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INTERACTIVE EFFECT OF SULPHUR AND NITROGEN ON GROWTH, YIELD AND QUALITY OF INDIAN MUSTARD (*BRASSICA JUNCEA* L.)

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ABSTRACT
The experiments were conducted during *Rabi* seasons of 2009-10 and 2010-11 at Research Farm of Directorate of Rapeseed and Mustard Research (DRMR), Sewar, Bhartpur (Rajasthan),India To achieve this objective, the different levels of sulphur (0,20,40,60 kg ha^{-1}) and nitrogen (0, 40, 80, 120 kg ha^{-1}) fertilization experiment was laid out in randomized complete block design consisting of three replications and data regarding various growth and yield parameters of Indian mustard were recorded using the standard procedures. The results revealed that the highest seed yield (2606.21 kg ha^{-1}) was obtained in T_7 (60 kg ha^{-1} S and 120 kg ha^{-1} N) followed by T_6 (40 kg ha^{-1} S and 120 kg ha^{-1} N) treatment which gave 2588.91 kg ha^{-1} seed yield while minimum seed yield (1417.02 kg ha^{-1}) was recorded in case of control *i.e*. with no S and N. Oil content progressively increased with increase of S level with N highest (41.73%) with a S level of 40 kg ha^{-1}. Glucosinolate content increased from 15.8 to 20.9 µmol/g as S rate was increased from 0 to 40 kg ha^{-1}.

KEY WORDS: Fertilizer, Nitrogen, Oil content; Protein content, Seed yield; Sulphur.

INTRODUCTION

High demands for food due to rapidly increasing population and changes in dietary habits are increasing pressure on agriculture. To meet the food requirements of this increased population, India is spending billions of dollars for importing food commodities, out of which edible oil is the single largest food item. Globally, India ranks 3rd in production after China and Canada contributing 14.8 %. The contribution of rapeseed-mustard to the total oilseed production in India is 26.0%, respectively. Domestic production of edible oils meets only 50% of the total requirements, while rest is imported. Huge gap between the consumption and domestic production of edible oils can be filled up by increasing the area under oilseed crops like rapeseed and mustard, sunflower and soybean or increasing production per unit area. India has ever increasing population. According to an estimate, it is going to reach 1.29, 1.36, 1.42 and 1.48 billion by 2015, 2020, 2025 and 2030 from 1.21 billion in 2011.Similarly, the living standard is also increasing resulting in enhanced per capita edible oil consumption. The annual growth of demand for edible oil would be 3.54% during 2011-2030. Accordingly, it is estimated that the per capita edible oil consumption would be 23.1 kg/annum by the year 2030 from the present level of 13.4 kg. Therefore, to attain the self-sufficiency in edible oil 34.1mt of edible oil equivalent to about 102.3 mt of oilseeds would be required. Productivity and quality of oilseed crops can possibly be improved by adopting better agronomic practices and replacing conventional rapeseed and mustard varieties, which has the potential to fit in the current cropping systems due to its premium quality oil (Starner, 1999; Manaf & Hassan, 2006) Considering about 20% contribution from sources like rice bran, cotton seed, palm oil, coconut and other tree-borne oilseeds, the edible oil requirement from annual oilseeds to meet the domestic demand would be 81.8 mt by 2030. If the contribution of rapeseed-mustard to the total annual oilseeds production is considered 20-25%, then production of 16.4-20.5mt rapeseed-mustard would be required. This target could be achieved through area expansion and/or increase in productivity of rapeseed-mustard. Among many agronomic factors responsible for low yield, imbalanced and injudicious use of fertilizers also limits the crop production. Sulphur has been reported to influence productivity of oil seed (Singh *et al*., 1999). Similarly, Biswas *et al*.(1995) reported that application of S fertilizer increased the seed yield of mustard. Higher rate of nitrogen application at sowing leads to more rapid leaf area development, prolong the life of leaves, improves leaf area duration after flowering and increases overall crop assimilation thus contributing to increased seed yield (Wright *et al.*, 1988). Sulphur (S) is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorous and potassium (Jamal *et al*., 2010). Several authors are of the opinion that oilseeds not only respond to applied S, but their requirement for S is also the highest among other crops, thereby attributing a role for the nutrient in oil biosynthesis (Fazili *et al.*, 2005; Ahmad *et al*., 2007; Munshi *et al*., 1990).There is ample evidence that the plant nutrients, S and N are involved in enhanced nitrate reductase activity in plants (Jamal *et al*., 2007; Ahmad *et al*., 2007). Nitrate reductase (NR) is the enzyme, which is involved in nitrogen metabolism, play important role in amino acid biosynthesis and regulates the protein synthesis (Nair and Abrol, 1977; Harris *et al*., 2000). Sulphur (S) and nitrogen (N) are closely related, synergistic and of vital importance for plants because S is part of a major constituent of amino acids, which in turn constitute the building blocks of proteins (Ceccotti, 1996). A strong interaction between sulphur and nitrogen for seed and oil production in oilseed crops has been reported by Abdin *et al.(*2003), Jamal *et al.* (2006), Farahbakhsh *et al.(*2006), Malhi *et al.* (2007), Fazil *et al*. (2010b), Sattar *et al*. (2011). It is, therefore, likely that the interaction between S and N metabolism is stronger in oilseed crops. Though experiment is able to demonstrate the essentiality of sulphur nutrition in optimizing seed and oil yield of Indian mustard, they provide significant information about the interactive effect of S and N application on growth and yield attributes in the Indian mustard differing in their yield potential. Keeping this in view the present studies were carried out to determine the interactive effects of sulphur and nitrogen on the growth, yield and oil quality of Indian mustard crop.

MATERIALS & METHODS

The experiments were conducted during *Rabi* seasons of 2009-10 and 2010-11 at Research Farm of Directorate of Rapeseed and Mustard Research (DRMR), Sewar, Bhartpur (Rajasthan),India (27.15^0N Lat.77.30^0E Long. 178.37 m asl). Temperature and rainfall etc. data for the growing period have depicted in Fig. I.

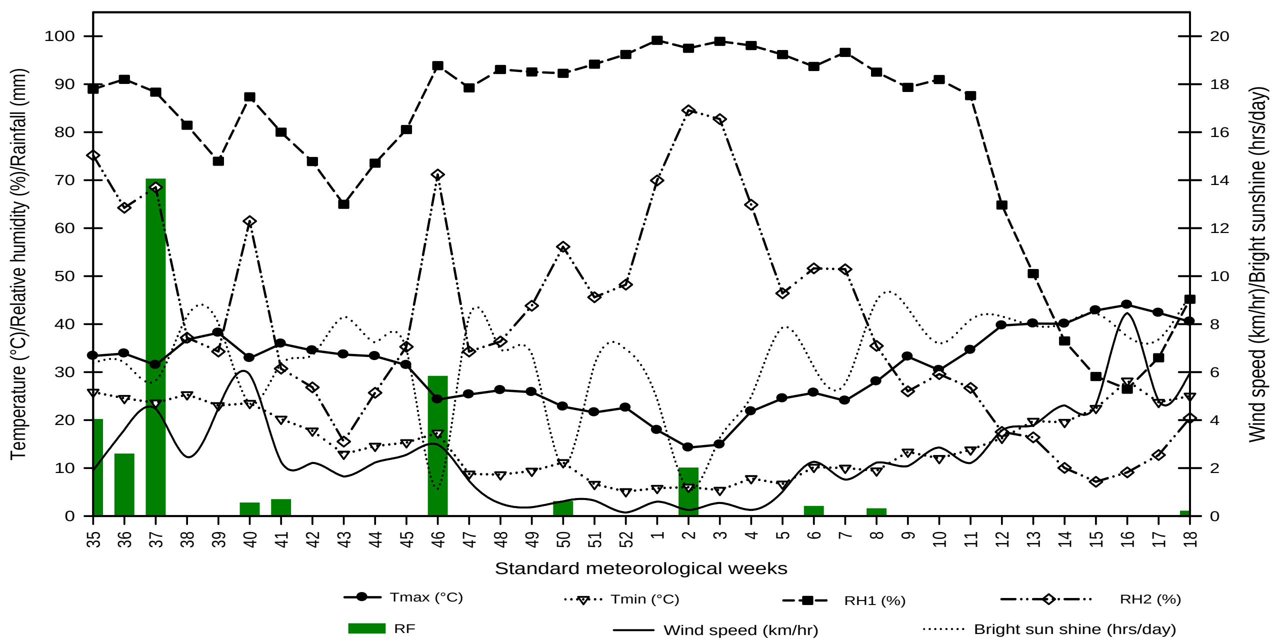

FIGURE 1: Weather conditions of the experimental sites at DRMR, Bharatpur

Before sowing the Indian mustard crop, soil samples were taken for physical and chemical analysis. Soil samples were collected from the experimental soil with the help of a soil auger to a depth of 0-30 cm prior to fertilizer application. Composite samples were air dried ground and passed through a 2 mm sieve and got analyzed for the physico-chemical properties. The soils are generally low to medium in organic matter content. Soil with a pH =7.9, total C =8.3 g kg^{-1}, total N=0.83 g kg^{-1}, Olsen P=28 mg kg^{-1}, and K=128 mg kg^{-1}. The experiment comprised of the following treatments as 0,20,40,60 kg ha^{-1} S and 0, 40, 80,120 kg ha^{-1}N. The experiment was laid out in randomized complete block design (RCBD) with consisting of three replications. Before seedbed preparation, pre-sowing irrigation of 10 cm was applied. When soil reached to proper moisture level seedbed was prepared. Sowing was done with the help of single row hand drill in 30 cm spaced rows using seed rate of 5 kg ha^{-1} and an interplant distance of 15 cm was maintained by thinning at 4-6 leaf stage. Crop was sown on October 16 and 12 and was harvested on March 10 and 16 in 2009-10 and 2010-11, respectively. Phosphorus @ 60 kg ha^{-1} was applied to all plots. Urea, SOP & MOP was used as a source of N, P and S. A standard dose for phosphorus (60 kg ha^{-1}), sulphur and half of nitrogen was side dressed at the sowing time and remaining half nitrogen was top dressed at flowering stage with irrigation. All other agronomic practices were kept normal and uniform for all the treatments. Plant protection measures were adopted to keep the crop free from weeds, insect pests and diseases. Crop was harvested when more than 50% siliquae were turned brown and was left in respective plots for almost one week for sun-drying. Sun-dried crop was threshed manually 4-6 days after harvesting depending upon the intensity of sunlight. Seed and biomass yield from the whole plots were measured and converted into kg ha^{-1}.Five plants were randomly selected from each plot for recording average plant height per plant, number of branches per plant and number of siliquae per plant. Twenty five siliqua were randomly selected from these five plants to calculate average number of seeds per siliqua. For determination of protein contents seed sample were taken randomly from each plot, ground and subjected to chemical analysis by using gunning and Hibbard's method of H_2SO_4 digestion and using Micro Kjeldahl's method for distillation (Jackson, 2000). From this whole process N % is obtained which then multiplied with a constant factor of 6.25 for protein content in the seed. Data collected from the experiments was analyzed statistically by using Analysis of Variance as described by Nageswar RG (1983).

RESULTS & DISCUSSION

Analysis of variance shows that plant height (cm) and all yield and yield components like number of siliqua per plant, number of seeds siliqua, 1000-seed weight (g), seed yield (kg ha^{-1}) biological yield (kg ha^{-1}) were significantly affected by the interactive effect of sulphur and nitrogen. Maximum plant height (155.9 cm) was recorded in treatment T_7 (60+120) followed by T_6 (40+120) with plant height (155.3 cm) while minimum plant height (131.7 cm) was observed in case of control T_1 (0+0). Maximum number of siliqua per plant (283.4) and number of seeds per siliqua (23.95) were recorded in treatment T_7 (60+120) that were statistically at par with T_6 (40+120) while minimum number of siliqua per plant and number of seeds per siliqua were recorded in case of control having the value of 226.2 and 12.62,respectively. Highest 1000-seed weight (3.76 g) was observed in treatment T_7 (60+120) followed by the treatment T_6 (40+120) whereas; minimum 1000-seed weight (3.20 g) was recorded in control T_1 (0+0). In case seed and biological yield maximum was recorded in treatment T_7 (60+120) whose value was 2606.21 kg ha^{-1} and 8146.25 kg ha^{-1}, respectively. Minimum seed and biological yield was recorded in control (Table 1). In T_5 (40+80) maximum harvest index (HI) was recorded that was followed by the treatment T_4 (20+80) whereas minimum HI was recorded in control.

TABLE 1: Interactive effect of sulphur and nitrogen on yield and yield components of Indian mustard

Treatments S+N kg ha^{-1}	Height (cm)	Number of siliqua $plant^{-1}$	Seed $siliqua^{-1}$	Seed weight (g) $plant^{-1}$	1000 seed weight (g)	Seed yield kg ha^{-1}	Biological yield kg ha^{-1}	Harvest index %
T_1 0+0	131.7 d	226.1 e	12.62 d	16.1 d	3.20 e	1417.02 f	5259.57 d	26.94 f
T_2 0+40	135.3 cd	241.5 d	15.20 cd	16.2 c	3.33 de	1669.73 e	5844.06 c	28.57 e
T_3 20+40	138.8 c	251.9 c	15.65 c	16.4 c	3.42 cd	1912.26 d	6123.62 c	31.23 d
T_4 20 +80	144.1 b	259.3 c	19.43 b	16.7 b	3.53 bcd	2306.08 c	7194.76 b	32.05 ab
T_5 40+80	147.0 b	267.3 b	20.15 b	16.8 b	3.62 abc	2441.93 b	7269.98 b	33.59 a
T_6 40+120	155.3 a	282.2 a	23.32 a	17.2 a	3.74 ab	2588.91 a	8155.07 a	31.75 c
T_7 60+120	155.9 a	283.4 a	23.95a	17.9 a	3.76 a	2606.21 a	8146.25a	31.99 bc

Means followed by the same letters within a column do not differ significantly ($P< 0.05$).

Growth attributes are the primary requirement for the development of the yield components: number of siliqua per plant, number of seeds per siliqua and 1000-seed weight. Yield components are positively correlated with seed yield (Jamal *et al.*, 2006; Farahbakhsh *et al*., 2006). These findings clearly indicate that crop supplied with balanced doses of S and N during growth and development produced the optimum number, size and length of siliqua per plant, because of the availability of more photoassimilates. The improvement in growth and yield attributes after combined application of S and N led to higher seed and biological yield (Table 1).The crop to produce an economic yield depends not only on the size of photosynthetic system, its efficiency, and the length of time for which it is active but also on translocation of dry matter into seed yield (Eriksen and Mortensen, 2002; Fazili *et al.*, 2010a; 2010b). Hence, harvest index is an important trait in determining economic yield and represents an increased physiological capacity to mobilize photosynthates and translocate them to organs of economic value (Jamal *et al*., 2006; Malhi *et al*., 2007). In case of quality parameters, application of sulphur and nitrogen enhanced the oil and protein contents and glucosinolate content. Maximum oil contents (41.37) of Indian mustard were recorded in T_6 followed by the treatment T_5 while lowest oil content (38.31) was observed in control treatment (Table 2).

TABLE 2: Interactive effect of sulphur and nitrogen on Oil content (%), glucosinolate content (µmol/g) and of Indian mustard

Treatments S+N kg ha^{-1}	Seed oil content %	Protein content %	Glucosinolate content (µmol/g)
T_1 0+0	38.31 g	19.32 f	15.8 e
T_2 0+40	39.32 f	20.14 e	16.5 d
T_3 20+40	39.41 e	20.44 d	18.0 c
T_4 20 +80	40.24 c	20.53 c	18.8c
T_5 40+80	40.57 b	20.88 b	19.0b
T_6 40+120	41.73 a	20.92 ab	19.9 b
T_7 60+120	40.02 d	21.16 a	20.9 a

Means followed by the same letters within a column do not differ significantly ($P< 0.05$).

Highest protein contents (21.16) were obtained in treatment T_7 which was statistically at par with treatment T_6 (Table 2) while lowest protein contents (19.32) were recorded in control treatment (T_1). Perusal of the data revealed that interactive effect of N and S significantly affected glucosinolate content of Indian mustard. Significantly higher value of the glucosinolate contents (20.9 µmol/g) were found in the treatment T_7 (60+120) nutrition as compared to control plots (15.8 µmol/g) Table 2.Glucosinolate contents increased from 16.5 to 19.0 µmol/g as N rate increased from 40 to 80 kg N ha^{-1}. Similarly, glucosinolate contents increased from 16.5 to 19.9 µmol/g when S rate increased from 0 to 40 kg S ha^{-1} indicating that the increase due to S rate was much higher than the increase due to N rates. Significant N×S interaction indicated that glucosinolate content increased with increase in both S and N and higher glucosinolate content was recorded in the plots that received 40 kg S ha^{-1} and 120 kg N ha^{-1}. Jan *et al.,* 2010, observed large increases in oil and protein concentrations at 40 kg S ha^{-1} while they did not notice further significant increase with increasing S level (60 kg Sha^{-1}). However, authors observed consistent increase in glucosinolate concentrations with the highest level of 60 kg Sha^{-1}. The application of 160 kg Nha^{-1} resulted in significant increase in protein contents while glucosinolate contents were found increased up to 120 kg Nha^{-1}. Moreover, oil concentrations were exhibited a negative trend to increasing N level.

The increase in seed protein content of Indian mustard with the application of N and S could be due to the fact that N is an integral part of protein and the protein of mustard contains relatively large quantities of the S containing amino acids like methionine and cystine (Gardner *et al*., 1985). The increase in protein content with the increase in N rate confirmed the findings of Kutcher *et al*. (2005) who found that protein contents of mustard increased significantly with the increasing N rates.The results obtained are in agreement with the earlier findings of Malhi and Leach (2000) who stated that applied S increased protein content of canola. Results reveal that oil content was higher when N and S were applied in combination (Table 1). The N:S ratio in the whole plant in general is 20:1 (Cram, 1990). Janzen and Bettany (1984) indicated the optimum ratio of available N to available S to be 7:1. Ratios below 7 gave the reduced seed yields. A rapeseed and mustard crop under field conditions recovered 27-31% of added S without N, but 37-38% with 60 kg N ha^{-1} (Sachdev and Deb, 1990). Sulfur and nitrogen both are required for the synthesis of protein, therefore, the ratio of total N to total S in plant tissue can reflect the ability of N and S in protein synthesis (Brunold and Suter, 1984). Thus, a change in the ratio of reduced-N to reduced-S (NR/SR), which is a reflection of the amount of S amino acids, suggests that protein metabolism has been significantly altered and has important implications for protein quality (Friedrich and Schrader, 1978).

CONCLUSION

Application of 120 kg ha^{-1} N and 40 kg ha^{-1} S would be a better combination for higher seed yield and oil content.

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