International Journal of Science, Environment and Technology, Vol. 6, No 1, 2017, 236 – 247

ISSN 2278-3687 (O)
2277-663X (P)

EFFECT OF TWO SULPHUR SOURCES ON GROWTH, YIELD AND NUTRIENT USE EFFEICIENCY OF BRASSICA

Ankita Negi, Navneet Pareek*, K.P. Raverkar and Ramesh Chandra
Department of Soil Science, College of Agriculture
G.B. Pant University of Agriculture and Technology, Pantnagar
U.S. Nagar, Uttarakhand, PIN-263 145
E-mail: pareeknav@gmail.com (**Corresponding Author*)

Abstract: An experiment was conducted at N.E. Borlaug Crop Research Centre, GBPUA&T, Pantnagar, in sandy loam soil during *rabi* season of 2010 to evaluate effect of either zypmite or gypsum for sulphur on mustard crop. Treatments comprised of combinations of two sources (zypmite and gypsum) and three levels (20, 40 and 60 kg ha^{-1}) of sulphur along with a control (no sulphur) replicated 03 times in randomized block design. The plant height and dry weight were significantly affected by different treatments at 60 DAS. Significant increase in number of branches per plant number of siliqua per plant, test seed weight and straw yield over control were recorded by 60 kg S ha^{-1} applied through zypmite. Grain yield showed numerical increase of 14.50% over control with 60 kg S ha^{-1} applied through zypmite.
Keywords: Mustard, Sulphur Sources, Zypmite, Gypsum.

Introduction

Sulphur is the fourth major plant nutrient after nitrogen (N), phosphorus (P) and potassium (K). Under sulphur deficient conditions, the efficiency of applied NPK fertilizers may be seriously affected and crop yield levels are not sustainable (Ahamd *et al.* 1994). Continuous removal of sulphur from soils through plant uptake has led to widespread sulphur deficiency and affected soil sulphur budget (Aulakh, 2003) all over the world. Nutritionally *Brassica* species in general require more sulphur during their growth (Zhao *et al.,* 1993), for the synthesis of both protein and naturally occurring glucosinolates. Both sulphur uptake and sulphur translocation in oilseeds vary as a function of growth stage and plant part. Oilseeds are particularly sensitive to sulphur deficiency as they require relatively more sulphur. Nitrogen and sulphur both are involved in plant protein synthesis. The shortage in sulphur supply for crops decreases the N-use efficiency of fertilizers (Ceccoti, 1996). The aim of this research work was to study the suitability of zypmite and gypsum as sulphur sources and their effect on nutrient and yield parameters in mustard crop.

*Received Dec 23, 2016 * Published Feb 2, 2017 * www.ijset.net*

Material and methods

The experiment was conducted during *rabi* season of 2010 at N. E. Borlaug Crop Research Centre, GBPUA&T, Pantnagar. Study area is located at 29°N latitude, 79.3°E longitude and an altitude of 243.8 m above mean sea level in the *Tarai* belt of Shivalik range of the Himalayan foothills. Two sulphur sources, zypmite and gypsum at 20, 40 and 60 Kg ha^{-1} doses were applied as basal. Plant height (cm) was recorded by selecting five plant samples randomly and tagged in each plot. Height of these plants was measured from ground level to the tip of the main stem at 60 and 90 days after sowing (DAS) and at harvest. Plant height data were averaged for per plant and reported in centimeters. Shoot samples were taken at 60 and 90 DAS washed with distilled water and first dried in air under fan. For oven dry weight, shoot samples were dried in hot air oven at 65-70°C till constant weight was attained and results were expressed in gram per plant. The total number of primary and secondary branches of three randomly tagged plants was counted at harvest in all the treatments. The mean of three plants was expressed as the number of primary and secondary branches per plant. At maturity, all plants were air dried and weighed to calculate biological yield. Seeds were separated, air dried, cleaned, weighed and data were recorded as grain yield and expressed as replicates mean in kg ha^{-1}. The stover yield was calculated by subtracting the grain yield from the biological yield of the respective plots and expressed as kg ha^{-1}.

Total number of siliqua was recorded from three tagged plants per plot at harvest. Means of three replicates were recorded and expressed as the number of siliqua produced per plant. Length of ten siliqua per plant from randomly tagged three plants was recorded at harvest. Mean of ten siliqua per plant was recorded as length of siliqua per plant.

Seeds of only five siliqua per plant from randomly tagged three plants were recorded at harvest. Mean number of seeds of five siliqua per plant was recorded as number of seeds per siliqua. The weight of thousand grains (g) was recorded from the grain samples drawn from the produce obtained from each of the net plot.

The ground grain and straw samples from each plot were digested in concentrated H_2SO_4 for total N and in di-acid mixture for total S. Total nitrogen content was analyzed following micro-kjeldahl method (Page *et al.*, 1982). Total S content was estimated by recording the absorbance for diluted plant digest along with some complex mixture on spectrophotometer at 420 nm, and computed the concentration of sulphur in diluted plant digest with the help of standard curve. The uptake of nitrogen in grain and straw was computed by using the given formula:

Nutrient uptake in grain/straw (kg ha^{-1}) =

Grain/straw yield (kg ha^{-1}) × Nutrient content of grain /straw (%) × 10^{-2}

Result and discussion

Effect on plant growth parameters

Plant height: The plant height and dry weight increased with crop age, maximum being near harvest time (Table-1). The plant height at 60 DAS was affected significantly with doses and ranged from 132.7 to 167.4 cm. At 60 DAS significant increases of 21.3 and 26.1 % in plant height was recorded with 40 and 60 kg sulphur applied with zypmite and 25.4% with 60 kg S ha^{-1} with gypsum over control. While at 90 DAS and at harvest plant height did not differ significantly with any of the S doses irrespective of its sources (Table 1).

Significant increase in plant height with the increasing levels of sulphur may be attributed to increased metabolic uses of sulphur in plants which seems to have promoted meristematic activities resulting in higher apical growth and expansion of photosynthetic surface. Zypmite contains some of the micronutrients as impurities in it may have some stimulatory effect in fast cell division and higher apical growth of the mustard. Steffenson, (1954) attributed stimulatory effect of sulphur to faster cell division showing increased height of shoot in mustard. Results of the resent study corroborated closely with the findings of Tomer *et al.* (1997) found that application of sulphur @ 60-90 kg ha^{-1} significantly increased plant height of mustard. Khan *et al.* (2004) reported that plant height of canola was highly significantly affected by S application. Cheema *et al.* (2011) also assessed the influence of different levels of sulphur (0, 20, 40, 60 kg ha^{-1}) fertilization on canola (*Brassica napus* L.) and reported the highest plant height (165.9 cm) with 60 kg S ha^{-1} due to the effect of S.

Plant dry matter: The plant dry matter of mustard crop varied between 41.4 to 72.9 g and 98.8 to 128.8 g at 60 and 90 DAS, respectively with different treatments (Table 1). Application of 40 and 60 kg S ha^{-1} through zypmite and gypsum significantly increased the plant dry matter accumulation at 60 DAS and highest increase of 76.2 and 65.5 per cent, respectively recorded at 60 kg S ha^{-1} over control.

The effects of S sources and doses on plant dry matter at 90 DAS was statistically non-significant, however highest numerical increase of 30.3 % was recorded with 60 kg S ha^{-1} with zypmite (Table. 1). The results were in accordance with the findings of Piri *et al.* (2012) who reported that the increase in the plant dry matter content may be due to increased availability of sulphur to plants because of application of different levels of sulphur, which stimulates the chloroplast protein synthesis and higher synthesis of chloroplast results in greater photosynthetic efficiency and ultimately increased dry matter production per plant. Zypmite is a micronutrient mixture, other than sulphur it also contains zinc, boron, calcium and magnesium. This might have helped in increasing the overall growth of the plant and plant dry matter. De and Nad, (1993) also observed that application of 45 kg S ha^{-1} significantly increased dry matter production of mustard. The results obtained further draws support from findings of Mishra and Agarwal, (1994) by reporting the similar trend in soybean crop.

Number of branches per plant: Application of 40 and 60 kg S ha^{-1} through zypmite significantly increased the number of branches per plant registering 28.6 and 47.6% increase over control respectively. The highest number of branches per plant i.e. 31 was obtained with the 60 kg S ha^{-1} applied through zypmite (Table. 2).

Rana *et al*. (2001) found that application of 40 kg S ha^{-1} significantly increased the number of primary branches in taramira cultivar. Piri *et al*. (2012) explained that the increase in number of primary branches of plant due to 45 kg S ha^{-1} may be due to enhanced photosynthesis, as sulphur is involved in the formation of chlorophyll and activation of enzymes.

Siliqua length: The highest siliqua length was observed with 60 kg S ha^{-1} applied through zypmite followed by gypsum at the dose sulfur registering 13.4 and 15.3 per cent increase numerical, respectively (Table 2). However increase use increased pod length from 6.4 to 15.3 per cent and through gypsum by 1.8 and 13.4 per cent over control.

The increase in pod length with increasing level of sulphur could be attributed to the role of sulphur in growth and development of oilseeds (Khalid *et al*. 2009). Mc Grath and Zhao, (1996) reported that sulphur is mainly responsible for enhancing the reproductive growth and the proportion of the reproductive tissues (inflorescences and pods) in total dry matter ontent in rapeseed.

Number of siliqua per plant: Number of siliqua per plant also affected significantly with the application of both sulphur sources and different levels of sulphur applied. Siliqua per plant in mustard ranged in between 299.3 in control and 484.3 at 60 kg S ha^{-1} applied through gypsum (Table 2). Application of 40 and 60 kg S ha^{-1} through gypsum significantly increased the number of siliqua per plant, by 54 and 62 per cent, respectively over control.

These results are in accordance with the findings of the early workers Rathore and Manohar (1989), Malik *et al*. (2004) exhibited that different S levels added through different S sources in different soils significantly numerically increased the number of siliqua per plant S ha^{-1} was applied as compare to control.

Test weight: The highest increasing test weight of mustard seeds varied between 2.99 to 3.92 g with (1000 seed weight) due to different treatments (Table 2). Both 40 and 60 kg S ha^{-1} irrespective of sources significantly increased weight test weight by 31.1 per cent was observed in the treatment where 60 kg S ha^{-1} applied through zypmite.

These findings clearly indicate that crop supplied with S during growth and development produced the optimum number, size and length of pods per plant, because of the availability of more photoassimilates stimulated by optimum supply. Besides, an increased supply of photosynthates to pods would also provide an opportunity for seeds to grow to their full potential, with an obvious increase in 1000-seed weight as observed in our study. With the results of Malhi *et al.* (2005), Sattar *et al.* (2011) who reported that 1000-seed weight of mustard increased with the increasing level of sulphur upto 60 kg ha^{-1}corroborate.

Effect on biological yield

Straw and grain yield: The straw yield of mustard ranged between 1634.3 to 1912.7 kg ha^{-1}. Application of 40 and 60 kg S ha^{-1} irrespective S source significantly increased straw yield and zypmite showed highest increase of 17.03 per cent in straw yield over control and followed by gypsum source, 20 kg S ha^{-1} through both the S sources numerically increased straw, yields over control (Fig. 1).

The grain yield increased numerically with difficulties. Grain yield of mustard was ranged between 1390 to 1594 kg ha^{-1} with different treatments and the highest yields 14.6% more over control was obtained with 60 hg S ha^{-1} applied through zypmite. Gypsum also increased grain yield by 7.9, 9.0 and 13.6 per cent over control with 20, 40 and 60 kgS ha^{-1}, respectively. Jat *et al*. (2003) also reported an increased in foliage yield of mustard with increasing sulphur levels. The increases in obtained present study were also in agreement with the findings of Piri *et al*. (2012) who stated that may be due to the effect of suphur in increasing growth attributes and grain.

In present study application of sulphur also resulted improvement in growth and yield parameters and therefore, finally increased the seed and straw yield. These findings are in accordance with the earlier reports of Tiwari *et al*. (2000). Similar trends in result were also reported by Ravi *et al*. (2008) who found the higher seed yield (1553 kg ha^{-1}) with the higher sulphur level (30 kg ha^{-1}) and the lowest seed yield in control (1172 kg ha^{-1}) in safflower. Ravi *et al*. (2008) further suggested about the difference in the seed yield was largely because of variations in the yield components *viz.*, number of capsules per plant, seed weight per head and 1000-seed weight. Cheema *et al*. (2001) findings were also in accordance to our findings that the highest seed yield i.e. 3406.21 kg ha^{-1} was obtained with 60 kg S ha^{-1} followed by 40 kg S ha^{-1} treatment which gave 3388.91 kg ha^{-1} seed yield while minimum seed yield (1417.02 kg ha^{-1}) was recorded in case of control.

Effect on nutrient use efficiency by mustard

Straw sulphur content and uptake: Recommended dose of fertilizer with different levels of sulphur at 40 and 60 kg ha^{-1} produced significant results over control in both the sources. Sulphur content in straw was found minimum 0.10 per cent in control, and increased with application of sulphur through both the sources. The content in straw ranged form 0.12 to 0.24 per cent in sulphur applied treatments (Fig. 2).

Sulphur uptake by straw ranged from 1.6 kg ha^{-1} to 4.67 kg ha^{-1} reflecting the increases in straw yields with different treatments. Sulphur uptake (kg ha^{-1}) in mustard with both sulphur sources i.e. zypmite and gypsum increased significantly and was the highest at 60 kg S ha^{-1}. The increased uptake of S could be attributed to increased biomass and plant S contents occurred due to S fertilization. Many workers recorded increased sulphur uptake due to the increased level of S application (Malhi and Gill, 2002).

Application of sulphur increases the availability of sulphur to oilseed crops which results in higher sulphur content in straw of crop. Similar results have been reported by Raut *et al.* (2000). The significant increase in sulphur uptake by mustard was also recorded by Bharati *et al*. (2003). Increase in sulphur uptake was due to increase in seed and straw yields.

Grain sulphur content and uptake: Sulphur content in grains varied from 0.28 to 0.58 per cent. Both 40 and 60 kg S ha^{-1} irrespective of sources registered significant increase in sulphur showed similar trend observed in grain yield (Fig. 3). The highest S uptake was obtained at 60 kg S ha^{-1} applied by Zypmite and followed by Gypsum at same dose.

Higher S uptake by grain in present study may be attributed to more S content in seed and higher grain yield in sulphur fertilized treatments. Malhi and Gill, (2002) also concluded that increased uptake of S could be because of increased grain S-content occurred due to S fertilization. Raja *et al*. (2007) found that application of 60 kg S ha^{-1} to TMV-4 recorded higher sulphur uptake in seeds of sesame. Piri *et al*. (2012) observed that application of sulphur increases the availability of sulphur for crop which results in higher sulphur content in seeds of mustard cv. *Brassica juncea*.

Straw N content and uptake: Application of 60 kg S ha^{-1} through zypmite and gypsum showed numerical increases in nitrogen content in straw by 29.5 and 27.0 per cent, respectively over control (Table 3). Highest nitrogen content was observed at 60 kg S ha^{-1} treatment applied through zypmite, followed gypsum. The lowest N content was in control treatment. Nitrogen uptake (kg ha^{-1}) in straw showed the similar trend and increased significantly with combination of different treatments Nitrogen uptake ranged from 20.00 kg ha^{-1} in control to (30.27 kg ha^{-1} in 60 kg S ha^{-1}. Nitrogen uptake by straw was significantly affected by different doses i.e. 40 and 60 kg S ha^{-1} in zypmite and 60 kg S ha^{-1} in gypsum treated plots. Among both the sources zypmite gave the highest nitrogen uptake in straw by 51.35 per cent at 60 kg S ha^{-1} treatment.

These findings also collaborate that increased uptake of nitrogen by sunflower crop with sulphur levels due to increased biomass yield. Nasreen and Haq (2002) reported that as the total dry matter increased over time, nitrogen uptake also increased.

Grain nitrogen content and uptake: Data postulated that the application of increased levels of sulphur numerically increased the N content in grains applied through both the sources. Highest N-content was observed in the treatment where 60 kg S ha^{-1} applied through gypsum followed by zypmite (Table 3). Nitrogen uptake (kg ha^{-1}) in grain increased significantly with combination of different treatments and nitrogen uptake by grain ranged from 42.57 kg ha^{-1} in control to 62.09 kg ha^{-1} being highest in treatment at 40 kg S ha^{-1} was applied through zypmite. The combination of RDF with different levels of sulphur numerically increased nitrogen uptake by grain, ranged between 13.69 to 45.85 per cent in mustard.

Kumar *et al*. (2002) revealed that the highest nitrogen uptake was recorded with the application of 60 kg S ha^{-1} at all the growth stages and by seeds. The interaction between N and S was synergistic and hence application of sulphur increases the concentration and uptake of nitrogen.

Conclusion

It could be concluded from the study that different dry matter and grain yields contributing parameters were favorably influenced resulting in significant increase of dry matter yield and appreciable increase of grain yield of mustard crop. The uptake of sulphur and nitrogen by straw and grain also increased appreciable by application of 40 and 60 kg S ha^{-1} through both the sulphur sources. The efficiency of both the sulphur fertilizers was comparable however, zypmite was slightly superior may be to its micronutrients and sulphur content. Both the sulphur fertilizers i.e. zypmite and gypsum were found comparable.

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Table 1. Effect of different sources and levels on plant height (cm) in mustard

Sources of sulphur	**Levels of S ha^{-1}**	**Plant height (cm)**			**Plant dry matter (g)**	
		60 DAS	**90 DAS**	**At harvest**	**60 DAS**	**90 DAS**
No sulphur	Control	132.7	166.1	180.2	41.4	98.8
Zypmite	20 kg	147.0	175.1	186.9	47.1	111.1
	40 kg	161.4	186.9	192.3	56.3	117.2
	60 kg	167.4	190.9	195.0	72.9	128.7
Gypsum	20 kg	148.4	170.0	186.6	45.9	112.2
	40 kg	156.9	186.1	193.0	60.1	116.2
	60 kg	166.4	191.2	200.4	68.5	121.9
LSD (p=0.05)		**16.47**	**NS**	**NS**	**9.17**	**NS**
CV		**5.99**	**6.20**	**8.51**	**9.21**	**8.31**

Table 2. Effect of different sources and levels on siliqua length (cm siliqua^{-1}) and test weight (g) in mustard

Source of sulphur	Levels of S ha^{-1}	No. of branches/plant	Siliqua length (cm siliqua^{-1})	No. of siliqua/ plant	Test weight (g)
No sulphur	Control	21	3.73	299.3	2.99
Zypmite	20	22	3.97	330.6	3.17
	40	27	4.07	461.0	3.40
	60	31	4.30	484.3	3.92
Gypsum	20	23	3.80	369.3	3.20
	40	24	4.23	386.3	3.54
	60	28	4.24	440.0	3.72
LSD (p=0.05)		**4.29**	**NS**	**103**	**0.33**
CV		**9.55**	**9.18**	**14.66**	**5.45**

Table 3. Effect of different sources and levels on sulphur content (%) and its uptake (kg ha^{-1}) by Straw in mustard

Sources of sulphur	Levels of S ha^{-1}	Straw		Grain	
		N content (%)	N uptake (kg ha^{-1})	N content (%)	N uptake (kg ha^{-1})
No sulphur	Control	1.22	20.00	3.07	42.57
Zypmite	20 kg	1.31	22.80	3.27	50.03
	40 kg	1.37	25.10	3.25	62.09
	60 kg	1.58	30.27	3.85	54.03
Gypsum	20 kg	1.31	22.60	3.21	48.40
	40 kg	1.28	23.00	3.27	49.30
	60 kg	1.55	29.54	3.88	61.53
LSD (p=0.05)		**0.10**	**NS**	**NS**	**12.26**
CV		**11.37**	**10.87**	**19.24**	**13.11**

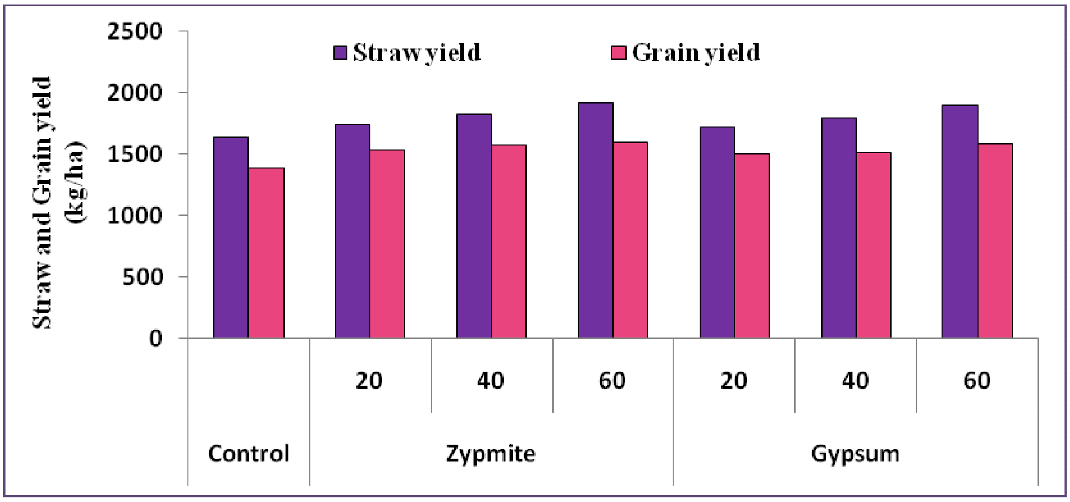

Fig 1. Straw and grain yield (kg ha^{-1}) as affect by different sources and levels of sulphur in mustard

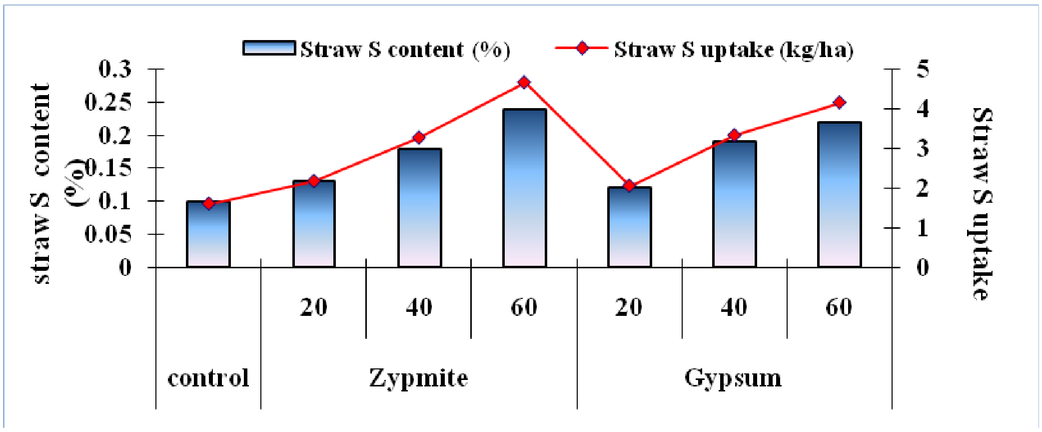

Fig 2. Sulphur content (%) and its uptake (kg ha^{-1}) by Straw as affect by different sources and levels of sulphur in mustard

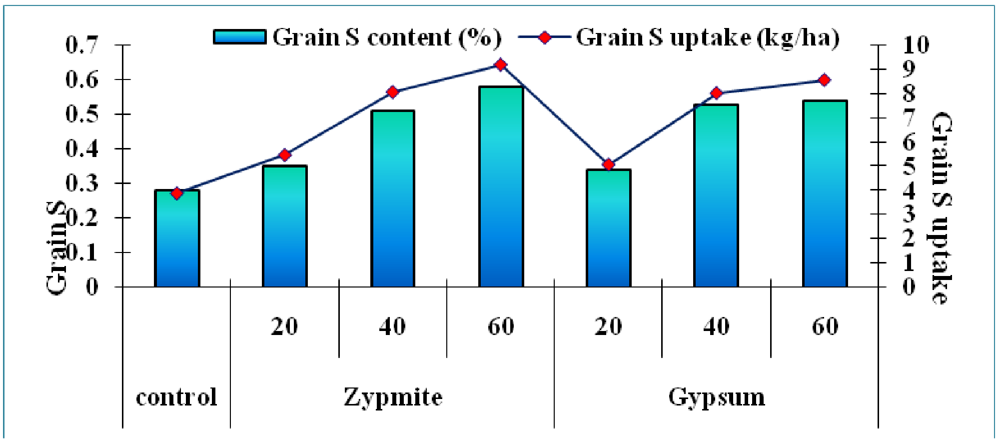

Fig 3. Sulphur content (%) and its uptake (kg ha^{-1}) by grain as affect by different sources and levels of sulphur in mustard