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Effect of different sources of sulphur on yield and quality of cauliflower (*Brassica oleracea*) under temperate conditions of Kashmir

O A KHAN[1], S K RAINA[2], D RAM[3], M A DAR[4], M A MALIK[5] and J A WANI[6]

Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar 190 025

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ABSTRACT

A field experiment was conducted to find the effect of different sources and levels of sulphur on yield and quality of cauliflower (*Brassica oleracea*) under temperate conditions of Kashmir. The experiment was laid out in randomized block design with three sources of sulphur, *viz*. elemental sulphur, gypsum and single superphosphate (SSP) and replicated thrice. The plots were given uniform dose of NPK (100:120:60 kg/ha). Gypsum recorded highest plant height, days to maturity, yield attributes and yield as compared to elemental sulphur and SSP; whereas, among the different levels of sulphur, 45 kg S/ha recorded highest value of plant height, days to maturity and yield attributes and yield. Among the quality parameters, ascorbic acid, protein content in curd was significantly higher with application of Gypsum and 45 kg S ha^{-1}, whereas, free nitrate (NO^{-3}) content was significantly lower in SSP (a desirable quality).

Key words: Cauliflower, Elemental sulphur, Gypsum, Quality, Single superphosphate, Sources of sulphur, Sulphur, Yield

Cauliflower is one of several vegetables in the species *Brassica oleracea*, in the family Brassicaceae. It is an annual plant that reproduces by seed. Typically, only the head (the white curd) is eaten. The cauliflower head is composed of a white inflorescence meristem. Cauliflower contains several phytochemicals, common in the cabbage family, which may be beneficial to human health. Sulforaphane, a compound released when cauliflower is chopped or chewed, may protect against cancer. Indole-3-carbinol, chemical that enhances DNA repair, and acts as an estrogen antagonist, slowing the growth of cancer cells. A high intake of cauliflower has been associated with reduced risk of aggressive prostate cancer (Krish *et al.* 2007).

Sulphur is one of the essential elements required for the normal growth of plants and concentration of sulphur in plants are lower than that of nitrogen and similar to phosphorus. In intensive crop rotations including oil crops, S removal can be very high, especially when the crop residue is removed from the field along with the product. This leads to considerable S depletion in soil if the corresponding amount of S is not applied through fertilizer. Plants take it up from the soil solution mainly in the form of sulphates (SO_4^{-2}) (Marschner 1995). After reduction in the plant S participates in various primary and secondary compounds, such as the amino acids systeine and methionene, vitamins B_1 and H, and enzymes and coenzymes (Haneklaus *et al.* 1997).

The members of brassica are characterized by their high sulphur need for growth and where sulphur is limited, it will reduce both crop yield and marketable quality, however, a large proportion of sulphur is present in sulphate in both roots and shoots (Westerman *et al.* 2000). Since Brassica originate from saline, sulphur enriched environments; the surplus sulphur taken up many not solely be utilized for growth, but also for synthesis of organic secondary compounds like glucosinolates or as an osmotic compound (Blake-Kalff *et al.* 1998). Therefore, realizing the importance of sulphur for brassica crops, the present study was undertaken to investigate the effect of soil applied elemental sulphur, gyupsum and single superphosphate (SSP) on growth, yield and quality of cauliflower under temperate conditions of Kashmir valley.

MATERIALS AND METHODS

The experiment was undertaken on the experimental farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar during *rabi* 2013 which is situated between 34°08' N and 74°83' E at an elevation of 1587 meters above mean sea level, temperate type of climate. During *rabi* season 2013 the mean rainfall, maximum day temperature and relative humidity was 14.92 mm, 21.71° and 69.67%, respectively. The composite soil sample taken before start of experiment was subjected to mechanical and chemical analysis. The experiment was

[2]Assistant professor (e mail: sanjayraina11@gmail.com), Division of Soil Science

laid out in randomized block design with three replications and twelve treatments with cauliflower (Swati) as test crop. The details of treatment are as: T_1 – 0 kg sulphur in the form of elemental S/ha (Control); T_2 – 15 kg sulphur in the form of elemental S/ha; T_3 – 30 kg sulphur in the form of elemental S/ha; T_4 – 45 kg sulphur in the form of elemental S/ha; T_5 – 0 kg sulphur in the form of gypsum/ha (control); T_6 – 15 kg sulphur in the form of gypsum/ha; T_7 – 30 kg sulphur in the form of gypsum/ha; T_8 – 45 kg sulphur in the form of gypsum/ha; T_9 – 0 kg sulphur in the form of single superphosphate (SSP)/ha (control); T_{10} – 15 kg sulphur in the form of single superphosphate (SSP)/ha; T_{11} – 30 kg sulphur in the form of single superphosphate (SSP)/ha; T_{12} – 45 kg sulphur in the form of single superphosphate (SSP)/ha. Nitrogen, phosphorus and potash were applied through urea (46% N), DAP (46% P_2O_5 and 18% N) and MOP (60% K_2O) as per package of practices. The entire dose of phosphorus and potassium alongwith half dose of nitrogen was given as basal and thoroughly mixed with soil. Moreover, sulphur was also applied to soil as per the treatments at the time of transplanting. Remaining half dose of nitrogen was given in two equal split doses at 30 and 60 days after transplanting. The phosphorus applied by SSP was adjusted with decreasing the dose of DAP and increasing urea accordingly. Seedlings were transplanted manually in rows at a spacing of 60 × 45 cm. The plant population was maintained by gap filling (re-transplanting) in case of death of any seedling. Various parameters were recorded from the randomly selected five plants from each treatment. At harvest, five plants were uprooted from each treatment and dried in an oven at 65 ± 5°C for 48 hr to find dry weight which was finally converted into quintals per hectare. Samples were then powdered for further chemical analysis. Nitrogen and crude protein were determined by Kjeldhal method as outlined by Tandon (1993). Phosphorus and potassium contents were estimated as per Jackson (1973). Sulphur content in plant samples was estimated by turbidity method (Chesnin and Yien 1951). Ascorbic acid content was determined in the cauliflower curd by the method described by Ranganna (1986). The data was subjected to statistical analysis as per the procedure outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant height

Significant effect of different sources and levels of sulphur was found on plant height at 30, 45, 60 and 75 days after sowing (DAT) (Table 1). However, no significant effect of different treatments was noticed on plant height at 15 DAT. Application of sulphur through gypsum resulted in significantly taller plants compared to SSP and elemental sulphur at all stages except 15 DAT where all three sources were statistically at par with each other; whereas, elemental sulphur recorded lowest plant height at all stages of crop development. Application of sulphur @ 45 kg/ha observed significantly taller plants as compared to sulphur application @15 kg/ha and control but was statistically at par with sulphur application @ 30 kg/ha; whereas, lowest plant height was recorded in control treatment (no sulphur application) at all the stages of plant growth upto harvesting stages. The increase in growth might be ascribed to better root formation due to sulphur, which in turn activated higher absorption of N, P, K and sulphur from soil and improved metabolic activity inside the plant (Kalaiyarasan *et al.* 2003). Zaman *et al.* (2011) also reported the increase in plant height of garlic with the application of sulphur upto 45 kg/ha. Jawahar *et al.* (2013) reported that application of 40 kg S/ha recorded highest growth (plant height, leaf area index, chlorophyll content, dry matter production and number of branches/plant), yield components (number of pods/plant and number of seeds/pod) and yield (grain and haulm) of blackgram.

Table 1 Effect of different sources and levels of sulphur on plant height (cm) of cauliflower

	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
Sources						
El. Sulphur	5.51	6.89	9.11	11.38	11.49	11.50
Gypsum	5.70	7.40	9.82	11.60	11.71	11.72
SSP	5.59	7.14	9.43	11.50	11.61	11.62
CD ($P \leq 0.05$)	NS	0.20	0.26	0.08	0.06	0.09
Doses						
0 kg/ha	5.24	6.88	8.60	10.98	11.49	11.50
15 kg/ha	5.41	7.04	8.90	11.07	11.58	11.59
30 kg/ha	5.83	7.24	9.24	11.12	11.63	11.64
45 kg/ha	5.95	7.41	9.38	11.20	11.71	11.72
CD ($P \leq 0.05$)	NS	0.23	0.28	0.09	0.09	0.12
Interaction	NS	NS	NS	NS	NS	NS

Days to maturity

Different sources of sulphur had no significant effect on days to maturity (Table 2). Days to maturity vary significantly under different levels of sulphur. The plants receiving sulphur at 45 kg/ha which was statistically at par with 30 kg S/ha, took more days to maturity as compared to 15 kg S/ha and control. The results were in conformity with that of Hocking *et al*. (1987), who stated that the application of sulphur led to more uptake of nutrients that in turn enhanced the vegetative growth leading to more days to maturity for a crop. Rehman *et al.* (2013) reported that the application of sulphur delayed the flowering and maturity, but significantly improved leaf area index, crop growth rate, net assimilation rate and chlorophyll contents.

Curd diameter

Application of sulphur through gypsum resulted in significantly larger curd diameter as compared to SSP and elemental sulphur (Table 2). Curd diameter varied significantly under different levels of sulphur. Application of sulphur at 45 kg S/ha recorded more curd diameter as

Table 2 Effect of different sources and levels of sulphur on growth and yield of cauliflower.

	Curd weight (g)	Curd diameter (cm)	Days to maturity	Yield (q/ha)
Sources				
El. Sulphur	498.16	15.78	90.16	224.91
Gypsum	507.58	15.93	91.50	232.58
SSP	504.91	15.89	90.83	229.16
CD ($P \leq 0.05$)	2.76	0.06	NS	6.05
Doses				
0 kg/ha	478.11	15.66	89.33	206.00
15 kg/ha	493.88	15.83	90.66	219.88
30 kg/ha	514.87	15.92	91.22	233.33
45 kg/ha	529.23	16.05	92.11	256.34
CD ($P \leq 0.05$)	3.19	0.72	0.90	6.99
Interaction	NS	NS	NS	NS

compared to other levels of sulphur but was statistically at par with 30 kg S/ha. These findings are in line with those of Hariram and Dwivedi (1992), who opined that the positive response of the crop to gypsum could be due to its higher solubility and increased photosynthetic activity of crop. Khalid *et al.* (2009) reported that the different S fertilizers increased S (SO^4-S) contents of soil in order of SSP<gypsum<ammonium sulphate.

Curd weight

Curd weight was recorded the maximum in plots receiving gypsum but statistically at par with those where SSP was applied (Table 2). Application of sulphur at 45 kg/ha resulted into significantly more curd weight followed by 30 kg S/ha. These findings were in line with those of Hariram and Dwivedi (1992), who opined that the positive response of crop to gypsum could be due to higher solubility and increased photosynthetic activity of crop.

Yield at harvesting

The ultimate test to judge the performance or efficiency of a particular treatment is yield (Table 2). All the three sources viz, elemental sulphur, gypsum and SSP had a significant effect on yield. Application of gypsum showed significantly higher yield than SSP and elemental sulphur. These findings were in line with those of Hariram and Dwivedi (1992). Yield varied significantly under different levels of sulphur. Application of sulphur at 45 kg/ha recorded the highest yield followed by 30 kg S/ha; whereas, the lowest yield was recorded in control treatment. Sulphur is mainly responsible for enhancing the reproductive growth and proportion of reproductive tissues (inflorescence) in total dry matter (McGrah and Zhao 1996). The significant increase in the yield with increasing levels sulphur to 45 kg/ha could be due to its role in synthesis of sulphur containing amino acids, proteins and enhanced photosynthetic activity of plant with increased cholorophyll synthesis (Juszczuk and Ostaszewska 2011). The improvement in yield due to increase in sulphur levels might be due to its important role in energy transformation, activation of enzymes and carbohydrate metabolism (Davidian and Kopriva 2010, Juszczuk and Ostaszewska 2011). Also, the better performance of gypsum treatment might be due to higher solubility, nutrient availability and uptake and the result of cumulative effect of increased yield attributes. The low oxidation rate of sulphide to sulphite and to sulphate form of sulphate and non-availability of other nutrients might be the causes for the low values registered under elemental sulphur. The results were in agreement with those of Singh and Ram (1990) and Shivran *et al.* (1996).

Dry matter yield

Application of gypsum recorded highest dry matter yield in curd and foliage, which was statistically at par with SSP but superior to elemental sulphur (Table 3). Plots receiving 45 kg S/ha recorded highest dry matter of curd and foliage though at par with those receiving 30 kg S/ha but significantly higher than the plots receiving 15 and 0 kg S/ha. The increased dry matter accumulation due to sulphur application could be attributed to low status of sulphur in the studied soil and its subsequent role in increase in chlorophyll contents and photosynthetic rate that paved the way for increased dry matter production (Jusczuk and Ostaszewaska 2011).

Quality parameters

*Ascorbic acid content of cauliflower***:** Application of gypsum showed an ascorbic acid content of 110.46 mg/100 g that was significantly higher than SSP and elemental sulphur having ascorbic acid content of 109.29 and 107.05 mg/100 g, respectively (Table 4). Application of sulphur at 45 kg/ha resulted in more ascorbic acid content (116.23 mg/100g) as compared to 30 kg S/ha, 15 kg S/ha and control. This could be attributed to the fact that adequate ratio of S and N shifts balance of transformation between protein and carbohydrate

Table 3 Effect of different sources and levels of sulphur on dry matter (q/ha) accumulation.

	Dry matter (curd)	Dry matter (foliage)
Sources		
El. Sulphur	22.46	18.01
Gypsum	23.22	18.63
SSP	22.95	18.36
CD ($P \leq 0.05$)	0.69	0.24
Doses		
0 kg/ha	20.61	16.50
15 kg/ha	22.00	17.58
30 kg/ha	22.75	18.43
45 kg/ha	23.85	18.95
CD ($P \leq 0.05$)	1.30	0.49
Interaction	NS	NS

Table 4 Effect of different sources and levels of sulphur on quality parameters of cauliflower.

	Ascorbic acid in curd (mg/100 g)	Free nitrate in curd (ppm)	Protein content in curd (%)
Sources			
El. Sulphur	107.05	1108.68	13.79
Gypsum	110.47	1068.76	14.23
SSP	109.29	1065.96	14.04
CD (P≤0.05)	1.02	21.07	0.43
Doses			
0 kg/ha	101.94	1152.12	13.04
15 kg/ha	106.84	1102.88	13.67
30 kg/ha	110.74	1058.76	13.79
45 kg/ha	116.23	1010.77	14.16
CD (P≤0.05)	3.21	24.33	0.57
Interaction	NS	NS	NS

systhesis that adequately responds in terms of ascorbic acid synthesis. Cekey *et al.* (2009) found similar results.

Free nitrate content: Presence of free nitrate is an undesirable quality of vegetables. Application of gypsum recorded a free nitrate content of 1068.75 ppm that was at par with that of SSP (1065.96 ppm) but was significantly lower than that of elemental sulphur having free nitrate content of 1108.76 ppm (Table 4). Enhancive reduction in the free nitrate due to gypsum could be ascribed to the fact that release of sulphate form gypsum is done in soil much more readily than other sources. Application of sulphur at 45 kg/ha resulted in lower free nitrate content (1010.77 ppm) as compared to 30, 15 and 0 kg S/ha which recorded free nitrate content of 1058.75, 1102.87 and 1152.11 ppm, respectively. The large increase of accumulated nitrate-N with low S supply corroborates the results reported by Friedrich and Schrader (1978), Migge *et al.* (2000) and Prosser *et al.* (2001). Low supply of S to plants compromises the activity of the nitrate reductase enzyme, causing nitrate-N to accumulate in plant tissue (Migge *et al.* 2000). According to Migge *et al.* (2000), expression and activity of nitrate reductase in S-limited plants may be suppressed by the accumulation of amino acids in plant tissues.

Crude protein: An examination of the data (Table 4) reveals that application of gypsum recorded a crude protein content of 14.23% that was statistically at par with SSP with a content of 14.04% but higher than elemental sulphur that had protein content of 13.79%, respectively. The highest protein content (14.16%) in curd was recorded in plots receiving 45 kg/ha. Sulphur doses of 45, 30 and 15 kg/ha were statistically at par with each other but higher than control (no S) in this regard. Since S forms an important component of amino acids like cysteine and methionine, thus more addition of S is likely to enhance more formation of amino acids and they thereafter will increase the protein synthesis (Kaur *et al.* 2011).

Thus, it can be concluded that gypsum as source and 45 kg S/ha proved to be superior for the highest productivity and best quality of cauliflower under temperate conditions of Kashmir.

REFERENCES

Cekey N, Slosar M, Uher A and Ferusova S. 2009. The effect of fertilization on the yield and the content of antioxidants in cauliflower. (*In*) Antioxidants 2009: anniversary volume from 1st year of scientific conference with international participation, Nitra Slovakia, 6 May 2009, SAU, Nitra, pp. 30–4.

Chesnin L and Yien C H. 1951 Turbidimetric determination of available sulphur. *Proceedings of Soil Science Society of America* **15:** 149–51.

Davidian J C and Kopriva S. 2010. Regulation of sulphate and variety on yield of summer groundnut in West Bengal. *Indian Journal of Agronomy.* **36:** 604–5.

Friedrich J W and Shrader L E. 1978. Sulfur deprivation and nitrogen metabolism in maize seedlings. *Plant Physiology* **61:** 900–3.

Gomez K A. and Gomez A L. 1984. *Statistical Procedures for Agricultural Research,* p 112, 2nd edn. An International Rice Research Institute Book, Willy InterScience Publication, New York.

Haneklaus S, Hoppe L, Bahadir M and Schnug E. 1997. Sulphur nutrition and alliin concentrations in *Allium* species. (*In*) Sulphur metabolism in Higher Plants. Molecular, Ecophysiological and Nutritional Aspects, p 361. Cram W J, De Kok L J, Stulen I, Brunold C and Rennenberg H (Eds). Backhuys Publishers, Leiden,

Hariram and Dwivedi K N. 1992. Effect of sources and levels of sulphur on yield and quality of chickpea. *Indian Journal of Agronomy* **37:** 112–4.

Hocking P J, Randall P J and Dinkerton A. 1987. Sulphur nutrition of sunflower (*Helianthus annus*) as effected by nitrogen supply, effect of vegetative growth, the development of yield components and seed and quality. *Field Crops Research* **16:** 157–75.

Jackson M L. 1973. *Soil Chemical Analysis*, 2nd edition, p 498. Printice Hall of India, New Delhi.

Jawahar S, Vaiyapuri V, Suseendran K, Kalaiyarasan C and Sriramachandrasekharan M V 2013. Effect of sources and levels of sulphur on growth and yield of rice fallow blackgram (*Vigna mungo*). *International Research Journal of Chemistry* **3:** 1–7.

Jusczuk I M and Ostaszewaska M. 2011. Respiratory activity, energy and redox status in sulphur-deficient bean plants. *Environmental and Experimental Botany* **74:** 245–54.

Kalaiyarasan C, Vaiyapuri V and Chandrasekharan M V S. 2003. Effect of sulphur sources and levels on the nutrient uptake, crop quality and sulphur use efficiency in groundnut. *Annals Agri. Res. New Series* **24(3):** 478–80.

Kaur G, Chandna R, Pandey R, Abrol Y P, Iqbal M and Ahmad A. 2011. Sulphur starvation and restoration affect nitrate uptake and assimilation in rapeseed. *Protoplasma* **248:** 299–311.

Khalid R, Khan K S, Yousaf M, Shabbir G and Subhani A. 2009. Effect of sulfur fertilization on rapeseed and plant available sulfur in soils of Pothwar, Pakistan. *Sarhad Journal of Agriculture* **25**(1): 65–71.

Kirsh V A, Peters U, Mayne S T, Subar A F, Chatterjee N, Johnson C C and Hayes. R B. 2007. Prostate, lung, colorectal and ovarian cancer screening trial. Prospective study of fruit and vegetable intake and risk of prostate cancer. *Journal of Natl Cancer Institute* **99**(15): 1200–9

Marschner H. 1995. *Mineral Nutrition of Higher Plants*. Academic

Press. New York, USA.

McGrah S P and Zhao F J. 1996. Sulphur uptake, yield responses and the interaction between nitrogen and sulphur in winter oilseed rape (*Brassica napus*). *Journal of Agricultural Sciences* **126:** 53–62.

Migge A, Bork C, Hell R and Becker T W. 2000. Negative regulation of nitrate reductase gene expression by glutamine and asparagines accumulating in leaves of sulphur-deprived tobacco. *Planta* **211:** 587–95.

Prosser I A, Purves, J V, Saker L R and Clarkson D T. 2001. Rapid disruption of nitrogen metabolism and nitrate transport in spinach plants deprived of sulphate. *Journal of Experimental Botany* **52:** 113–21.

Ranganna S. 1997. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. TataMcGraw Hill Publication Co Ltd, New Delhi.

Rehman H U, Iqbal Q, Faroow M, Wahid A, Afzal I and Basra S M A. 2013. Sulphur application improves the growth, seed yield and oil quality of canola. *Acta Physiologiae Plantarum* **35**(10): 2999–3006.

Shivran A C, Khangarot S S, Shivran A L and Gora D R. 1996. Response of cluster bean (*Cyamopsis tetragonoloba*) varieties to sulphur and phosphorus. *Indian Journal of Agronomy* **41:** 340–2.

Singh P N and Ram H. 1990. Effect of P and S application on protein and amino acid content in chickpea. *Indian Journal of Pulse Research* **3:** 36–9.

Tandon H L S. 1993. *Methods of Analysis of Soil, Plant, Water and Fertilizers*. Fertilizer Development and Consultation Organization, New Delhi.

Westerman S, Weidner W, De Kok L.J and Stulen I. 2000. Effect of H_2S exposure on 35S-sulfate uptake, transport and utilization in curly kale. *Phyton (B Aires)* **40:** 293–302.

Zaman M S, Hashem M A, Jahiruddin M and Rahim M A. 2011. Effect of sulphur fertilization on the growth and yield of garlic (*Allium sativum* L.). *Bangladesh Journal of Agricultural Research* **36**(4): 647–56.