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Influence of Different Rates of Nitrogen and Sulfur on Growth, Yield and Yield Attributes of Cabbage (*Brassica oleraceae* L.)

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ABSTRACT

The field experiment was conducted at Lovely Professional University, Phagwara, during *rabi* season on the sandy loam soils to study the influence of different rates of nitrogen and sulfur on growth and yield attributes of cabbage (*Brassica oleraceae* L.). The experiment was laid in Factorial Randomized Block Design (FRBD) consisting of eight treatments and three replications viz. (N_1: 0 kg N per ha, N_2: 100 kg N per ha, N_3: 125 kg N per ha, N_4: 150 kg N per ha, S_1: 0 kg S per ha, S_2: 30 kg S per ha, S_3: 60 kg S per ha and S_4: 90 kg S per ha). The different growth and yield attributes viz. plant height (cm), number of unfolded leaves per plant, diameter of cabbage head (cm), weight of cabbage head (kg) and yield of cabbage (t/ha) were recorded at different growth stages and at the time of harvesting. The results revealed that the application of 150 kg nitrogen and 90 kg sulfur per hectare gave the maximum values in all the growth and yield attributes compared to all the other treatments as well as control.

Keywords Cabbage, Nitrogen, Sulfur, Yield.

INTRODUCTION

Cabbage (*Brassica oleraceae* L.) is grown as an annual vegetable crop for its dense-leaved heads. It is a leafy green, red (purple), or white (pale green) biennial plant. Cabbage heads generally range from 0.5 to 4 kilograms, and can be purple, green or white. China, Russia and India are the largest cabbage producers in the world and Russia is the biggest cabbage consumer in the world. China accounts for 32.8 million tons of cabbage produced in the world. The top cabbage producing European countries in the list are Russia (3.3 million tons), Ukraine (1.9 million tons), Poland (1.9 million tons) and Romania (1 million tons). The United States accounts for 964,830 tons of total world production. The most preferable soil for cabbage is light sand to heavier clay soil with high content of organic matter (Saha *et al.* 2022). The ideal soil pH ranges from 5.5 to 6.5 (Alemayehu *et al.* 2021).

As cabbage is a vegetative bud it is very responsive to nitrogen fertilizer. The application of nitrogen fertilizers is essential for the formation of primary and secondary metabolites in plants (Kacjan *et al.* 2021). If nitrogen is in excess it will lead to loose head formation which is undesirable and if there is deficiency there will be no head formation. As for

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sulfur, it plays an important role in plant nutrition. Sulfur is actively involved in the synthesis of amino acid, chlorophyll, protein and oil. Sulfur also provides winter hardiness and drought tolerance, control of insect pests and disease. Keeping all these factors in consideration, the present investigation was planned as with objective as to study the effect of nitrogen and sulfur on growth, yield and yield attributes of cabbage.

MATERIALS AND METHODS

The experiment was conducted at the field of Lovely Professional University, Phagwara, situated geographically at 31°14'43.8"N and 75°41'44.1"E and 254 meters above sea level during *rabi* season 2019. It falls under central plain zone of agro climate zone of Punjab. The soil of the experimental site was alkaline in nature. The climate is a typically semi-arid condition, characterized by extremes of temperatures during both summer and winters. During winters, the temperatures may go as low as 5°C. In Phagwara (Punjab), there is little rainfall throughout the year. The average annual temperature is 24.1°C. The experiment consisted of eight treatments (0 kg N per ha, 100 kg N per ha, 125 kg N per ha, 150 kg N per ha, 0 kg S per ha, 30 kg S per ha, 60 kg S per ha, 90 kg S per ha). The experiment was laid out in Factorial Randomized Block Design (FRBD) and replicated three times. The field was prepared into ridges and furrows. Five plants were selected at random at the time of collecting data from each plot and mean data on the following parameters: Plant height (cm), number of unfolded leaves per plant, diameter of head (cm), weight of cabbage head (kg) and yield per hectare (t/ha) were recorded. The mean value for all the treatments was calculated and the statistical analysis carried out on OPSTAT software.

RESULTS AND DISCUSSION

Plant height (cm) (30, 60 and 90 DAT)

Effect of nitrogen

The treatment N_4 (150 kg/ha) showed the maximum growth in all three stages i.e., 30 DAT, 60 DAT and 90 DAT with a reading of 12.03 cm, 16.80 cm, 19.16 cm respectively. The minimum growth was recorded in control N_1 (0 kg/ha). At 30, 60 and 90 DAT the treatment N_4 (150 kg/ha) showed 51.03%, 37.33% and 22.33% increase in height compared to control N_1 (0 kg/ha).

Table 1. Effect of nitrogen and sulfur on plant height (cm) of cabbage at 30, 60 and 90 days of transplanting.

Treatments	30 DAT	60 DAT	90 DAT
Nitrogen			
N_1 (0 kg N per ha)	7.96	12.23	15.66
N_2 (100 kg N per ha)	9.43	13.96	17.56
N_3 (125 kg N per ha)	10.33	14.73	18.23
N_4 (150 kg N per ha)	12.03	16.80	19.16
SE (m) ±	0.54	0.43	0.27
CD at 5%	1.35	1.54	0.95
CV	6.67	5.24	2.66
Sulfur			
S_1 (0 kg S per ha)	8.03	12.06	15.56
S_2 (30 kg S per ha)	9.40	13.63	16.70
S_3 (60 kg S per ha)	10.16	14.53	17.4
S_4 (90 kg S per ha)	11.03	15.86	18.03
SE (m) ±	0.13	0.12	0.37
CD at 5%	0.49	0.44	1.33
CV	2.49	1.58	3.85

The data (Table 1) shows that there is significant increase in height of cabbage plant with increasing doses of nitrogen. This might be due to the fact that cabbage, being a vegetative bud responds very well to nitrogen and nitrogen increases vegetative growth vigorously. Similar results were found out by Kurre *et al.* (2023).

Effect of sulfur

The maximum readings for 30 DAT, 60 DAT and 90 DAT were recorded in S_4 (90 kg/ha) with a reading of 11.03 cm, 15.86 cm, 18.03 cm respectively. At 30, 60 and 90 DAT, treatment S_4 (90 kg/ha) showed 37.34%, 31.49% and 15.84% increase in plant height compared to control S_1 (0 kg/ha).

The increase in height with increasing levels of sulfur may be due to better nutritional environment at the rhizosphere due to availability of sulfur. Better availability of sulfur helps in growth and development

Table 2. Effect of nitrogen and sulfur on number of unfolded leaves per plant.

Treatments	30 DAT	60 DAT	90 DAT
Nitrogen			
N_1 (0 kg N per ha)	9.10	11.36	14.16
N_2 (100 kg N per ha)	9.70	14.00	17.43
N_3 (125 kg N per ha)	11.20	16.10	18.36
N_4 (150 kg N per ha)	13.46	17.06	18.90
SE (m) ±	0.14	0.25	0.36
CD at 5%	0.52	0.89	1.26
CV	2.37	3.00	3.61
Sulfur			
S_1 (0 kg S per ha)	9.10	12.23	14.36
S_2 (30 kg S per ha)	9.86	13.33	16.26
S_3 (60 kg S per ha)	10.76	15.06	17.16
S_4 (90 kg S per ha)	12.60	16.36	17.70
SE (m) ±	0.16	0.25	0.25
CD at 5%	0.58	0.89	0.91
CV	2.69	3.08	2.73

as sulfur have positive interaction with nitrogen so it also helps enhance utilization of each other.

Number of unfolded leaves per plant (30, 60 and 90 DAT)

Effect of nitrogen

The maximum number of leaves in case of nitrogen for 30 DAT, 60 DAT and 90 DAT was observed in treatment N_4 (150 kg/ha) which was 13.46, 17.06 and 18.90 respectively. The minimum number of leaves were recorded in control N_1 (0 kg/ha) in all cases. At 30 DAS, the treatment N_4 (150 kg/ha), number of unfolded leaves was an increment of 47.98% over N_1 (0 kg/ha). At 60 DAT and 90 DAS, the increase in number of unfolded leaves over control N_1 (0 kg/ha) by treatment N_4 (150 kg/ha) was 50.14% and 33.40% respectively (Table 2).

The increase in number of leaves of cabbage with increasing nitrogen may be due to the fact that cabbage is a vegetative bud and it responds well to nitrogen as nitrogen increases vegetative growth and produces good quality folliage.

Effect of sulfur

In case of sulfur, the maximum number of leaves for 30 DAT, 60 DAT and 90 DAT was observed in treatment S_4 (90 kg/ha) which was 12.60, 16.36 and 17.70 respectively. The minimum number of unfolded leaves was shown by control S_1 (0 kg/ha) in all cases. AT 30 DAT, treatment S_4 (90 kg/ha) showed an increase of 38.46% in number of unfolded leaves compared to control (0 kg/ha). There was a difference of 33.79% in number of unfolded leaves between treatment S_4 (90 kg/ha) and control S_1 (0 kg/ha). At 90 DAT, treatment S_4 (90 kg/ha) had an increase of number of leaves by 23.19% over control S_1 (0 kg/ha).

The increase in number of leaves with increasing levels of sulfur might also be due to the overall better availability of sulfur and other nutrients. Moreover sulfur also enhances the utilization of nutrient like N. Sulfur also makes the plant robust which leads to less falling of leaves due to diseases and pests (Bhagavatagoudra and Rokhade 2001).

Diameter of cabbage head

Effect of nitrogen

The maximum diameter was recorded in treatment N_4 (150 kg/ha) which had an average length of 12.00 cm. The control N_1 (0 kg/ha) had the lowest (9.23 cm) average diameter. The treatment N_4 (150 kg/ha) had an increase of 29.96% in cabbage head diameter compared to control N_1 (0 kg/ha) (Table 3).

The increase of diameter of cabbage heads with increasing nitrogen levels was possibly due to higher synthesis of carbohydrate and their translocation to the sink which ultimately helped in the formation of larger and comparatively broader cabbage heads. It is clearly shown in the Table (Table 3) that the diameter of cabbage heads were significantly increased by increasing doses of Mohammadullah *et al*. (2020) also found similar results.

Effect of sulfur

The maximum diameter was reported in treatment S_4 (90 kg/ha) which had a mean diameter of 11.40 cm. Minimum mean diameter was in control S_1 (0 kg/ha) which had a reading of 9.70 cm. There was 17.52% increment in the diameter of cabbage heads of treat-

Table 3. Effect of nitrogen and sulfur on diameter of cabbage head (cm), Mean weight of cabbage heads (kg/plant) and yield (t/ha).

Treatments	Mean diameter of cabbage head (cm)	Mean weight of cabbage heads (kg/ plant)	Yield (t/ha)
Nitrogen			
N_1 (0 kg N per ha)	9.23	0.43	11.94
N_2 (100 kg N per ha)	10.16	0.53	14.81
N_3 (125 kg N per ha)	11.30	0.60	16.85
N_4 (150 kg N per ha)	12.00	0.66	18.51
SE (m) ±	0.15	0.01	0.45
CD at 5%	0.55	0.05	1.61
CV	2.53	5.10	5.10
Sulfur			
S_1 (0 kg S per ha)	9.70	0.47	13.14
S_2 (30 kg S per ha)	10.06	0.52	14.53
S_3 (60 kg S per ha)	10.60	0.59	16.38
S_4 (90 kg S per ha)	11.40	0.62	17.40
SE (m) ±	0.17	0.01	0.35
CD at 5%	0.63	0.04	1.24
CV	2.97	3.96	3.96

ment S_4 (90 kg/ha) compared to control S_1 (0 kg/ha).

Sulfur, as it aids in the better growth parameters ultimately results in bigger heads with larger diameter. Similar results were found by (Bhagavatagoudra and Rokhade 2001).

Mean weight of cabbage heads after harvesting

Effect of nitrogen

The highest weight of cabbage head was recoded in treatment N_4 (150 kg/ha) where the average weight of cabbage head was 0.67 kg. The lowest average weight (0.43 gm) was recorded in control N_1 (0 kg/ha). There was an increase of 55.11% in the weight of cabbage heads in treatment N_4 (90 kg/ha) over control N_1 (0 kg/ha) (Table 3).

There is an increase in mean weight of cabbage heads with increasing nitrogen levels. This might be due to the fact that nitrogen increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis through photosynthesis and ultimately increases yield. The mean weight of cabbage heads or total yield per head was significantly increasing with increasing levels of nitrogen Yeshiwas (2017) found similar results.

Effect of sulfur

For treatments containing sulfur, the maximum weight per cabbage head was recorded in treatment S_4 (90 kg/ha) which had an average weight of 0.62 kg. The minimum weight was recorded in control S_1 (0 kg/ha) which had an average weight of 0.47 kg. The treatment S_4 showed an increase of 32.55% in the weight of cabbage heads over control S_1 (0 kg/ha).

This increase in yield might be due to the important role of sulfur in lowering the pH to neutral level of the soil, which led to increase in the availability of many nutrients.

Yield of cabbage (t/ha)

Effect of nitrogen

The maximum yield was recorded in treatment N_4 (150 kg/ha) with a yield of 18.51 t/ha. The minimum yield was of control N_1 (0 kg/ha) which had a yield of 11.94 t/ha. The treatment N_4 (150 kg/ha) showed an increase in yield by 55.03% compared to control N_1 (0 kg/ha) (Table 3).

There was substantial increase in yield with higher dose of nitrogen. The reason may be that nitrogen being an essential part of nucleic acid, enhanced better reproductive part of plant which resulted in improvement of yield attributing characters and finally yield (Verma and Nawange 2024, Jat *et al.* 2015).

Effect of sulfur

The maximum yield was recorded in treatment S_4 with a yield of 17.40 t/ha. The minimum yield was recorded in control S_1 with a yield of 13.14 t/ha. The treatment S_4 showed an increase in yield by 32.39% compared to control S_1.

The application of increasing levels of sulfur up to 90 kg S/ha lead to significant increase in the diameter of head, yield per plant and total yield per

hectare. This increase in yield due to application of sulfur may be attributed to balanced nutrition and increased growth and yield parameters indicating that sulfur is crucial for achieving better yields. This concludes that cabbage gives a positive response to application of sulfur. Bairwa *et al.* (2017) found out increase in yield with increase in application of sulfur doses in cabbages.

CONCLUSION

For getting maximum yield of cabbage crop under agro climatic zone of Punjab the application of nitrogen 150 kg/ha and sulfur 90 kg/ha were superior over all other treatments as well as control. Thus, it can be concluded that treatments N_4 (150 kg N/ha) and S_4 (90 kg S/ha) gave the best possible outcome in the experiment. It is recommended to apply 150 kg N/ha and 90 kg S/ha for the superior growth, yield as well as profitability of cabbage.

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