:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x Yield (kg}^{-1}\text{)}}{100}$$

Economic

The cost of cultivation was calculated for different treatments on the basis of existing market prices of inputs and operations. The total cost was calculated by adding the expenditure incurred in all kinds of operations as per treatment on per hectare basis in terms of ₹ ha^{-1}. The gross returns were calculated by multiplying the total seed yield with prevalent market prices of the items and then they were presented in ₹ ha^{-1} basis as per the treatments. Treatment wise net returns were computed by deducting the total cost of cultivation from the gross returns. Benefit: Cost ratio was calculated by dividing net returns with the cost of cultivation for each treatment.

Results and Discussion

Yield attributing characters

Data pertaining to yield attributing characters *viz.*, length of silique (cm), number of silique $plant^{-1}$, seeds $silique^{-1}$ and test weight (g) were significantly affected by Nitrogen and Sulphur levels. The maximum silique length was recorded into N_4 followed by N_3 and N_2. However, the least silique length of Rapeseed was recorded into N_1. Among the Sulphur levels S_4 was recorded significantly higher silique length (11.12 cm) followed by S_3 and S_2 even though, the least silique length (8.61 cm) was recorded under S_1. Among the Nitrogen level, each successive increase in nitrogen level, the number of silique $plant^{-1}$ was increased and recorded significant difference. Maximum number of silique (547.17 $plant^{-1}$) was recorded under N_4 over N_3 and N_2. Though, the minimum number of silique (331.33 $plant^{-1}$) was recorded into N_1. Due to application of Sulphur, maximum number of silique (729.67 $plant^{-1}$) was recorded into S_4 over S_3 and S_2 while S_1 was recorded minimum number of silique (412.83 $plant^{-1}$). Significantly more number of seeds $silique^{-1}$ was recorded into N_4 which was recorded statistically at par with N_3 and N_2. Although, lesser number of seeds $silique^{-1}$ was recorded into Control. Among the Sulphur level, significantly more number of seeds $silique^{-1}$ was recorded under S_4 which was recorded statistically at par S_3 followed by S_2. Although, the lesser number of seeds $silique^{-1}$ was recorded under S_1. These results are closely related to Dongarkar *et al.* (2005) [5], Rimi *et al.* (2015) [21], Kalita *et al.* (2017) [8], Zangani *et al.* (2021) [26] and Kumar *et al.* (2021) [12].

Yield (q ha^{-1})

Rapeseed yield is the integration of physico-chemical processes occurring in the plant which in turn are influenced by environmental conditions and management practices. The economic yield of Rapeseed depend upon various factors *viz.*, siliqua length (cm), number of siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$ and test weight (g). Data pertaining to seed, stover and biological yield and harvest index of rapeseed were affected by application of different levels of Nitrogen and Sulphur and show a significant difference of Rapeseed. Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) recorded significantly higher seed yield (14.95 q ha^{-1}) of Rapeseed followed by Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2) with the value of 13.27 and 11.94 q ha^{-1}, respectively. However, lowest seed yield of Rapeseed was recorded in Control (N_1) Dongarkar *et al.* (2005) [5] and Kumar *et al.* (2011) [13]. The increase in seed and stover yield of Rapeseed was recorded because of increased in number of primary and secondary branches $plant^{-1}$ which ultimately increase in number of leaves $plant^{-1}$ and leaf area index which is resulted in higher photosynthesis leading to accumulation of more photosynthates which ultimately reflated in yield. Application of Sulphur levels had significant difference in seed yield of Rapeseed. The maximum seed yield (14.46 q ha^{-1}) of Rapeseed was recorded with application of Sulphur @ 45 kg ha^{-1} (S_4) followed by Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). Though, the lowest seed yield of Rapeseed was noticed in Control (S_1) plot which was received no Sulphur. This increment might be due to more accumulation of amino acids and amide substances and their translocation to the reproductive organs which influenced growth and yield due to application of Sulphur.

A scrutiny of the data revealed that among the Nitrogen levels, maximum stover yield (51.03 q ha^{-1}) of Rapeseed was recorded with application of Nitrogen @ 80 kg ha^{-1} (N_4) which was significantly superior to rest of the Nitrogen levels. Though, the minimum stover yield of Rapeseed was recorded in Control (N_1) followed by application of Nitrogen @ 40 kg ha^{-1} (N_2) and Nitrogen @ 40 kg ha^{-1} (N_3). The stover yield of Rapeseed was significantly affected by application of Sulphur levels and it was varied from 30.71 to 50.63 q ha^{-1}. The maximum stover yield of Rapeseed was recorded with the application of Sulphur @ 45 kg ha^{-1} (S_4) followed by Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). While, the minimum stover yield (30.71 q ha^{-1}) was recorded in Control (S_1). The increase in seeds and stover yield is because of increased number of leaf and leaf area with application of Nitrogen played an important role in synthesis of chlorophyll and amino acid which leads to increase in photosynthesis leading to accumulation of more photosynthates which is ultimately reflected in yield. Nitrogen influences source to sink relationship and in addition to higher production of photosynthates it leads to increase translocation to reproductive parts.

Biological yield of Rapeseed was significantly fluctuated by the levels of Nitrogen and Sulphur application during experimentation. Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) exhibited significantly higher biological yield (65.99 q ha^{-1}) of Rapeseed followed by Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). However, the lowest biological yield of Rapeseed was recorded in Control (N_1). Among the Sulphur levels, application of Sulphur @ 45 kg ha^{-1} (S_4) was produced significantly higher biological yield of Rapeseed as compared to application of Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). While, the lowest biological yield of Rapeseed was recorded in Control (S_1). This increase in yield because of application of Sulphur accumulates more amino acids and amide substances and their translocation to the reproductive organs which influence growth and yield. These results are corroborated with Dongarkar *et al.* (2005) [5], Keerthi *et al.* (2017) [9], Yadav *et al. (*2017) [25], Rajput *et al.* (2018) [20] and Agnihotri *et al.* (2021) [2].

Harvest index of Rapeseed was significantly influenced by application of Nitrogen and varied from 22.21 to 22.64%. The maximum harvest index (22.64%) of Rapeseed was recorded with the application of Nitrogen @ 80 kg ha^{-1} (N_4). While, the application of Nitrogen @ 60 kg ha^{-1} (N_3), Nitrogen @ 40 kg ha^{-1} (N_2) and Control (N_1) were recorded statistically at par with each other. Among the levels of Sulphur application, significantly higher harvest index (22.59%) of Rapeseed was recorded with the application of Sulphur @ 45 kg ha^{-1} (S_4). However, the application of Sulphur @ 35 kg ha^{-1} (S_3), Sulphur @ 25 kg ha^{-1} (S_2) and Control (S_1) were recorded statistically at par with each other during investigation.

Among the Nitrogen levels, the oil content (%) of Rapeseed was varied from 33.85 to 39.29%. The application of Nitrogen @ 80 kg ha^{-1} (N_4), Nitrogen @ 60 kg ha^{-1} and Nitrogen @ 40 kg ha^{-1} was increased to the tune of 5.44, 4.02 and 1.94% oil content as compared to Control (N_1). However, statistically lowest oil content (33.85%) of Rapeseed was recorded without application of Nitrogen *i.e.* Control (N_1). Among the Sulphur levels, the oil content (%) of Rapeseed was significantly affected by application of Sulphur and it was increased with the level of Sulphur was increased. Application of Sulphur @ 45 kg ha^{-1} (S_4), Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2) were increased to the tune of 6.89, 5.06 and 2.16% oil content over without application of Sulphur i.e. Control (S_1) which was recorded lowest oil content per cent.

Oil yield of Rapeseed is depending upon the levels of Nitrogen and Sulphur application and it was increased with increased in Nitrogen and Sulphur doses. Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} was recorded 17.34 and 39.11% more oil yield as compared to application of Nitrogen @ 60 kg ha^{-1} and Nitrogen @ 40 kg ha^{-1}, respectively. However, without application of Nitrogen N_1 (Control) was recorded lowest oil yield of Rapeseed during investigation with the value of 341.59 kg ha^{-1}. Application of Sulphur was significantly affect the oil yield of Rapeseed and it was increased as the level of Sulphur application was increased. Application of Sulphur @ 45 kg ha^{-1} (S_4), Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2) was recorded 91.78, 91.30 and 59.21% more oil yield of Rapeseed over Control (S_1). Oil content and oil yield were increased due to Application of Sulphur play an important role in formation of glycosides, glucosinolates and activation of enzymes which is a biochemical and hydrolysis reaction in plants which produce higher amount of oil as well as alkyl isothiocyanates which is responsible for pungency. Similar trend was observed by Kumar *et al*. (2011) [13], Jan *et al.* (2010) [7], and Raghuvanshi *et al.* (2018) [19].

Content per cent (Seeds and Stover)

Among the Nitrogen levels in respect of Nitrogen content per cent in seeds and stover of Rapeseed was recorded significant difference. Significantly higher Nitrogen content (2.97% in seeds and 0.46% in stover) of Rapeseed was recorded with application of Nitrogen @ 80 kg ha^{-1} (N_4) followed by Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2) however, minimum Nitrogen content (1.20% in seeds and 0.26% in stover) was recorded in Control (N_1). In respect of Sulphur application, significantly higher Nitrogen content (2.70% in seeds and 0.38% in stover) was recorded with application of Sulphur @ 45 kg ha^{-1} (S_4) which was remained at par with application of Sulphur @ 35 kg ha^{-1} (S_3) followed by Sulphur @ 25 kg ha^{-1} (S_2). Though, the lowest Nitrogen content (seeds and stover) was recorded in Control (S_1) during experimentation.

Phosphorus content per cent in seeds and stover was significantly affected by application of Nitrogen and Sulphur levels in stover. Maximum content per cent of Phosphorus in seeds and stover was recorded with application of Nitrogen @ 80 kg ha^{-1} (N_4) with the value of 0.53 and 0.27% in seeds and stover, respectively followed by application of Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). Though, the minimum content per cent of Phosphorus in seeds and stover was recorded in Control (N_1). Among the Sulphur levels in seeds, application of Sulphur @ 45 kg ha^{-1} (S_4) was registered maximum content per cent however, application of Sulphur @ 35 kg ha^{-1} (S_3), Sulphur @ 25 kg ha^{-1} (S_2) and Control (S_1) were recorded similar content per cent. In case of stover of Rapeseed, maximum content per cent of phosphorus was recorded with application of Sulphur @ 45 kg ha^{-1} (S_4) followed by Sulphur @ 35 kg ha^{-1} (S_3). However, application of Sulphur @ 25 kg ha^{-1}

(S_2) and Control (S_1) were recorded minimum content per cent.

Content per cent of potassium in seeds was significantly affected by Nitrogen and Sulphur levels. Application of Nitrogen @ 80 kg ha^{-1} (N_4) was registered maximum potassium content (0.58 and 0.87%) followed by Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). However, minimum potassium content per cent in seeds and stover was recorded in Control (N_1). Among the Sulphur levels, application of Sulphur @ 45 kg ha^{-1} (S_4) was recorded maximum potassium content per cent in seeds and stover followed by Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). However, minimum content per cent of potassium was recorded in Control (S_1).

Content per cent of Sulphur in seeds and stover of Rapeseed was significantly affected by application of Nitrogen and Sulphur levels. Maximum content per cent in seeds and stover was recorded with application of Nitrogen @ 80 kg ha^{-1} (N_4) followed by Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). However, minimum content per cent of Sulphur was recorded in Control (N_1). Sulphur content per cent in seeds and stover of Rapeseed was recorded significant difference. Application of Sulphur @ 45 kg ha^{-1} (S_4) was recorded maximum Sulphur content in seeds (0.408%) and stover (0.189%) followed by Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). Though, minimum content per cent in seeds and stover was recorded in Control (S_1).

Uptake (Seeds and Stover kg ha^{-1})

Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) was recorded significantly higher uptake in seeds (44.40 kg ha^{-1}) and stover (24.52 kg ha^{-1}) as compared to application of Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). Although, the minimum uptake of Nitrogen by seeds (11.95 kg ha^{-1}) and stover (9.08 kg ha^{-1}) were recorded in Control (N_1).

Uptake of phosphorus in seeds and stover was significantly affected application of Nitrogen and Sulphur levels. Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) was registered significantly more Nitrogen uptake and thereafter Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). Though, the minimum phosphorus uptake was recorded under Control (N_1) with the value of 4.92 and 6.49 kg ha^{-1} in seeds and stover, respectively. The application of Sulphur @ 45 kg ha^{-1} (S_4) was registered significantly more phosphorus uptake followed by Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). However, Control (S_1) was recorded least phosphorus uptake in seeds and stover with the value of 4.45 and 6.67kg ha^{-1}, respectively.

Uptake of potassium in seeds and stover of Rapeseed was significantly affected by application on Nitrogen and Sulphur levels. Among the Nitrogen level, application of Nitrogen @ 80 kg ha^{-1} (N_4) was registered significantly higher potassium uptake which was remained at par with application of Nitrogen @ 60 kg ha^{-1} (N_3) except seeds followed by Nitrogen @ 40 kg ha^{-1} (N_2) although, minimum potassium uptake was recorded in Control (N_1). Among the Sulphur levels, application of Sulphur @ 45 kg ha^{-1} (S_4) was registered significantly higher uptake in seeds and stover therefore application of Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). While, minimum potassium uptake of Rapeseed was recorded in Control (S_1).

Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) was recorded significantly highest Sulphur uptake in seeds and stover followed by Nitrogen @ 60 kg ha^{-1} (S_3) and Nitrogen @ 40 kg ha^{-1} (N_2). While, lowest Sulphur uptake in seeds and stover of Rapeseed was recorded in Control (N_1). Among the Sulphur levels, application of Sulphur @ 45 kg ha^{-1} (S_4) was recorded significantly highest Sulphur uptake in seeds and stover followed by application of Sulphur @ 35 kg ha^{-1} (S_3), Sulphur @ 25 kg ha^{-1} (S_2) and lowest Sulphur uptake in seeds and stover of Rapeseed was recorded in Control (S_1).

Total uptake (kg ha^{-1})

Total uptake of Nitrogen was influenced by application of Nitrogen and Sulphur levels. Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) was recorded significantly higher total Nitrogen uptake with the value of 68.91 kg ha^{-1} followed by Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). Though, the minimum total Nitrogen uptake was recorded with the value of 21.04 kg ha^{-1} in Control (N_1). Among the Sulphur levels, application of Sulphur @ 45 kg ha^{-1} (S_4) was recorded significantly higher total Nitrogen uptake with the value of 64.34 kg ha^{-1} followed by Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). However, the minimum total Nitrogen uptake was recorded in Control (S_1) with the value of 16.93 kg ha^{-1}. Kumar *et al.* (2011) [13].

Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) was registered 19.53 and 44.41% more total phosphorus uptake as compared to application of Nitrogen @ 60 kg ha^{-1} and Nitrogen 40 kg ha^{-1}, respectively. Though, the minimum total phosphorus uptake (11.42 kg ha^{-1}) was registered in Control (N_1). The levels of Sulphur, application of Sulphur @ 45 kg ha^{-1} (S_4) was registered 8.65 and 15.84% more total phosphorus uptake as compared to application of Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2). However, the least total phosphorus uptake (11.11 kg ha^{-1}) was recorded in Control (S_1).

Among the Nitrogen levels, application of Nitrogen @ 80 kg ha^{-1} (N_4) was registered 15.43 and 28.84% more total potassium uptake as compared to application of Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2), respectively. However, minimum total potassium uptake was recorded in Control (N_1) with the value of 31.61 kg ha^{-1}. Among the Sulphur levels, application of Sulphur @ 45 kg ha^{-1} (S_4) was increased in total potassium uptake to the tune of 9.18 and 19.03% as compared to application of Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2), respectively. While, minimum total potassium uptake 29.53 kg ha^{-1} was registered in Control (S_1).

Among the Nitrogen and Sulphur levels, total Sulphur uptake was registered significant difference. Application of Nitrogen @ 80 kg ha^{-1} (N_4) was increased to the tune of 21.47 and 51.12% over application of Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2), respectively. However, minimum total Sulphur uptake was recorded in Control (N_1).

Application of Sulphur @ 45 kg ha^{-1} (S_4) was registered significantly increased in total Sulphur uptake to the tune of 9.21 and 17.66% over application of Sulphur @ 35 kg ha^{-1} (S_3) and Sulphur @ 25 kg ha^{-1} (S_2), respectively. However, lowest total Sulphur uptake in seeds and stover of Rapeseed was recorded in Control (S_1). Similar trend was observed by Kumar *et al.* (2011) [13], Pradhan *et al.* (2017) [18], Chaurasiya *et al.* (2019) [4] and Sharma *et al.* (2020) [23].

Economics (₹ ha^{-1})

Among the levels of Nitrogen application, maximum cost of cultivation (22683 ₹ ha^{-1}) of Rapeseed was recorded with application of Nitrogen @ 80 kg ha^{-1} (N_4) followed by Nitrogen @ 60 kg ha^{-1} (N_3) and Nitrogen @ 40 kg ha^{-1} (N_2). However, the minimum cost of cultivation was recorded in control (N_1). Cost of cultivation was fluctuated by application of Sulphur, maximum cost of cultivation (22415 ₹ ha^{-1}) of Rapeseed was recorded with application of Sulphur @ 45 kg ha-1 (S_4) followed by Sulphur @ 35 kg ha-1 (S_3), Sulphur @ 25 kg ha-1 (S_2). Whereas, the minimum cost of cultivation was recorded in Control (S_1).

The gross return of Rapeseed was fluctuated by application of Nitrogen and Sulphur. Among the Nitrogen level, application of Nitrogen @ 80 kg ha-1 (N_4), Nitrogen @ 60 kg ha-1 (N_3) and Nitrogen @ 40 kg ha-1 (N_2) were fetched 50.43, 33.46 and 19.45%, respectively more gross return as compared to Control (N_1). However, application of Sulphur @ 45 kg ha-1 (S_4), Sulphur @ 35 kg ha-1 (S_3) and Sulphur @ 25 kg ha-1 (S_2) was fetched 65.25, 58.41 and 48.78% more gross return as compared to Control (S_1) during experimentation.

The net return (₹ ha-1) was varied with the level of Nitrogen and Sulphur application. Application of Nitrogen @ 80 kg ha-1 (N_4), Nitrogen @ 60 kg ha-1 (N_3) and Nitrogen @ 40 kg ha-1 (N_2) was fetched 63.40, 36.99 and 16.38% more net return as compared to without application of Nitrogen i.e. Control (N_1). Although, the application of Sulphur @ 45 kg ha-1 (S_4) was fetched maximum net return (44855 ₹ ha-1) followed by Sulphur @ 35 kg ha-1 (S_3) with the value of 42183 ₹ ha-1 and Sulphur @ 25 kg ha-1 (S_2) with the value of 38373 ₹ ha-1**.** However, lowest net return (23156 ₹ ha-1) of Rapeseed was recorded in Control (S_1) during investigation.

Benefit cost ratio of Rapeseed was affected by application of Nitrogen and Sulphur. Among the Nitrogen level, maximum B:C ratio (2.07) of Rapeseed was recorded with application of Nitrogen @ 80 kg ha-1 (N_4) followed by Nitrogen @ 60 kg ha-1 (N_3) (1.75) and Control (N_1) (1.63) similar trend was observed by Kumar *et al.* (2011) [13]. Though the minimum B:C ratio (1.51) of rapeseed was recorded with application of Nitrogen @ 40 kg ha-1 (N_2) with the value of 1.51. Among the Sulphur level, application of Sulphur @ 45 kg ha-1 (S_4) was recorded maximum B:C ratio (2.00) followed by Sulphur @ 35 kg ha-1 (S_3) with the value of 1.89 and Sulphur @ 25 kg ha-1 (S_2) with the value of 1.73 similar trend was observed by Kumar *et al.* (2011) [13]. However, minimum B:C ratio (1.32) of Rapeseed was recorded in Control (S_1) during experimentation. Similar trend was observed by Ojha *et al.* (2018) [15], Kumar *et al.* (2018) [11] and Sharma *et al.* (2022) [22].

Table 1: Effect of Nitrogen and Sulphur levels on yield attributing characters of Rapeseed

Treatments	Siliqua length (cm)	Siliqua plant-1	Seeds siliqua-1	Test weight (g)
Nitrogen levels				
N_1	9.27	331.33	16.42	2.85
N_2	9.88	377.17	18.08	3.26
N_3	10.30	431.17	19.58	3.66
N_4	10.82	547.17	20.50	3.91
S.Em±	0.07	3.20	0.81	0.04
CD (P=0.5)	0.24	11.29	2.85	0.14
Sulphur levels				
S_1	8.61	412.83	17.92	3.31
S_2	9.91	419.75	18.42	3.35
S_3	10.63	424.58	18.67	3.46
S_4	11.12	429.67	19.58	3.56
S.Em±	0.08	0.55	0.38	0.02
CD (P=0.5)	0.24	1.62	1.13	0.05

Table 2: Yield (seed, stover and biological), harvest index oil content per cent and oil yield of Rapeseed as influenced by various levels of Nitrogen and Sulphur

Treatments	Yield (q ha-1)			Harvest index (%)	Oil content (%)	Oil yield (kg ha-1)
	Seed	Stover	Biological			
Nitrogen levels						
N_1	9.94	34.91	44.85	22.21	33.85	341.59
N_2	11.94	42.00	53.94	22.22	35.79	429.14
N_3	13.27	46.61	59.89	22.21	37.87	508.75
N_4	14.95	51.03	65.99	22.64	39.29	596.99
S.Em±	0.23	0.74	0.95	0.08	0.28	9.61
CD (P=0.5)	0.81	2.63	3.38	0.28	0.97	33.91
Sulphur levels						
S_1	8.75	30.71	39.46	22.21	33.17	292.15
S_2	13.02	45.77	58.79	22.21	35.33	465.14
S_3	13.86	47.45	61.32	22.26	38.24	558.90
S_4	14.46	50.63	65.09	22.59	40.06	560.29
S.Em±	0.13	0.43	0.54	0.09	0.43	8.88
CD (P=0.5)	0.40	1.28	1.58	0.28	1.27	26.07

Table 3: Effect of Nitrogen and Sulphur levels on N, P, K and S content per cent in seed and stover of Rapeseed

Treatments	N content (%)		P content (%)		K content (%)		S content (%)	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Nitrogen levels								
N_1	1.20	0.26	0.50	0.19	0.51	0.76	0.389	0.135
N_2	1.89	0.30	0.51	0.21	0.54	0.83	0.402	0.161
N_3	2.64	0.39	0.52	0.24	0.56	0.83	0.407	0.192
N_4	2.97	0.46	0.53	0.27	0.58	0.87	0.414	0.221

S.Em±	0.06	0.01	0.02	0.01	0.01	0.05	0.002	0.002
CD (P=0.5)	0.20	0.05	NS	0.04	0.03	NS	0.006	0.008
Sulphur levels								
S_1	0.93	0.28	0.51	0.22	0.52	0.80	0.398	0.164
S_2	2.18	0.36	0.51	0.22	0.52	0.81	0.401	0.174
S_3	2.57	0.38	0.51	0.23	0.55	0.84	0.405	0.182
S_4	3.01	0.39	0.52	0.24	0.59	0.85	0.408	0.189
S.Em±	0.09	0.01	0.00	0.00	0.01	0.02	0.000	0.001
CD (P=0.5)	0.26	0.03	0.01	NS	0.03	NS	0.001	0.004

Table 4: Effect of Nitrogen and Sulphur levels on uptake of N, P, K and S in seed and stover of Rapeseed

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
Nitrogen levels								
N_1	11.95	9.08	4.92	6.49	5.04	26.57	3.87	4.71
N_2	22.58	12.75	6.05	8.99	6.39	34.95	4.80	6.76
N_3	34.98	18.40	6.89	11.28	7.39	38.74	5.40	8.95
N_4	44.40	24.52	7.94	13.78	8.69	44.56	6.19	11.28
S.Em±	0.92	0.65	0.24	0.73	0.10	2.42	0.10	0.15
CD (p =0.5)	3.24	2.30	0.84	2.58	0.36	8.55	0.35	0.53
Sulphur levels								
S_1	8.17	8.76	4.45	6.67	4.56	24.97	3.48	5.04
S_2	28.43	17.06	6.66	10.25	6.71	36.62	5.22	7.96
S_3	35.35	18.48	7.07	10.96	7.57	39.67	5.57	8.64
S_4	43.90	20.44	7.54	12.05	8.64	42.94	5.95	9.57
S.Em±	1.451	0.41	0.10	0.25	0.15	1.05	0.06	0.08
CD (p =0.5)	4.43	1.19	0.29	0.72	0.45	3.07	0.18	0.23

Table 5: Effect of Nitrogen and Sulphur levels on total uptake of N, P, K and S in Rapeseed

Treatments	Total N uptake (kg ha^{-1})	Total P uptake (kg ha^{-1})	Total K uptake (kg ha^{-1})	Total S uptake (kg ha^{-1})
Nitrogen levels				
N_1	21.04	11.42	31.61	8.58
N_2	35.33	15.04	41.33	11.56
N_3	53.36	18.17	46.13	14.35
N_4	68.91	21.72	53.25	17.47
S.Em±	1.17	0.96	2.38	0.24
CD (p= 0.5)	4.12	3.40	8.38	0.85
Sulphur levels				
S_1	16.93	11.11	29.53	8.52
S_2	45.50	16.91	43.33	13.19
S_3	53.83	18.03	47.24	14.21
S_4	64.34	19.59	51.58	15.52
S.Em±	1.51	0.33	1.07	0.12
CD (p= 0.5)	4.44	0.97	3.14	0.36

Table 6: Effect of Nitrogen and Sulphur levels on profitability of Rapeseed

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C Ratio
Nitrogen levels				
N_1	17551	46236	28685	1.63
N_2	22145	55529	33384	1.51
N_3	22411	61709	39298	1.75
N_4	22683	69556	46873	2.07
Mean	21197	58257	37060	1.75
Sulphur levels				
S_1	17551	40707	23156	1.32
S_2	22193	60566	38373	1.73
S_3	22304	64487	42183	1.89
S_4	22415	67270	44855	2.00
Mean	21116	58257	37141	1.76

Conclusion

On the basis of experimental findings, it can be concluded that application of Nitrogen @ 80 kg ha^{-1} (N_4) along with Sulphur @ 45 kg ha^{-1} (S_4) was exhibited maximum yield attributing characteristics, yield and nutrients uptake. Besides, it also increases gross returns, net returns and B:C ratio over application of Nitrogen @ 40 and 60 kg ha^{-1} similarly application of Sulphur @ 25 and 35 kg ha^{-1} and control.

References

1. AOAC. Official methods of analysis (12th Edition), William Sterwetzled, publications. Washington, DC; c1990. p. 506-508.
2. Agnihotri D, Shanker S, Maurya SP. Effect of Nitrogen levels on Growth and Productivity of Mustard (*Brassica juncea* L.) Varieties. Techno fame - A Journal of Multidisciplinary Advance Research. 2021;10(2):31-33.
3. Anonymous. Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan (August 06-07-2021); c2020-21.
4. Chaurasiya A, Singh S, Singh V, Singh N, Singh A. Effect of nitrogen and sulphur nutrition on interaction effect, quality parameters, nutrient content or uptake & economics of Indian mustard (*Brassica juncea* L.) in Western UP. International Journal of Conservation Science. 2019;7(1):787-791.
5. Dongarakar KP, Pawar WS, Khawale VS, Khutate NG, Gudadhe NN. Effect of Nitrogen and Sulphur on Growth and Yield of Mustard (*Brassica juncea* L.). Journal of Soils and Crops. 2005;15(1):163-167.
6. Jackson. Estimation of P in digested plant samples obtained from crop was used; c1973.
7. Jan A, Ahmad G, Arif M, Jan MT, Marwat KB. Quality parameters of canola as affected by nitrogen and Sulphur fertilization. Journal of Plant Nutrition. 2010;33(3):381-390.
8. Kalita S, Mundra SL, Solanki NS, Sharma NK. Weed management and Nitrogen Application for improved yield of mustard. Indian Journal of Weed Science. 2017;49(1):85-87.
9. Keerthi P, Pannu RJ, Dhaka AK, Chaudhary K. Effect of sowing time nitrogen on growth, yield and nutrient uptake by Indian mustard (*Brassica juncea* L.) under western Haryana. Chemical Science Review and Letters. 2017;6(24):2526-2532.
10. Kumar H, Yadav DS. Effect of phosphorus and Sulphur levels on growth, yield and quality of Indian mustard (*Brassica juncea* L.) cultivars. Indian Journal of Agronomy. 2007;52(2):154-7.
11. Kumar M, Singh PK, Yadav KG, Chaurasiya A, Yadav A. Effect of nitrogen and sulphur nutrition on growth and yield of Indian mustard (*Brassica juncea* L.) in western UP. Journal of Pharmacognosy and Phytochemistry. SP. 2018;(1):445-448.
12. Kumar PP, Singh R, Khan W, Ahmed S. Effect of Sulphur levels and spacing on yield attributes and economics of yellow mustard (Sinapis alba). The Pharma Innovation Journal. 2021;10(8):1131-1134.
13. Kumar S, Verma SK, Singh TK, Singh S. Effect of Nitrogen and Sulphur on growth, yield and nutrient uptake by Indian mustard (*Brassica juncea*) under rainfed condition. Indian Journal of Agricultural Sciences. 2011;81(2):145-9.
14. Nichiporovich AA. Aims of research on photosynthesis of plants as a factor of soil productivity. In: Nichiporovich, AA (Ed.). Photosynthesis of productive system. Israel Programme Science Trans Jerusalem; c1967. p. 3-36.
15. Ojha RB, Basyal B, Khanal B, Pande KR. Nitrogen-sulphur use economics in rapeseed productivity at Rampur, Chitwan, Nepal. Advances in Plants & Agriculture Research. 2018;8(4):312-316.
16. Piper CS. Sprotein and Plant Analysis. International Science Publication, John Willey and Sons. Inc. New York; c1966.
17. Piri I, Sharma SN. Effect of levels and source of Sulphur on yield attributes, yield and quality of Indian mustard (*Brassica juncea* L.). Indian Journal of Agronomy. 2006;51(3):217-20.
18. Pradhan SS, Bohra JS, Pradhan S, Verma S. Effect of fertility level and cow urine application as basal and foliar spray on growth and nutrient uptake of Indian mustard (*Brassica juncea*). Ecology environment and conservation. 2017;23(3):1549-1553.
19. Raghuvanshi N, Kumar V, Dev J. Effect of nitrogen levels on mustard (*Brassica juncea* L.) Cuzern and Cross varieties under late sown condition. Current Journal of Applied Sciences and Technology. 2018;30(2):1-8.
20. Rajput RK, Singh S, Varma J, Rajput P, Singh M, Nath S. Effect of different levels of nitrogen and sulphur on growth and yield of Indian mustard (*Brassica juncea* L.) czerny and coss.) In salt affected soil. Journal of Pharmacognosy and Phytochemistry. 2018;7(1):1053-1055.
21. Rimi TA, Islam MM, Siddik MA, Islam S, Shovon SC, Parvin S. Response of seed yield contributing characters and seed quality of rapeseed (*Brassica compestris* L.) to nitrogen and zinc. International Journal of Scientific and Research Publication. 2015;5(11):187-193.
22. Sharma AK, Samuchia D, Sharma PK, Mandeewal RL, Nitharwal PK, Meena M. Effect of Nitrogen and Sulphur in the Production of the Mustard Crop (*Brassica juncea* L.). International Journal of Environment and Climate Change. 2022;12:132-137.
23. Sharma S, Chaudhray S, Singh R. Effect of boron and sulphur on growth, yield and nutrient uptake of mustard (*Brassica juncea* L.). International journal of chemical studies. 2020;8:1998-2001.
24. Tabatabai MA, Brener JM. A simple turbidimetric method of determining total Sulphur in plant material. Agronomy Journal. 1970;62:805-806.
25. Yadav KG, Kushwaha C, Singh PK, Kumar M, Yadav SK, Nishant. Effect of nutrient management on yield and nutrient uptake by Indian mustard (*Brassica juncea* L). Journal of Pharmacognosy and Phytochemistry. 2017;SP1:556-559.
26. Zangani E, Afsahi K, Shekari F, Mac SE, Mastinu A. Nitrogen and phosphorus addition to soil improves seed yield, foliar stomatal conductance and photosynthetic response of rapeseed (*Brassica napus* L.). Agriculture. 2021;11(6):483.