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Influence of Sulphur and Spacing on Growth and Yield Attributes of Knol-Khol (*Brassica oleracea* Var. *Gongylodes* L.) Var. Early White Viana

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A B S T R A C T

A field experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) during *Rabi* season 2014-15 on loamy sand soil. The experiment consisting 16 treatment combinations i.e. four levels of each sulphur (0 kg, 20 kg, 40 kg and 60 kg sulphur ha^{-1}) and spacing (30x20 cm, 30x30 cm, 45x30 cm and 45x45 cm) tested in randomized block design with three replications. Results revealed that application of 60 kg sulphur $ha^{-1}$with 45x45 cm spacing to the knol-khol crop significantly increased the plant height (cm)at harvest, days taken to initiation of knob, days taken to marketable maturity of knob, diameter of knoband volume of knob as compared to control, 20 kg sulphur ha^{-1} and 30x20 cm and 30x30 cm spacing but statistically at par with 40 kg sulphur ha^{-1} and 45x30 cm spacing, whereas number of leaves per plant, chlorophyll content (mg/g) in leaves, fresh weight of leaves and knob per plant (g) and Knob: leaf ratio were found significantly maximum at 40 kg sulphur ha^{-1} and 45x30 cm spacing as compared to control, 20 kg sulphur ha^{-1} and 30x20 cm and 30x30 cm spacing being statistically at par with 60 kg sulphur ha^{-1} and 45x45 cm spacing. The combined application of 40 kg sulphur ha^{-1} with 45x30 cm spacing proved to be most superior treatment combination in terms of diameter of knob and volume of knob, whereas 40 kg sulphur ha^{-1} with 30x30 cm spacing in terms of total knob yield (q ha^{-1}). In case of plant height at 30 DAT, sulphur and spacing levels was found to be non significant.

Introduction

In India, the cultivation of knol-khol is popular in Kashmir, West Bengal and some parts of South India. Knol-khol (*Brassica oleracea* var. gongylodes) is a winter season crop and is originated from the coastal countries of Mediterranean region (Choudhary, 1967). It is commonly grown in Northern India and also in some parts of Rajasthan. The stem swells and stores edible food material specially starch and sugars. When consumed as raw it gives sweetish taste with slight aroma. The stem develops entirely above ground, which is edible and vary delicate in flavour and texture (Singh, 1989). Knol-khol is characterized by formation of knob (tuber) which arises from thickening of the stem tissue above the cotyledon. The formation of knob is best seen at the temperature range of 15-180c. The fleshy turnip like enlargement develops entirely above the ground. The knob is harvested for human consumption either as raw or cooked.

When eaten raw it gives sweetish taste with slight aroma. It is also utilized for making salad and pickles. Occasionally young leaves are also cooked as vegetable. It is well documented that growth and quality of plants are greatly influenced by a wide range of nutrients. Sulphur is an essential plant nutrient and plays a vital role in biosynthesis of certain amino acids (Cysteine, cystine and methionine) and also helps in the synthesis of co-enzyme-A and formation of chlorophyll and nitrogenase enzyme.

Sulphur is reported from two natural growth regulators viz., thiamine and biotin. Sulphur occurs in glutathione that is important to oxidation reduction reaction (Kanwar, 1976). It is one of the constituents of vitamin B1, some volatile oils and amino acids like methinine (21% S). It is involved in various metabolic and enzymatic processes in the plant (Goswami, 1988). Most of the soils of Rajasthan are alkaline in nature and characterized by high pH values, which ranges between 8.0-10.0, while, the pH of the soils of present experiment was 8.2. At this pH value, the availability of plant nutrients is very low so sulphur fertilization might prove to be beneficial as it brings the soil pH low.

Keeping adequate plant population per unit area, Knol-khol is most important for its better growth and higher yield. The influenced of spacing on growth, size of knob, days to maturity and yield of Knol-khol under different agro-climatic condition have been reported by various workers.

The spacing of crop may be varied according to climatic condition, soil fertility and cultivars adaptation to particular region. Under the wider spacing, the plant was more vigorous in terms of leaf size, which might be due to less competition for light, nutrients and moisture as compared' to closer spacing (Rai *et al*., 2003).

Materials and Methods

The experiment was laid out at Horticulture farm, S.K.N. College of Agriculture, Jobner, Distict Jaipur (Rajasthan) during *Rabi* season 2014-15. The climate of Jobner is typically semi-arid characterized by extremes of temperature both in summer and winter, low rainfall and moderate relative humidity. Maximum temperature in summer ranges between 30 to 48^{0}C whereas, in winter, temperature falls down to as low as -1^{0}C. The average rainfall varies between 250 to 500 mm. The crop was transplanted on 18/10/2014 and harvested as last picking on 12/12/2014. The mean daily temperature maximum and minimum during the growing season of knol-khol fluctuated 35.0 and 2.0^{0}C, relative humidity ranged from 52 to 70 per cent. The soil was loamy sand in texture, slightly alkaline in reaction, poor in organic carbon (0.15 %) with low available nitrogen (128 kg ha^{-1}), phosphorus (16.63 kg ha^{-1}) and sulphur (8.40 mg kg^{-1}) and medium in potassium content (154.1 kg ha^{-1}). The experiment was comprised of 16 treatment combination will be carried out in Randomized Block Design (RBD) with four levels of each Sulphur (0, 20, 40 and 60 kg ha^{-1}) and spacing (30x20, 30x30, 45x30 and 45x45 cm). Two raised nursery beds of dimensions of 3 m x 1 m x 0.15 m (Length x Width x Height) were prepared by mixing well rotten FYM in soil @ 15 kg m^{-2}. Seeds of knol-kholcv. Early White Vienna obtained from National Seed Corporation was treated with 0.02 percent thiram to save the seedlings from damping off disease.

Treatment application

Sulphur

Sulphur was applied as per treatment through agriculture grade elemental sulphur and was broadcasted uniformly before transplanting

and incorporated in the soil. The agricultural grade of elemental sulphur (100 % S) was applied as per treatment before 20 days of transplanting.

Spacing

Sowing of the seedlings was carried out as per the scheduled levels of spacing viz. 30x20 cm, 30x30 cm, 45x30 cm and 45x45 cm.

Transplanting

Five weeks old seedlings were transplanted on 18th October 2014, when average height of seedlings was about 5-7 cm. The distance between row to row and plant to plant was kept at four levels of spacing (30x20, 30x30, 45x30 and 45x45 cm).

Characters studied and observations recorded

Growth parameters

Plant height (cm), Number of leaves per plant, Total chlorophyll content in leaves (mg/g), Days taken to initiation of knob and Days taken to marketable maturity of knob.

The amount of total chlorophyll was calculated as advocated by Arnon (1949).

Total chlorophyll (mg/g) =

$$\frac{A\ (652) \times 29 \times \text{Total volume (ml)}}{\alpha \times 1000 \times \text{Weight of sample (g)}}$$

Where,
A= Absorbance specific wave lengths
α is the path length = 1 cm

Yield and yield attributes

Diameter of knob (cm), Volume of knob (cc), Knob: leaf ratio and Total yield of knob (q ha^{-1}).

Results and Discussion

Effect of sulphur on growth attributes

It is apparent from data (Table 1) that varying sulphur levels influenced the plant height significantly. Application of 60 kg sulphur recorded the maximum plant height (30.40 cm) at harvest and proved superior to control and 20 kg sulphur with 18.06 and 6.85 per cent higher at harvest, respectively. Application of 60 kg sulphur was found to be statistically at par with 40 kg sulphur per ha. The difference in plant height at 30 DAT due to application of 60 kg, 40 kg and 20 kg sulphur were found non-significant to each other. Due to sulphur fertilization, xylem and collenchymas fibre are also reported to be thickened resulting into more pronounced growth of plant (Biswas *et al.*, 1995). Increasing vegetative growth of knol-khol due to sulphur fertilization in the present investigation are in close conformity with the finding of Yadav and Paliwal (1990), Sekhawat (1992), Dhar *et al.*, (1999) and Bhagavatagoudra and Rokhade (2001).

Increasing levels of sulphur application to knol-khol recorded maximum number of leaves per plant and total chlorophyll content in leaves with 60 kg sulphur. Application of 40 kg sulphur being at par with 60 kg sulphur proved significantly superior indicated an increase of 29.65, 9.57 and 22.58, 8.57 per cent in number of leaves per plant and chlorophyll content in leaves over control and 20 kg sulphur, respectively. It is obvious because of the fact that the application of sulphur has been reported to improve not only the availability of the sulphur but of other nutrients too, as sulphur results in lowering the soil pH (Hossan and Olsen, 1966). It also plays an important role in energy transformation, activation of a number of enzymes, carbohydrate metabolism and chlorophyll formation. The present

investigations are in close conformity with the finding of Nagda (1970), Yadav (1990), and Bhagavatagoudra and Rokhade (2001).

Sulphur also plays an important role in the production of chlorophyll. It was found that the sulphur increased the chemical and biological activation of iron in the leaves resulting in increased chlorophyll content, Ergle and Eaton (1951), Singh *et al.,* (1988), Biswas *et al.,* (1995) and Chhipa (2005).

Data presented in same table also revealed that application of different sulphur levels significantly affected the days taken to initiation of knob and days taken to marketable maturity of knob. The right time knob initiation was recorded with the application of 40 kg sulphur (29.07 days and 52.66 days) and 60 kg sulphur (28.77 days and 50.85 days) which were found statistically at par to each other. Although the initiation of knob and marketable maturity of kno under control and 20 kg sulphur were induced later.

The days taken to initiation of knob and marketable maturity of knob reduced significantly due to sulphur fertilization, whereas the highest level of sulphur brought about highly significant reduction in days taken to initiation of knob and marketable maturity of knob in comparison to control. This was perhaps due to a vital role of sulphur in the activation of a number of enzymes and also in carbohydrate metabolism in plant, thus may have provided proper inter plant balance thereby enhancing early maturity and initiation of knob (Tandon, 1986) which in turn might have favoured better knob formation and development and resulted in increased growth and ultimately higher yield.

The results are in close conformity with those of Meena (2004), Jamre *et al.,* (2010) and Gautam (2012).

Effect of sulphur on yield attributes

A perusal of data (Table 1) showed that application of sulphur levels had significant effect on diameter of knob and volume of knob. Maximum diameter and volume of knob (7.75 cm and 115.92 cc) was recorded in S_3 treatment (60 kg sulphur per ha), while minimum diameter and volume of knob (6.27 cm and 98.80 cc) was recorded in S_0 (control) treatment. Application of sulphur up to 60 kg per ha being at par with 40 kg per ha, significantly improved the diameter and volume of knob indicating an increase of 23.60, 10.24 and 17.33, 6.92 per cent over control and 20 kg sulphur per ha, respectively. The increase in yield and yield attributes might be due to the important role of sulphur in lowering the pH of saline alkaline soil resulting in increased availability of many nutrients (Hossan and Olsen, 1966) or might to be the activation of a number of enzymes and also in carbohydrate metabolism (Tandon, 1986) which in turn might have favoured better knob formation and development and resulted in increased growth and ultimately higher yield. The results are in close conformity with those of Hara *et al.,* (1981), Bijania and Dixit (1996), Bhagavatagoudra and Rokhade (2001) and Gautam (2012).The fresh weight of leaves and knob, knob: leaf ratio and total yield (q/ha) increased significantly with increasing levels of sulphur. The maximum fresh weight of leaves (156.86 g), knob (133.37 g), knob: leaf ratio (1.18) and total yield (223.64 q/ha) was recorded in 60 kg sulphur per ha while miminum was recorded in control (70.35g, 72.71 g, 0.97 and 156.70 q/ha). Application of 40 kg sulphur being at par with 60 kg sulphur gave significantly higher fresh weight of leaves and knob, knob: leaf ratio and total yield indicating an increase of 109.77, 28.85 and 73.72, 22.41 and 20.62, 5.41and 38.25, 13.15 per cent over control and 20 kg sulphur, respectively. The increase in yield attributes was probably due to source and sink

relationship. The increase in yield attributes can be attributed to increase the size of source and consequently the enhanced partitioning of photosynthetes toward sink. The results revealed that application of 60 kg sulphur per ha significantly increased the knob yields per ha of knol-khol as compared to control and 20 kg sulphur per ha, which were found statistically at par with 40 kg sulphur per ha. These finding corroborates with the findings of Sekhawat (1992), Dhar *et al.,* (1999), Jamre *et al.,* (2010), Gautam (2012) and Talukder *et al.,* (2013)

Effect of spacing on growth attributes

The perusal of data (Table 1) revealed that the plant height at harvest, number of leaves per plant and total chlorophyll content in leaves was significantly affected by various spacings. The maximum plant height at 30 DAT and at harvest (16.88 cm and 30.16 cm), number of leaves per plant (9.62) and increase in chlorophyll content(0.77 mg/g) was recorded with 45x45 cm spacing, while minimum was recorded under 30x20 cm spacing (16.08 cm and 26.40 cm, 7.55 and 0.64 mg/g). The spacing 45x45 cm was found superior over 30x20 cm and 30x30 cm spacing at these parameters which is statistically at par with 45x30 cm spacing, respectively, but in case of plant height at 30 DAT, spacing 45x45 cm were found non-significant to other spacing levels.

The close spacing offered severe competition between the plants for nutrients, moisture, light and space due to which tallness in plants was observed. On the other hand at wider spacing plant received more sunlight and more nutrients due to less number of plants which could increase the plant height, number of leaves per plant and chlorophyll content in leaves. The present results are in close aggrement with the findings of Patil *et al.,* (2003), Singh *et al.,* (2004), Prasad *et al.,* (2010), Khatun *et al.,* (2011), Moniruzzaman (2011), Solunke *et al*., (2011), Dev (2012), Thirupal *et al.,* (2014), and Mehta *et al.,* (2015). A critical examination of the data (Table 1) revealed that levels of spacing significantly affected days taken to initiation and marketable maturity of knob over 30x20 cm and 30x30 cm. Spacing 45x45 cm (28.81 days and 51.09 days) registered right time initiation of knob and marketable maturity of knob over 30x20 cm and 30x30 cm spacing which is statistically at par with 45x30 cm spacing (29.51 days and 52.74 days). The delay in initiation and marketable maturity of knob were recorded in 30x20 cm spacing (34.14 and 57.85 days).The days taken to initiation of knob and marketable maturity of knob reduced significantly under wider spacing. The spacing is important characteristics to know the variation of different parameters performance of a crop.

Proper spacing in knol-khol reduce the days which are require for initiation of knob and marketable maturity of knob and also decrease the percentage of it. Closer spacing reduce more time taken to initiation of knob than wider spacing because closer spacing decrease the maturation of crop by less availability of sunlight, fertilization space and more activity of tissues in a given area. The right time maturity was observed in closest spacing. In wider spacing, plants have to take more time to complete their physical and biological activities due to more availability of space, sunlight and fertilization. When the time taken to initiation of knob is reduced the days taken to marketable maturity is also reduced in closer spacing. These results are in close conformity with the findings of Patil *et al*., (2003) in knol-khol, Khan *et al.,* (1991), Bhangre *et al.,* (2011), Dev (2012) and Thirupal *et al.,* (2014) in broccoli who reported that close spacing reduced the days to knob initiation, head initiation, flower bud initiation, maturity and harvest duration of crop.

Table.1 Effect of sulphur and spacing on growth attributes of knol-khol

Treatments	Plant height		Number of leaves per plant	Chlorophyll content	Days taken to initiation of knob	Marketable maturity of knob
	At 30 DAT	At harvest				
Sulphur level						
S_0 (0 kg/ha)	15.83	25.75	7.42	0.62	34.98	58.19
S_1 (20 kg/ha)	16.56	28.45	8.78	0.70	31.06	55.29
S_2 (40 kg/ha)	16.78	30.23	9.62	0.76	29.07	52.66
S_3 (60 kg/ha)	16.91	30.40	9.78	0.79	28.77	50.85
SEm±	0.35	0.60	0.21	0.02	0.65	0.79
CD at 0.05%	1.02	1.74	0.60	0.04	1.86	2.28
Spacing						
D_0 (30x20 cm)	16.08	26.40	7.55	0.64	34.14	57.85
D_1 (30x30 cm)	16.30	28.23	8.92	0.69	31.43	55.31
D_2 (45x30 cm)	16.82	30.05	9.52	0.74	29.51	52.74
D_3 (45x45 cm)	16.88	30.16	9.62	0.77	28.81	51.09
SEm±	0.35	0.60	0.21	0.02	0.65	0.79
CD at 0.05%	1.02	1.74	0.60	0.05	1.86	2.28

Table.2 Effect of sulphur and spacing on yield attributes and yield of knol-khol

Treatments	Diameter of knob	Volume of knob	Fresh weight of leaves/plant	Fresh weight of knob/plant	Knob:leaf ratio	Total yield (q/ha)
Sulphur level						
S_0 (0 kg/ha)	6.27	98.80	70.35	72.71	0.97	156.70
S_1 (20 kg/ha)	7.03	108.42	114.54	103.19	1.11	191.45
S_2 (40 kg/ha)	7.45	113.13	147.58	126.31	1.17	216.63
S_3 (60 kg/ha)	7.75	115.92	156.86	133.37	1.18	223.64
SEm±	0.14	1.60	3.42	2.89	0.01	3.89
CD at 0.05%	0.40	4.62	9.87	8.34	0.03	11.24
Spacing						
D_0 (30x20 cm)	6.48	100.35	81.01	77.68	1.03	194.21
D_1 (30x30 cm)	6.97	108.23	113.05	101.46	1.10	219.16
D_2 (45x30 cm)	7.38	112.99	143.20	124.78	1.14	209.60
D_3 (45x45 cm)	7.67	114.71	152.08	131.66	1.15	165.45
SEm±	0.14	1.60	3.42	2.89	0.01	3.89
CD at 0.05%	0.40	4.62	9.87	8.34	0.03	11.24

Table.3 Interactive effect of sulphur and spacing on diameter, volumeand yield of knob of knol-khol

Spacings	Sulphur levels											
	diameter of knob (cm)				volume of knob (cc)				Yield of knob (q ha^{-1})			
	Control	20 kg/ ha	40 kg/ ha	60 kg/ ha	Control	20 kg/ ha	40 kg/ ha	60 kg/ ha	Control	20 kg/ ha	40 kg/ ha	60 kg/ ha
30x20 cm	5.50	6.98	7.02	6.40	80.13	101.72	110.46	109.09	153.23	188.75	221.12	213.73
30x30 cm	6.00	7.13	7.21	7.55	100.92	110.81	108.73	112.44	173.40	213.31	238.45	251.48
45x30 cm	6.55	6.51	8.39	8.08	105.05	110.02	118.96	117.93	169.75	202.78	226.73	239.15
45x45 cm	7.03	7.51	7.17	8.98	109.11	111.14	114.36	124.21	130.42	160.97	180.22	190.20
S.Em.±	0.28				3.20				9.41			
C.D. (P = 0.05)	0.80				9.25				27.17			

Effect of spacing on yield and yield attributes

Data (Table 1) further revealed that levels of spacing also significantly influenced the diameter and volume of knob. Maximum diameter of knob (7.70 cm) and volume of knob (114.71 cc) was recorded in D_3 treatment (45x45 cm spacing) while minimum (6.48 cm and 100.35 cc) was recorded in D_0 treatment (30x20 cm spacing). The spacing 45x45 cm (D_3) was found statistically at par with 45x30 cm spacing (D_2) represented a significant increase of 18.36 and 10.04 per cent by diameter and 14.30 and 5.98 per cent by volume of knob over 30x20 cm and 30x30 cm spacing, respectively.

Interactive effect of sulphur levels and spacing on diameter (cm) and volume of knob (cc)

Data in Table 1 showed that the combined effects of different sulphur levels and spacing on diameter of knob were found to be significant. The application of 60 kg sulphur along with 45x45 cm spacing recorded the maximum diameter of knob (8.98 cm) and volume of knob (124.21 cc) per plant but in case of diameter it was found statistically at par with 40 kg sulphur per ha with 45x30 cm spacing. The treatment combination of 40 kg sulphur with 45x30 cm spacing registered an increase of 52.55 per cent in diameter of knob over control with 30x20 cm spacing proved as good as 60 kg sulphur along with 45x45 cm spacing and found significantly superior to rest of the treatment combinations. While, in case of volume of knob it was found statistically at par with 60 kg sulphur per ha with 45x30 cm spacing and 40 kg sulphur per ha with 45x30 cm spacing. The treatment combination of 40 kg sulphur with 45x30 cm spacing proved as good as 60 kg sulphur along with 45x45 cm spacing and 60 kg sulphur with 45x30 cm spacing found significantly superior to rest of the treatment combinations. Application of 40 kg sulphur with 45x30 cm spacing registered an increase of 48.46 per cent in diameter of knob over control with 30x20 cm spacing.

A perusal of data (Table 2) revealed that applied levels of spacing significantly enhanced the fresh weight of leaves and knob per plant and knob: leaf ratio over 30x20 cm and 30x30 cm spacing. The maximum fresh weight of leaves (152.08g) and knob (131.66 g) and knob: leaf ratio (1.15) was recorded in 45x45 cm spacing whereas minimum was recorded in 30x20 cm spacing (81.01, 77.68 g and 1.03). However, spacing 45x30 cm was found statically at par with 45x45 cm spacing. The increase in fresh weight of leaves and knob and knob: leaf ratio under 45x30 cm spacing was found to be 76.77, 26.67 and 60.63, 22.98 and 11.65 and 4.55 per cent over 30x20 cm and 30x30 cm spacing, respectively.

Data presented in Table 3 further reveal that total yield of knol-khol was significantly influenced by different spacing levels over 45x45 cm spacing. The spacing 30x30 cm was recorded significantly higher yield per hectare over 45x45 cm and 30x20 cm spacing which was found statistically at par with 45x30 cm spacing. The mean increase in total yield per ha due to 45x30 cm spacing over 45x45 cm and 30x20 cm spacing were 26.32 and 7.92 per cent, respectively. The combined or interaction effect of sulphur levels with spacings on total yield of knol-khol (per hectare) was found to be significant. Application of 60 kg sulphur with 30x30 cm spacing gave highest total yield per hectare (251.48 q) being at par with 60 kg sulphur with 45x30 cm spacing and 40 kg sulphur with 30x30 cm spacing. Application of 40 kg sulphur along with 30x30 cm spacing registered an increase of 55.62 per cent in per hectare yield over control, respectively.

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