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Seed Yield and Quality Parameters of Cabbage (*Brassica oleracea var. capitata*) in relation to Different Sources and Levels of Sulphur

R. BHAT, Z. RASHID, SHAHID B DAR* and S. MUFTI

Research Scholar, Division of Agronomy, Foa, Wadura, SKUAST-Kashmir.

Abstract

Sulphur is increasing and after nitrogen, phosphorus and potassium is forth important macro nutrient. In this study three sources of sulphur i.e., Gypsum, Elemental sulphur and Potassium Sulphate with three levels i.e., 40, 70 and 100 kg S ha^{-1} for each source were tried. The pooled data showed sulphur from potassium sulphate recorded the lowest days to first flower (246), days to 75% seed maturity (328.1), and highest number of branches plant^{-1} (35), number of siliqua plant^{-1} (709.5), 1000 seed weight (3.87g), seed count siliqua^{-1}(20.8), seed yield plant^{-1} (12.9 g), seed yield hectare^{-1} (4.8 q), highest Dry matter (9.6 g), TSS (7.6o Brix), Crude protein (20.6%), head compactness (0.032) and oil content (29.7%).Application of increasing levels of sulphur upto 100 kg ha-1 significantly increased the seed yield contributing characters in cabbage as lowest days taken to first flower (250.8), lowest days to 75% seed maturity(334.1) and highest number of branches plant^{-1} (31.7), siliqua plant^{-1} (671.60), seed count siliqua^{-1} (17.9), 1000 seed weight (2.6g), seed yield plant^{-1} (11.90 g) and seed yield hectare^{-1} (4.4q) whereas, among quality parameters highest vitamin C (59.1 mg/100), dry matter weight (9.0 g), Crude protein (18.3), and Head compactness (0.026) were recorded with sulphur application of 70 kg ha^{-1}.

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Introduction

Cabbage (*Brassica oleracea var. capitata*) is the second most important cole crop after cauliflower. Cabbage falls under cole group and all cole crops have one common trait i.e., genetic potential to thicken various parts. Cabbage is distinguished by its swollen heads which is formed by thickening of edible buds with tightly packed overlapping leaves

CONTACT Shahid B Dar sbd.agron@gmail.com Research scholar, Division of Agronomy, Foa, Wadura, Skuast Kashmir.

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manifesting a large head. The shape of head may be round, conical, oblong and flat or Savoy depending on the variety[1]. It is consumed throughout the country by every class of people as fresh vegetables or raw as salad and is also having nutritional values, medicinal effects, and other therapeutic properties. Cabbage may be cheap in price but very high in protective vitamins having a very low caloric value and very rich in nutrients. Glucosinolates present in cabbage are a class of nitrogen and sulphur containing compounds shown to have cancer preventing properties. They have been shown to inhibit the activity of some chemical carcinogens. The plant enzyme mynosinase is released upon consumption of glucosinolate containing vegetables and catalyses glucosinolate hydrolysis[2]. Cabbages are highly responsive to fertilizer application. Fertilizers offer the best means of increasing yield and maintaining soil health. In addition to N, P and K nutrients, sulphur has been found to be very much beneficial[3]. Sulphur application is essential to improve production and productivity in addition to quality of cabbage.

Cabbage for seed production is a winter biennial crop and sulphur also provides winter hardiness and drought tolerance besides control of insects, pests and diseases. Optimum use of fertilizers containing sulphur improves utilization of nutrients, especially nitrogen. Sulphur requirement for *Brassica* crops is high as compared to other crops and shortage of sulphur limits both crop yield and quality. Over the last two decades, sulphur deposition from the atmosphere has declined significantly from 50 to 20,000 tonnes. The atmosphere now only supplies between 1 to 3.5 kg S ha^{-1} yr^{-1}. In addition crops yields have also increased resulting in the need to supply more sulphur in organic or inorganic form to meet annual crop demand[4].

The climatic conditions of Kashmir Valley is ideal for seed production of cabbage (European type) as it requires chilling treatment (Vernalization) for bolting and seed production. The seed production of European type of cabbage is being carried out in the valley on commercial scale since 1947. The quality of seed is greatly affected by the oil content of the seed, which is related to the sulphur application in the soil. Moreover, the oil content present in the seed influences the viability of the seed and in maintaining the quality. Hence keeping this necessity in view different different sources and levels were used to study their effect on seed yield attributes, seed yield and quality parameters of cabbage.

Materials and Methods

Field experiments were carried out at Vegetable Experimental Farm, Division of Vegetable Science Rabi season of 2012-13 and 2013-14 located at 34.1 ^{0}N & 74.89 ^{0}E at an altitude of 1587 m above MSL. The soil (0-15 cm) of experimental site was well drained silty clay loam in texture with pH 7.00, high in organic carbon (0.97%), medium in available N (242.6 kg/ha), available P (21.5 kg/ha), available K (165.6 kg/ha) and available S (22.6 kg/ha). The experiment was laid in a randomized block design with three replications having 10 treatments (Table 1) comprising different combinations of sulphur levels and sulphur sources viz, 40 kg S ha^{-1} through Gypsum (T_1), 70 kg S ha^{-1} through Gypsum (T_2), 100 kg S ha^{-1} through Gypsum(T_3), 40 kg S ha^{-1} through Elemental sulphur (T_4), 70 kg S ha^{-1} through Elemental sulphur (T_5), 100 kg S ha^{-1} through Elemental sulphur (T_6), 40 kg S ha^{-1} through Potassium sulphate (T_7), 70 kg S ha^{-1} through Potassium sulphate (T_8), 100 kg S ha^{-1} through Potassium sulphate (T_9) and control (T_{10}). A uniform dose of nitrogen @150 kg N ha^{-1}, Phosphorus @60 kg P_2O ha^{-1}, Potassium @60 kg K_2O kg ha^{-1} and FYM @30 t ha^{-1} was applied to each plot. However, amount of potassium supplied in plots involving application of sulphur from potassium sulphate was reduced from uniform dose of potassium. In Sulphur through different sources and levels as per treatment was applied as basal dose. Elemental sulphur was applied 15 days prior to transplanting of seedling. Cabbage (Golden Acre)

Table 1: Treatment combination details

T_1	:	40kg S ha^{-1} through Gypsum
T_2	:	70kg S ha^{-1} through Gypsum
T_3	:	100kg S ha^{-1} through Gypsum
T_4	:	40kg S ha^{-1} through Elemental sulphur
T_5	:	70kg S ha^{-1} through Elemental sulphur
T_6	:	100kg S ha^{-1} through Elemental sulphur
T_7	:	40kg S ha^{-1} through Potassium sulphate
T_8	:	70kg S ha^{-1} throughPotassium sulphate
T_9	:	100kg S ha^{-1} throughPotassium sulphate
T_{10}	:	Control

oil content by Sochslet method, TSS by hand refractometer and presented as oBrix and Head compactness was estimated as per the formula[8].
Where,
Z = Index of compactness
C = Net weight of head
W = Average lateral and polar diameter of head.

Cabbage seed yield was calculated and expressed in quintals hectare^{-1}. The data were analyzed as per the standard procedure for Analysis of Variance (ANOVA)[9]. The difference in the treatment mean was tested by using critical difference (CD) at 5% level of probability.

Results and discussion

The results of present investigation have shown that both the sources and levels of sulphur significantly influenced the seed yield attributes of cabbage under study. The data presented in Table 2, indicated that all the sources of sulphur had a significant effect on various seed yield attributes of cabbage under study as days to first flower, days to 75% seed maturity, number of branches plant^{-1}, number of siliqua plant^{-1}, seed count siliqua^{-1}, seed yield plant^{-1} (g), seed yield hectare^{-1} (q), 1000 seed weight (g), germination percentage, and oil content (%). Potassium sulphate as a source of sulphur recorded the lowest days to first flower (246), days to 75% seed maturity (328.1), and highest number of branches plant^{-1} (35), number of siliqua plant^{-1} (709.5), seed yield plant^{-1} (12.9 g), seed yield hectare^{-1} (4.8 q), 1000 seed weight (3.87g), seed count siliqua-1 (20.8), and oil content (29.7%). The highest days to first flower (271.6), highest days to 75 % seed maturity (350.8) and lowest number of branches plant^{-1} (24.5), number of siliqua plant^{-1} (462.8), seed yield plant^{-1} (6 g), seed yield hectare^{-1} (2.24 q), 1000 seed weight (2.8 g), seed count siliqua^{-1} (14.3), and oil content (17.2%) was recorded under control. The superiority of potassium sulphate as a source of sulphur in inducing the increase in seed yield attributes of

Table 2: Seed yield attributes and seed yield as influenced by different sources and levels of sulphur (Pooled data of two years)

Treatment	Days to first flowering	Germination (%)	75% seed maturity	Branches plant^{-1}	Siliqua plant^{-1}	Seed count siliqua^{-1}	1000 seed weight (g)	Yield plant^{-1} (g)	Seed yield hectare^{-1}(q)
Sulphur sources									
Gypsum	258.8	92.5	342.2	28.8	626.8	16.9	3.63	11.2	4.1
Elemental sulphur	262.8	92	346.7	25.5	553.8	14	3.21	9	3.3
Potassium sulphate	246	98.1	328.1	35	709.5	20.8	3.87	12.9	4.8
Graded levels of sulphur ha^{-1}									
40 kg	261.3	92.7	343.05	27.3	563.7	17.1	3.25	9.8	3.65
70 kg	255.5	94.4	340	30.2	654.8	16.6	3.62	11.4	4.2
100 kg	250.8	95.4	334.1	31.7	671.6	17.9	3.85	11.9	4.4
Control	271.6	88	350.8	24.5	462.8	14.3	2.8	6	2.25
Control versus rest control mean	1.6	0.5	1.55	0.7	7.9	0.5	0.06	0.14	0.05
Sources CD ($p \leq 0.05$)	1.6	0.5	1.55	0.7	7.9	0.5	0.06	0.14	0.05
Levels	0.68	0.2	0.66	0.31	3.4	0.2	0.03	0.06	0.02

cabbage could be attributed to highly soluble nature and readily available sulphur (sulphate) in potassium sulphate as compared to Gypsum and Elemental sulphur[10,11,12].

Further, the application of increasing levels of sulphur upto 100 kg ha^{-1} significantly increased the seed yield contributing characters in cabbage as lowest days taken to first flower (250.8), lowest days to 75% seed maturity (334.1) and highest number of branches plant^{-1} (31.7), number of pods plant^{-1} (671.60), seed yield plant^{-1} (17.90g), seed yield hectare^{-1} (4.4 q), 1000 seed weight (3.85 g), seed count siliqua^{-1} (17.9) and oil content (26.5%) were recorded with Sulphur application of 70 kg ha^{-1}.

The increase in seed yield and seed yield attributes might be due to the important role of sulphur in lowering the pH of soil resulting in increased availability of many nutrients[13]. Since sulphur increases the amino acid and protein production which ultimately improves yield[14]. Sulphur is also important for various important processes like energy transformation, activation of enzymes, partitioning of photosynthates to economic parts, thus contributes to yield. Increase in oil content with sulphur application may be attributed to the fact that sulphur is the component of acetyl CoA required for the biosynthesis of oil, acetyl CoA is converted to moloyl CoA in fatty acid synthesis[15]. Increase in seed yield by application of sulphur are in confermation with the results obtained by several other researchers[16,17,18,19].

Significant results were also recorded by both the sources and levels of sulphur with respect to dry matter content, total soluble solids, crude protein content and head compactness in cabbage. However,

Table 3: Seed quality parameters as influenced by different sources and levels of sulphur (Pooled data of two years)

Treatment	Vitamin C content (mg/100g)	Dry-matter weight (g)	Total soluble solids (oBrix)	Crude protein content (%)	Chlorophyll content (mg/g)	Head compa-ctness	Oil content (%)
			Sulphur sources				
Gypsum	53.8	8.6	6.6	18.6	0.99	0.023	22.6
Elemental sulphur	53.7	8.1	6.1	13.1	0.99	0.019	20.1
Potassium sulphate	53.7	9.6	7.6	20.6	0.98	0.032	29.7
			Graded levels of sulphur ha^{-1}				
40 kg	48.1	8.5	6.6	16.6	0.802	0.023	21.1
70 kg	59.1	9	6.8	18.3	1.01	0.026	24.8
100 kg	54	8.7	7.1	17.4	1.15	0.025	26.5
Control versus rest control mean	44.4	7.9	6.1	12.2	0.68	0.015	17.2
Sources CD ($p \leq 0.05$)	NS	0.09	0.12	0.32	NS	0.0005	0.6
Levels	0.3	0.09	0.12	0.32	0.03	0.0005	0.6
Control versus rest	0.1	0.05	0.05	0.14	0.01	0.0002	0.2

there is no significant effect of sources of sulphur on vitamin C (mg 100^{-1}) and Chlorophyll content (mg g^{-1}) in cabbage. The data presented in Table 3 indicated that all the sources of sulphur had a significant effect on Dry matter (g), TSS (oBrix), Crude protein (%) and head compactness. Potassium sulphate as a source of sulphur recorded significantly the highest Dry matter (9.6 g), TSS (7.6oBrix), Further study of the Data revealed that with increase in levels of sulphur there is a significant increase in quality characters of cabbage. Vitamin C (59.1 mg/100), Dry matter weight (9.0 g), Chlorophyll content (1.15 mg/g), Crude protein (18.3), and Head compactness (0.015) increases significantly with the increasing levels of sulphur upto 70 kg ha^{-1}. However there is a significant increase in TSS (7.1oBrix) by application of sulphur upto 100 kg ha^{-1}. Dry matter production is one of the important measures for judging the optimum plant growth. Increase in dry matter significantly indicates that the nutrients seem to be readily and sufficiently available for crop growth in treatments with high dry matter content. Increase in dry matter content with the application of sulphur could be due to increased availability, uptake and better translocation of nutrients. Sulphur enhances starch accumulation, better protein synthesis, efficient synthesis and translocation of photosynthates, which is a good indication of physiologically efficient plants. Sulphur forms the components of secondary metabolic compound, i.e. many volatile precursors which play important role in determining the quality of produce[20]. These results are in conformity with the results in cabbage[21] and in broccoli[22]. The increase in vitamin C is due to large uptake of nitrogen which would have contributed in higher rate of carbohydrate synthesis and thus translocation, in tomato. Sulphur also plays an important role in the production of chlorophyll[23]. Sulphur increases the chlorophyll content of leaf, which has nitrogen as a constituent and thus increased concentration in plants[24]. It was reported to increase the chemical and biological activation of iron in the leaves resulting in increased chlorophyll[25]. The increase in crude protein is directly correlated with nitrogen content so the increase in nitrogen content under the influence of sulphur results in higher protein content in fenugreek[26]. Similar observations have been reported in cauliflower [27].

The interaction effect between sources and levels of sulphur on seed yield $plant^{-1}$ during 2012-13, 2013-14 and in pooled data was found significant (Table-4). The seed yield $plant^{-1}$ varied significantly among different sulphur sources when fertilizer sulphur was applied as Gypsum, Elemental sulphur and Potassium Sulphate. Similarly at 40, 70, and 100 kg S ha^{-1}, seed yield $plant^{-1}$ g varied significantly among different sulphur levels. Significantly higher seed yield $plant^{-1}$ of 13.6 g , 13.4 g and 13.4 g during the year 2012-13, 2013-14 and in pooled data, respectively was recorded with treatment combination 100 kg S ha^{-1} as potassium sulphate which was statistically superior to all other treatment combination. The increase in cabbage yield and yield components due to sulphur application may be attributed to proper utilization of carbohydrates and greater absorption of other essential nutrients in presence of sulphur and due to favourable effects of sulphur on vegetative growth and subsequently on yield of crop. Sulphur is a constituent of chloroplast and application of sulphur helps in increase in photosynthetic activity, resulting in increased food synthesis and dry matter content, which in turn results in high yield. The increase in

Table 4: Interaction effect of sources and levels of sulphur on seed yield $plant^{-1}$ (g) in cabbage

Treatment	**Sulphur Levels (kg ha^{-1})**								
	2012-2013			**2013-2014**			**Pooled**		
Sulphur sources	40	70	100	40	70	100	40	70	100
Gypsum	10.1	12.1	12.4	9.5	11.3	12.1	9.8	11.7	12.2
E. sulphur	7.8	9.6	10.1	7.4	9.2	9.9	7.6	9.42	10
P. sulphate	12.3	13.4	13.6	12.2	13.1	13.4	12.2	13.2	13.4
CD ($p \le 0.05$)		**0.08**			**0.1**			**0.08**	

yield due to sulphur application may be attributed to balanced nutrition and increased growth and yield parameters indicating that sulphur is crucial for achieving higher yield[28].

Conclusion

In light of the experimental findings summarized above, application of sulphur along with the optimum dose of fertilizers improves yield and quality of cabbage and amongst various treatment combinations, application of 70 kg S ha^{-1} as potassium sulphate showed better response with respect to seed yield attributes, seed yield and quality parameters.

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