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Effect of Sulphur and Row Spacing on Growth and Yield of Yellow Mustard (*Sinapis alba)*

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ABSTRACT: A field study was carried out at Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, SHUATS, Prayagraj (U.P.) in *Rabi* 2020 to study the effect of sulphur and row spacing on development and yield of yellow mustard. Sulphur plays a vital part in chemical composition of seed and increases the percentage of oil content of seed. The experimental site was uniform in topography and sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in Organic carbon (0.38%), medium available N 225 kg ha^{-1}, higher available P 19.50 kg ha^{-1} and medium available K 213.7 kg ha^{-1}. The treatments which are Sulphur levels at (30 kg S/ha, 45 kg S/ha and 60 kg S/ha) and spacing (40×20 cm, 50×20 cm and 60×20 cm) was used. The research was placed out in Randomized Block Design through nine treatments each replicated thrice. Between all the treatments, application of 60 kg S with 60 cm row spacing noted maximum plant height (96.38 cm), branches (13.33), dry weight (19.28 g), siliquae per plant (139.33), seeds per siliquae (43.09), and test weight (3.28 g) while application of S 60 kg with 40 cm row spacing recorded maximum grain yield (1.60t/ha), stover yield (5.92t/ha) and Harvest Index (22.38 %).

Keywords: Yellow Mustard, Sulphur (S), Row Spacing, siliquae and seed yield.

INTRODUCTION

Yellow Mustard (*Sinapis alba*) is an important oilseed crop belongs to family Cruciferae (Brassicaceae). Crucifers holding high amounts of glucosinolates have a high Sulphur demand (Rakesh *et al*., 2016). Among seven edible oilseeds cultivated in India, rapeseed-mustard backs 28.6% in the total oilseeds production also ranks second after groundnut sharing 27.8% in the India's oilseed economy.

Major mustard produce states in India Rajasthan (40.82%), Haryana (13.33%), Madhya Pradesh (11.76%), Uttar Pradesh (11.40%), West Bengal (8.64%) according to 2018-19 year (Rathi *et al*., 2019). The seeds are highly nutritive comprising 38-57% erucic acid, 5-13% linoleic acid and 27% oleic acid. They are not only rich sources of energy and carriers of fat soluble vitamins A, D, E and K but they form the ingredients of foods and flavour's, cosmetics and condiments, soap and detergents, lubricants and laxatives and also known for their medical and therapeutic use (Chauhan *et al*., 2020).

Sulphur is a secondary plant nutrient which plays a significant role in increasing production specially in oil seed crops. Yellow mustard crop stay predominantly sensitive to sulphur deficiency mostly due to the fact that sulphur plays a vital part in chemical composition of seed and increases the percentage of oil content of seed. Sulphur increases the oil content and gives pungency to oil as it forms certain disulphide linkages (Khan *et al*., 2002).

Among the sources, application of gypsum increased the seed yield of mustard as compared with single super phosphate. Application of S in combination with balanced quantities of other nutrients significantly increased the oil content of mustard (5-6%) (Verma *et al*., 2018).

Row Spacing play an important role in enhancing complete production of crops as it is possible to affect interception, absorption, penetration and utilization of incoming solar radiation. Plant density is another important character, which can be used to achieve the maximum production from per unit area. The ideal plant density with suitable Spacing is dependent on variety, its growth habit and agro-climatic environment (Sondhiya *et al*., 2019). It is important to adjust plant population through Row Spacing which might help in avoiding unnecessary crowding. Higher plant population per unit area beyond an optimal limit results in competition between the plants for natural resources, resulting weaker plant and may cause severe lodging (Jangir *et al*., 2017).

MATERIALS AND METHODS

The present examination was carried out during *Rabi* 2020 at Crop Research Farm, Department of

Agronomy, SHUATS, Prayagraj, U.P., which is located at 25.28°N latitude, 81.54°E longitude and 98 m altitude above the mean sea level. Super goldy variety used for sowing yellow mustard.

The experiment placed out in Randomized Block Design which consisting of nine treatments with T1: 30 kg/ha Sulphur + 40×20 cm, T2: 30 kg/ha Sulphur + 50×20 cm, T3: 30 kg/ha Sulphur + 60×20 cm, T4: 45 kg/ha Sulphur + 40×20 cm, T5: 45 kg/ha Sulphur + 50×20 cm, T6: 45 kg/ha Sulphur + 60×20 cm, T7: 60 kg/ha Sulphur + 40×20 cm, T8: 60 kg/ha Sulphur + 50×20 cm, T9: 60 kg/ha Sulphur + 60×20 cm were replicated thrice.

The experimental site was uniform in topography and sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in Organic carbon (0.38%), medium available N (225 kg ha^{-1}), higher available P (19.50 kg ha^{-1}) and medium available K (213.7 kg ha^{-1}). Nutrient sources were Urea, DAP, MOP to fulfill the necessity of Nitrogen, phosphorous and potassium. Gypsum used to fulfill the requirement of sulphur. The application of fertilizers were applied as basal at the time of sowing. Nitrogen applied as split dose half as basal dose remaining as top dressing. In the period from germination to harvest several plant growth parameters were recorded at frequent intervals along with it after harvest several yield parameters were recorded those parameters are growth parameters, plant height, branches per plant and plant dry weight are recorded. The yield parameters like siliquae/plant, seeds/siliquae, grain yield, 1000 seed weight, stover yield and harvest index were recorded and statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design (Gomez K.A. and Gomez A.A. 1984).

RESULTS AND DISCUSSION

Effect of sulphur and Row spacing on plant height in yellow mustard: Data in Table 1, tabulated the plant height (cm) of yellow mustard and there was increasing in plant height improved with the development of research. The plant height was significantly higher in different growth intervals with levels of Sulphur (S) and Spacing. At harvest, $T_9$60 kg/ha S + 60×20 cm recorded maximum plant height (96.38 cm). However, plant height (95.51 cm) with T_8 60 kg/ha S + 50×20 cm, 94.27 cm T_6 45 kg/ha S + 60×20 cm and (93.90 cm) with T_7 60 kg/ha S + 40×20 cm were statistically at par with T_9 compared to other treatments. The possibility in increase in plant height due to widest (increased) plant spacing might be due to the fact that the increased spacing between plants resulted in enhanced space, sun-light, nutrients and soil moisture for increased photosynthesis, metabolic activities, growth and development (Sondhiya *et al*., 2019) and presence of Sulphur plays vital role in increased metabolic uses of sulphur in plants which seems to have promoted meristematic activities resulting in higher apical growth and expansion of photosynthetic surface (Negi *et al*., 2017).

Effect of sulphur and Row spacing on branches in yellow mustard: Data in Table 1, tabulated the branches per plant of yellow mustard and there was increasing in crop age branches was enhanced with the advancement of experimentation. The branches per plant were significantly higher in all different growth intervals with levels of Sulphur (S) and Spacing. At harvest, T_9 which is 60 kg/ha S + 60×20 cm recorded significantly maximum number of branches/plant (13.33). However, in T_8, T_6 which are 60 kg/ha S + 50×20 cm and 45 kg/ha S + 60×20 cm statistically at par to the T_9 which is 60 kg/ha S + 60×20 cm. Increase of Sulphur fertilization up to 60 kg/ha significantly increased the number of branches/plant due to known role of sulphur to enhanced photosynthesis, as sulphur is involved in the formation of chlorophyll and activation of enzymes (Negi *et al.*, 2017) and under widest (increased) plant spacing between plants resulted in enhanced space, sun-light, nutrients and soil moisture for increased photosynthesis, metabolic activities, growth and development (Kumari *et al*., 2012).

Table 1: Effect of Sulphur and row Spacing on growth attributes of yellow mustard.

Sr. No.	Treatments	Plant height (cm)	No. of Branches	Dry weight (g)	CGR (g/m^2/day)
1.	Sulphur 30 kg/ha + 40×20 cm	82.42	9.40	17.32	2.35
2.	Sulphur 30 kg/ha + 50×20 cm	84.89	10.47	17.45	1.77
3.	Sulphur 30 kg/ha + 60×20 cm	88.58	10.80	17.76	1.31
4.	Sulphur 45 kg/ha + 40×20 cm	86.01	10.60	17.63	2.02
5.	Sulphur 45 kg/ha + 50×20 cm	92.27	11.43	17.96	1.56
6.	Sulphur 45 kg/ha + 60×20 cm	94.27	12.67	18.49	1.23
7.	Sulphur 60 kg/ha + 40×20 cm	93.90	12.50	18.24	1.86
8.	Sulphur 60 kg/ha + 50×20 cm	95.51	13.23	18.75	1.50
9.	Sulphur 60 kg/ha + 60×20 cm	96.38	13.33	19.28	1.30
F- test		S	S	S	S
S. EM (±)		0.13	0.83	0.24	0.38
C. D. (P = 0.05)		0.38	2.50	0.71	1.13

Effect of sulphur and Row spacing on dry weight (g), CGR (g/m^2/day) and RGR (g/g/day) in yellow mustard

Data in Table 1 tabulated the plant dry weight (g) of yellow mustard and there was increasing in plant dry weight better with improvement of experimentation. The plant dry weight was significantly higher in all different growth intervals with levels of Sulphur (S) and Spacing. At harvest, T_9 (60 kg/ha S + 60×20 cm) recorded significantly maximum dry weight (19.28 g). However, 18.75 g in T_8 (60 kg/ha S + 50×20 cm), 18.49 g in T_6 (45 kg/ha S + 60×20 cm) and 18.24 g in T_7 (60 kg/ha S + 40×20 cm) were statistically at par with T_9 (60 kg/ha S + 60×20 cm). At harvest, maximum crop growth rate (2.35 g/m^2/day) was observed inT_1 (Sulphur 30 kg/ha + 40×20 cm). However 2.02 g/m^2/day in T_4 (Sulphur 45 kg/ha + 40×20 cm) and 1.86g/m^2/day inT_7 (Sulphur 60 kg/ha + 40×20 cm) which were at par with the T_1 (Sulphur 30 kg/ha + 40×20 cm).

Presence of sulphur plays a vital role which stimulates the chloroplast protein synthesis and higher synthesis of chloroplast results in better photosynthetic efficiency and finally increased dry matter production/plant (Jyothi *et al.,* 2012). Similar result was reported by (Negi *et al*., 2017).

Effect of Sulphur and Row spacing on No. of siliquae/plant, seeds/siliquae and test weight (g) in yellow mustard.

Number of Siliquae/plant: Data in Table 2 tabulated the no. of siliquae per plant of yellow mustard and there was increasing in number of siliquae per plant was improved with the advancement of experimentation. Maximum number of siliquae/plant (139.33) was recorded in T_9 (60 kg/ha S + 60×20 cm). However, 138.80 siliquae/plant in T_8 (60 kg/ha S + 50×20 cm), 137.90 in T_6 (45 kg/ha S + 60×20 cm) and 133.80 in T_7 (60 kg/ha S + 40×20 cm) which were statistically at par with T_9 (60 kg/ha S + 60×20 cm). The increment in number of siliquae/plant with increasing dose of sulphur application might be better for root growth, cell multiplication, elongation and cell expansion in the plant body by higher dose of sulphur application, which finally increased the seed yield (Chauhan *et al*., 2020). Similar results also reported by (Jat *et al*., 2007).

No. of Seeds/siliquae: Data in Table 2 tabulated the no. of seeds/siliquae of yellow mustard and there was increasing in number of seeds/siliquae was improved with the advancement of experimentation. Highest number of seeds/siliquae (43.09) was recorded in T_9 (60 kg/ha S + 60×20 cm). However, (42.47) in T_8 (60 kg/ha S + 50×20 cm), (42.33) in T_6 (45 kg/ha S + 60×20 cm) and (41.87) in T_7 (60 kg/ha S + 40×20 cm) which were statistically at par with T_9 (60 kg/ha S + 60×20 cm). The present result revealed that sulphur application 60 kg/ha recorded significantly at harvest, number of seeds/siliquae. Increase the value of these yield contributing characters with higher doses of sulphur was due to the evidences that the adequate sulphur was available during the entire period of crop growth for better vegetative growth and development of mustard plant (Singh *et al*., 2010).

Test weight (g): Data in Table 2 tabulated the test weight of yellow mustard and there was increasing in test weight (g) was improved with the advancement of experimentation. Maximum test weight (3.09 g) recorded in T_9 (60 kg/ha S + 60×20 cm). However, 3.09 g T_8 (60 kg/ha S + 50×20 cm), 3.08 in T_7 (60 kg/ha S + 40×20 cm) and 3.01 g in T_6 (45 kg/ha S + 60×20 cm)which were statistically at par with T_9 (60 kg/ha S + 60×20 cm). Results clearly show that crop provided with sulphur during growth and development produced the optimum number, size and length of siliquae, because of the availability of more photoassimilates stimulated by optimum supply. As well, an increased supply of photosynthates to siliquae would also provide an opportunity for seeds to grow to their full potential, with an apparent increase in test weight as observed (Rana *et al*., 2005).

Table 2: Effect of Sulphur and row spacing on yield attributes of yellow mustard.

Treatments	Siliquae/plant	Seeds/Siliquae	Test weight (g)
1. 30 kg/ha S + 40×20 cm	124.00	40.33	2.73
2. 30 kg/ha S + 50×20 cm	126.33	40.37	2.84
3. 30 kg/ha S + 60×20 cm	129.40	40.70	2.92
4. 45 kg/ha S + 40×20 cm	128.43	40.53	2.86
5. 45 kg/ha S + 50×20 cm	131.10	41.20	2.94
6. 45 kg/ha S + 60×20 cm	137.90	42.33	3.01
7. 60 kg/ha S + 40×20 cm	133.80	41.87	3.08
8. 60 kg/ha S + 50×20 cm	138.80	42.47	3.09
9. 60 kg/ha S + 60×20 cm	139.33	43.09	3.28
F- test	S	S	S
S. EM (±)	3.29	0.61	0.09
C. D. (P = 0.05)	9.85	1.83	0.28

Effect of Sulphur and row spacing on yield, yield attributes in yellow mustard: Data in Table 3 tabulated the yield, yield attributes of yellow mustard and there were increasing seed yield (1.60 t/ha) and stover yield 5.92 t/ha) which are recorded maximum with the application of T_7 which is (60 kg/ha Sulphur + 40×20 cm) which was significantly higher. Sulphur (S) 60, 45 kgha^{-1} + 40×20 cm, 50×20 cm recorded seed yield (1.57, 1.54 t/ha) and stover yield (5.74, 5.64 t/ha) respectively which were statistically at par with (60 kg/ha Sulphur + 40×20 cm).

Although in the harvest index maximum recorded through application of 30 kg S/ha + 50×20 cm and minimum recorded with Sulphur 60 kg/ha + 60×20 cm.

The increase in grain yield was mainly due to increase in the plant population per unit area due to closer spacing between plants. Though wider spacing rows the yield attributes where the plants received increased space, light, nutrients and moisture (Sondhiya *et al.*, 2019). Sulphur also stimulates the pod setting, seed formation and oil synthesis in the seed of mustard and it increases the biological, seed and stover yields of mustard (Singh *et al*., 2010).

Table 3: Effect of Sulphur and row spacing on yield, yield attributes of yellow mustard.

Treatments	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1. 30 kg/ha S + 40×20 cm	1.46	5.10	22.29
2. 30 kg/ha S + 50×20 cm	1.33	4.64	22.38
3. 30 kg/ha S + 60×20 cm	1.29	4.55	22.17
4. 45 kg/ha S + 40×20 cm	1.54	5.64	21.47
5. 45 kg/ha S + 50×20 cm	1.47	5.31	21.77
6. 45 kg/ha S + 60×20 cm	1.38	4.94	21.83
7. 60 kg/ha S + 40×20 cm	1.60	5.92	21.38
8. 60 kg/ha S + 50×20 cm	1.57	5.74	21.48
9. 60 kg/ha S + 60×20 cm	1.49	5.50	21.30
F- test	S	S	NS
S. EM (±)	0.02	0.09	0.38
C. D. (P = 0.05)	0.07	0.26	-

Fig. 1. (a &b). Field layout preparation before seed sowing at crop research; **(c & d).** Top dressing at 45DAS and spraying of insecticide at crop research farm.

CONCLUSION

On basis of present research, suggests that application of 60 kg S/ha + Spacing 60×20 cm resulted highest plant height (96.38 cm), number of branches per plant (13.33), siliquae/plant (139.33), seeds/siliquae (43.09) where as application of Sulphur (S) 60 kg/ha + Spacing 40×20 cm resulted maximum seed yield of (1.60 t/ha), stover yield (5.92 t/ha) and harvest index (22.38 %).

FUTURE SCOPE

Since, the findings were based on the research done in one season under agro-ecological conditions of Prayagraj it may be repeated for confirmation and farmer recommendations.

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Conflict of Interest. None of the authors of this paper features a financial or personal relation with people or organizations that would inappropriately influence or bias the content of the paper. We pledge you that the content of the paper is never been published.

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