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IMPROVING KNOL-KHOL (*BRASSICA OLERACEA* VAR. GONGYLODES L.) PRODUCTIVITY: A STUDY ON SULPHUR LEVELS AND PLANT SPACING INTERACTIONS

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ABSTRACT

A field experiment entitled "Improving Knol-Khol Productivity: A Study on Sulphur Levels and Plant Spacing Interactions" was carried out at the Horticulture Research Farm, School of Agricultural Sciences, Nirwan University, Jaipur (Rajasthan), during October 2024 to March 2025. The experiment comprised 16 treatment combinations involving four sulphur levels, S0 (control), S1 (15 kg/ha), S2 (30 kg/ha), S3 (45 kg/ha) and four plant spacings, D0 (30 × 20 cm), D1 (30 × 30 cm), D2 (45 × 30 cm), D3 (45 × 45 cm). The results revealed that the application of 45 kg S/ha (S3) in combination with 45 × 45 cm spacing (D3) exhibited significant superiority in improving vegetative growth and quality attributes of knol-khol. This treatment recorded the maximum plant height, number of leaves per plant, total chlorophyll content, knob diameter, knob volume, fresh weight of leaves and knob per plant, knob:leaf ratio, total yield per plant, sulphur content in knob, TSS, protein content and ascorbic acid content. It also resulted in the minimum days to knob initiation and marketable maturity, indicating accelerated crop development under higher sulphur availability and wider spacing. With respect to total yield per hectare, however, the 30 × 30 cm spacing (D1) outperformed the wider spacing treatments due to higher plant population density. Overall, the study highlights that S3 (45 kg S/ha) optimizes growth and quality, while D1 (30 × 30 cm) is more beneficial for maximizing total yield. The combined analysis suggests that appropriate sulphur nutrition and balanced plant spacing are crucial for enhancing productivity and quality of knol-khol.

Keywords: Knol-Khol, Plant Spacing, Yield Attributes, Growth, Yield and Rabi.

Introduction

Knol-khol (*Brassica oleracea* var. gongylodes L.) is a winter season crop and originates from the coastal countries of the Mediterranean region (Choudhary, 1967). It has been under cultivation by the Romans since 600 B.C. (Bose, 1986). In India, the cultivation of knol-khol is popular in Kashmir, West Bengal and some parts of South India. It is commonly grown in Northern India and also in some parts of Rajasthan. The stem swells and stores edible food material, especially starch and sugars. When consumed raw, it gives a sweetish taste with a slight aroma. The stem develops entirely above ground, which is edible and varies in flavour and texture (Singh, 1989).

Knol-khol contains approximately 1.1 g of protein, 20 mg of calcium, 0.4 mg of iron, 36 IU of vitamin A and 0.7 mg of other minerals per 100 g of its edible portion. It is also a source of thiamine, riboflavin, nicotinic acid, and ascorbic acid (Choudhary, 1967). The knob is primarily consumed as a cooked vegetable, though it is also commonly used in salads and pickles. Occasionally, the tender young leaves are cooked and consumed as well. With its growing popularity in both metropolitan and smaller urban areas, there is an increasing need to standardize agrotechniques for its successful cultivation, particularly in semi-arid regions.

Sulphur is an integral component of the two natural growth regulators, viz., thiamine and biotin,

which play a crucial role in various biochemical processes in plants. Sulphur forms a structural part of glutathione, which is an important compound involved in cellular oxidation-reduction reactions (Kanwar, 1976). Additionally, it is one of the constituents of vitamin B1, volatile oils and amino acids like methionine and is involved in various metabolic and enzymatic processes in the plant (Goswami, 1988).

The soils of Rajasthan are predominantly alkaline in nature and characterized by high pH values, typically ranging between 8.0-10.0.In the present study, the soil used to conduct the experiment was alkaline in nature with a pH level of 8.2, at which the availability of several essential plant nutrients is markedly reduced. Under such alkaline conditions, sulphur fertilization becomes particularly advantageous, as it can contribute to a gradual reduction in soil pH and thereby enhance the availability of essential nutrients to plants.

Maintaining an optimal plant density is crucial for the proper growth and higher yield of knol-khol. The impact of plant spacing on growth parameters like knob size, days to maturity and yield has been extensively studied under various agro-climatic conditions. Further, spacing requirements can vary depending on climatic conditions, soil fertility, and the adaptability of specific cultivars to a region. Wider spacing generally results in more vigorous plant growth, particularly in terms of leaf development, which may be attributed to reduced competition for light, nutrients, and moisture compared to closer spacing (Rai *et al*., 2003). Among various agronomic practices, appropriate plant spacing combined with the timely application of balanced fertilizer doses is especially important under the semi-arid conditions of Rajasthan. Considering these factors, the present investigation titled "Improving Knol-Khol Productivity: A Study on Sulphur Levels and Plant Spacing Interactions" was undertaken to evaluate the crop's performance under the specific agro-climatic conditions of Jaipur. Wider plant spacing generally promotes greater vegetative vigour, particularly in terms of leaf size, due to reduced intra-specific competition for light, nutrients and soil moisture, as reported by Bairwa *et al.* (2017). Therefore, the present study focuses on understanding the impact of sulphur levels and plant spacing on the growth, yield and quality attributes of knol-khol, thereby generating region-specific recommendations suitable for the semi-arid environment of Jaipur.

Materials and Methods

A field experiment entitled "Improving Knol-Khol Productivity: A Study on Sulphur Levels and Plant Spacing Interactions" was conducted at the Horticulture Research Farm of the School of Agricultural Sciences, Nirwan University, Jaipur (Rajasthan) during October 2024 to Feb 2025. The experiment consisted of 16 treatments, namely, 4 levels of sulphur S0 (control), S1 (15 kg/ha), S2 (30 kg/ha) and S3 (45 kg/ha) and 4 plant spacing D0 (30x20 cm), D1 (30x30 cm), D2 (45x30 cm) and D3 (45x45 cm). Among these, the treatment involving S3 (45 kg/ha) and spacing D3 (45x45 cm) was of particular interest due to its influence on crop performance. Growth, yield, and quality parameters were recorded at the time of harvest following standard procedures. The collected data were subjected to statistical analysis using the Analysis of Variance (ANOVA) method as outlined by Gomez and Gomez (1984).

Result and Discussion

Plant height (cm)

The height of the plant represents its growth and vigour. The maximum plant height in knol khol was influenced significantly by different treatments of sulphur during the course of experimentation (Fig. 1). The maximum plant height (32.50 cm) was recorded with S3 (45 kg/ha) and the minimum (28.85 cm) was recorded in S0 (control) as compared to the other sulphur treatments. The plant spacing shows a significant response. All the results varied significantly from each other. The maximum plant height (32.27 cm) was recorded in D3 (45x45 cm), and the minimum D0 (28.50 cm) was found in control 30x20 cm as compared to the other spacing.

The results of the present investigation have shown that increasing levels of sulphur significantly increased the plant height at harvest. The results revealed that application of sulphur at the rate of 45 kg ha^{-1} and plant spacing at (45x45 cm) have significantly increased the plant height at harvest. Similarly, results were recorded by Mansa (2017) in red cabbage, Kakani (2012) in cauliflower, Sawale (2004) and Maheshkumar and Rawat (2002) in cabbage. The increase in plant height and vigour may be because plants with wider spacing received more sunlight and nutrients due to fewer plants, as reported by Moniruzzaman (2011).

Number of leaves per plant

The number of leaves per plant represents its growth and vigour. The maximum number of leaves per plant in knol khol was influenced significantly by

different treatments of sulphur and spacing during the course of experimentation (Fig. 2). The maximum number of leaves per plant (12.88) was recorded with S3 sulphur @ (45 kg/ha) and minimum (9.52) was recorded in S0 (control) as compared to the other sulphur treatments. The plant spacing shows significant response. All the result was varying significantly with each other. The maximum number of leaves per plant (12.73) was recorded in D3 (45x45 cm) and minimum D0 (9.56) was found in control (30x20 cm) as compared to the other spacing.

Among sulphur levels, the effect of sulphur on the number of leaves per plant and plant spread was found to be significant. The highest number of leaves and plant spread was recorded in 45 kg/ha sulphur. Similar results were recorded by Mansa (2017) in red cabbage, Kakani (2012) in cauliflower and Haque *et al.,* (2015) in cabbage.

Days taken to initiation of knob

Data presented in Fig. 3 indicate that increasing sulphur application levels in knol-khol cultivation. The minimum days taken to initiation of knob in knol khol was influenced significantly by different treatments of sulphur and spacing during the course of experimentation (Table 4.2). The minimum days taken to initiation of knob (30.87 days) was recorded with S3 sulphur @ (45 kg/ha) and maximum (36.98 days) in S0 (control) as compared to the other sulphur treatments. The plant spacing shows significant response. All the result was varying significantly with each other. The minimum days taken to initiation of knob (30.91 days) was recorded in D3 (45x45 cm) and maximum in D0 (36.24 days) was found in control (30x20 cm) as compared to the other spacing.

Sulphur fertilization significantly reduced the number of days required for both knob initiation and marketable maturity in knol-khol. The highest sulphur application level led to a highly significant reduction in these parameters compared to the control. This effect may be attributed to sulphur's essential role in activating various enzymes and its involvement in carbohydrate metabolism within the plant. These functions likely contributed to maintaining a proper inter-plant physiological balance, thereby promoting earlier knob initiation and maturity (Tandon, 1986). Consequently, this may have supported improved knob formation and development, resulting in enhanced plant growth and ultimately higher yields. These findings are in close agreement with those reported by Jamre *et al.* (2010) and Gautam (2012).

Days taken to marketable maturity of the knob

The effect of increasing sulphur application levels in knol-khol cultivation is presented in Table-4.3. The minimum days taken to marketable maturity of knob in knoll-khol was influenced significantly by different treatments of sulphur and spacing during the course of experimentation (Fig.4). The minimum days taken to marketable maturity of knob (52.95 days) was recorded with S3 sulphur @ (45 kg/ha) and maximum (60.29 days) in S0 (control) as compared to the other sulphur treatments. The plant spacing also showed a significant response. The minimum days taken to marketable maturity of knob (53.19 days) was recorded in D3 (45x45 cm), and the maximum in D0 (59.95 days) was found in control (30x20 cm) as compared to the other spacing.

Sulphur fertilization significantly reduced the number of days required for both knob initiation and marketable maturity in knol-khol. The highest sulphur application level led to a highly significant reduction in these parameters compared to the control. This effect may be attributed to the role of sulphurin activating various enzymes and its involvement in carbohydrate metabolism in plants. These functions likely contributed to maintaining a proper inter-plant physiological balance, thereby promoting earlier knob initiation and maturity (Tandon, 1986). Consequently, this may have facilitated better knob initiation and development, thereby promoting overall plant growth and contributing to increased yield. These results are consistent with the observations reported by Jamre *et al*. (2010) and Gautam (2012).

Diameter of knob (cm)

The diameter of the knoll-khol knob was significantly influenced by different sulphur levels and plant spacing treatments. Data presented in Fig.5 and Table-4.3 showed that the maximum knob diameter of 9.85 cm was recorded under S3 (45 kg S/ha), while the minimum knob diameter of 8.37 cm was observed in S0 (control). Similarly, plant spacing exerted a significant effect on knob diameter. The widest spacing, D3 (45×45 cm), produced the largest knob diameter (9.77 cm), whereas the narrowest spacing, D0 (30×20 cm), resulted in the smallest diameter (8.58 cm).That the interaction between sulphur levels and plant spacing had a significant effect on knob diameter. The combination of 45 kg S/ha with 45 × 45 cm spacing recorded the maximum knob diameter (10.98 cm per plant), which was significantly superior to all other treatment combinations.

The significant improvement in knob diameter and volume with increasing sulphur levels may be attributed to sulphur's role in reducing soil pH in saline-alkaline conditions, thereby enhancing nutrient availability (Hossan and Olsen, 1966). Additionally, sulphur is known to activate several enzymes and play a crucial role in carbohydrate metabolism (Tandon, 1986), which collectively support improved knob initiation and development, enhanced plant growth, and ultimately higher yields. These findings align closely with the reports of Hara *et al.* (1981), Bijania and Dixit (1996), Bhagavata Goudra and Rokhade (2001) and Gautam (2012).

Variations in yield due to plant spacing may be attributed to improved light interception and greater nutrient availability under wider spacing conditions. Similar observations were reported by Kumar *et al.* (2021) in sprouting crops.

Productivity (q/ha)

The highest productivity in knol-khol was influenced significantly by different treatments of sulphur and spacing. Data represented in Fig. 6 indicate that increasing sulphur application levels in knol-khol cultivation influence the total yield. The maximum productivity of243.74 q/ha was recorded with S3 sulphur @ (45 kg/ha) and the minimum productivity of 176.90 q/ha was recorded in S0 (control). The plant spacing showed a significant response. All the results were varying significantly from each other. The maximum productivity (229.25 q/ha) was recorded in D1 (30x30 cm), and the minimum productivity (185.55) was found in D3 (45x45 cm) as compared to the other spacing. Increasing the space inversely affects the productivity of knol-khol. This may be due to a lesser number of plants accommodated in a given area when spacing is increased. These results are in close conformity with the findings of Thirupal *et al.* (2014) in broccoli.

The combined effects of different sulphur levels and spacing on productivity were found to be significant. The application of 45 kg/ha sulphur along with 30x30 cm spacing recorded the maximum productivity of 253.55 q/ha. The treatment combination with 45 kg/ha sulphur, along with 30x30 cm spacing and found to be significantly superior to the rest of the treatment combinations.

TSS content in knob (%)

Data presented in Fig. 7 indicate that increasing sulphur application levels have a positive effect on TSS content in knol-khol knob. The maximum TSS content in knob (9.33 %) was recorded with S3 sulphur @ (45 kg/ha), and the minimum (8.10 %) in S0 (control) as compared to the other sulphur treatments. The plant spacing also showed a significant response. All the results were varying significantly from each other. The maximum TSS content in knob (9.28 %) was recorded in D3 (45x45 cm), and the minimum (8.22 %) was found in D0 (30x20 cm) as compared to the other spacing.

The increase in TSS content with higher sulphur levels may be attributed to the role of sulphur in improving overall metabolic activities, particularly in the synthesis and translocation of carbohydrates. Sulphur enhances the activity of certain enzymes involved in photosynthesis and carbohydrate metabolism, which promotes the accumulation of soluble solids in the knob. Adequate sulphur supply also improves nutrient uptake efficiency and growth, which further supports better synthesis and storage of sugars and related compounds, thereby increasing TSS content.

Protein content in knob (%)

Data presented in Fig. 8 indicate the level of protein estimated in different treatments. The maximum protein content in the knob was significantly influenced by different sulphur treatments and spacing during the experiment. The highest protein content in the knob (4.49%) was observed with S3 sulphur @ (45 kg/ha), while the lowest (2.58%) was recorded in S0 (control) compared to other sulphur treatments. Plant spacing also showed a significant response. All results varied significantly from each other. The highest protein content in the knob (4.38%) was observed in D3 (45x45 cm), while the lowest (2.81%) was found in D0 (30x20 cm) compared to other spacings.

The results may be because nitrogen and sulphur are the main ingredients of protein and increase in their availability increase the utilization of nitrogen for the synthesis of protein. Sulphur synthesized some sulphur containing amino acids like cysteine and methionine and resulted in increased protein content, which is in accordance with the findings of (Hunashikatti *et al.,* 2000; Gautam 2012; Verma and Nawange, 2015).

Conclusion

Based on the findings of the present investigation, it can be concluded that sulphur levels and plant spacing exerted a significant influence on growth, yield and quality attributes of knol-khol. Among the different sulphur levels, the application of 45 kg S/ha (S3) resulted in the highest plant height, number of leaves per plant, knob diameter, total yield, TSS content and protein content of the knob. Similarly, the widest spacing of 45×45 cm (D3) proved superior in recording maximum growth and quality parameters,

along with minimum days required for knob initiation and marketable maturity.

However, with respect to total yield per hectare, the spacing 30×30 cm (D1) produced the maximum yield due to optimum plant population per unit area. Thus, the combination of 45 kg S/ha with a spacing of 45×45 cm may be recommended for better growth and improved quality of knol-khol, whereas 30×30 cm spacing may be considered when the primary objective is to maximize total yield per unit area.

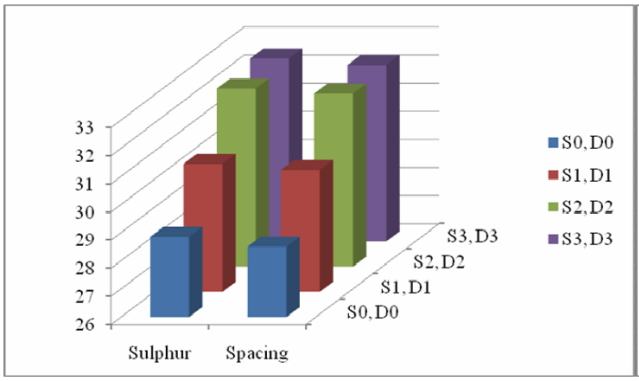

Fig. 1 : Effect of sulphur and spacing on plant height (cm) of knoll-khol

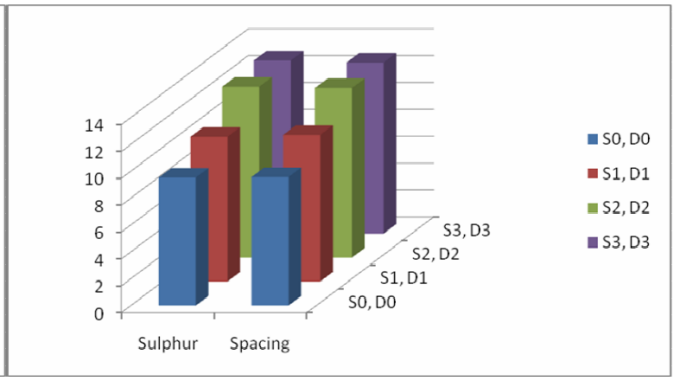

Fig. 2 : Effect of sulphur and spacing on number of leaves per plant of knoll-khol

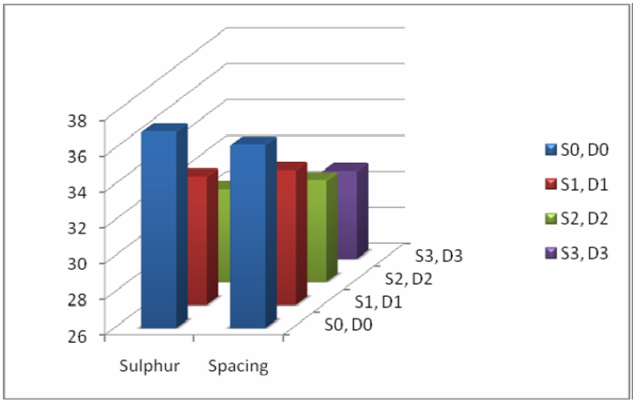

Fig. 3 : Effect of sulphur and spacing on Days taken to initiation of knob.

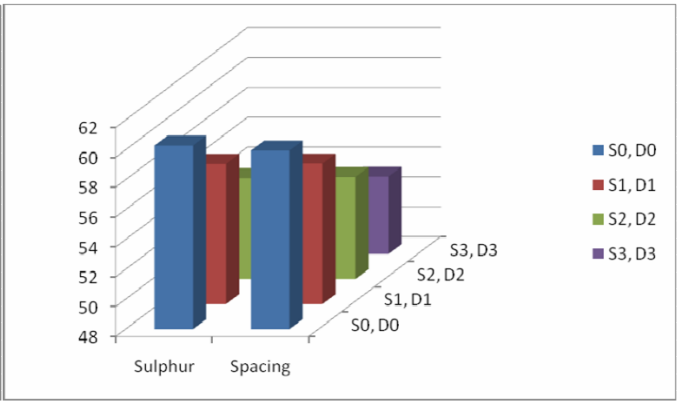

Fig. 4 : Effect of sulphur and spacing on days taken to marketable maturity of knob

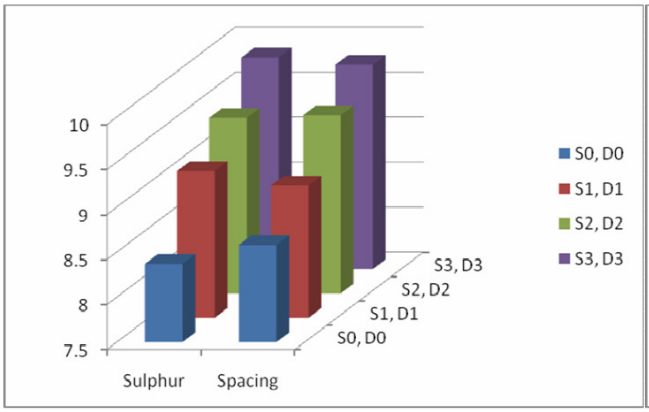

Fig. 5 : Effect of sulphur and spacing on diameter of knob (cm)

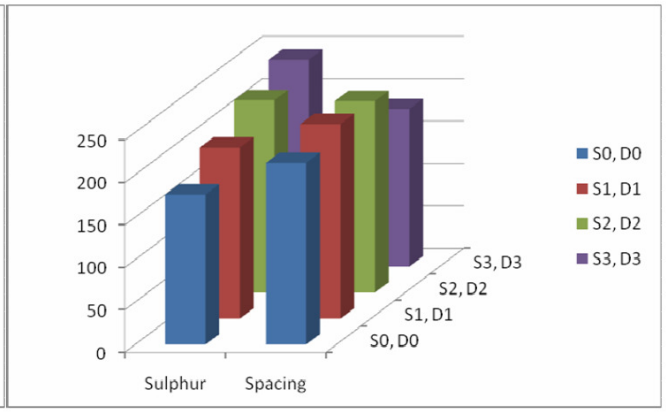

Fig. 6 : Effect of sulphur and spacing on total yield (q/ha)

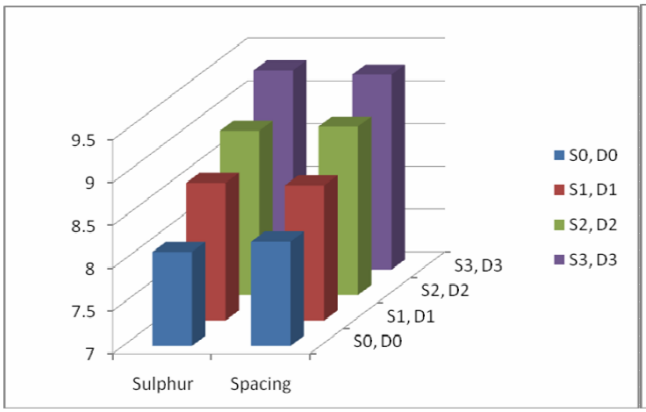

Fig. 7 : Effect of sulphur and spacing on TSS content in knob (%)

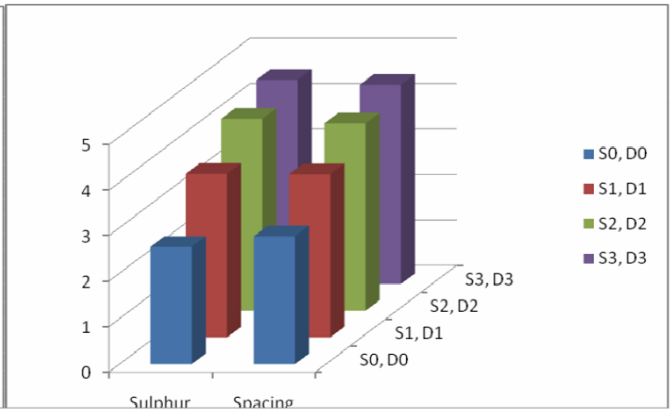

Fig. 8 : Effect of sulphur and spacing on protein content in knob (%)

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