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Effect of NPK and Sulphur on Growth, Yield and Quality of Cauliflower (*Brassica oleracea* var. *botrytis* L.)

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ABSTRACT

A field experiment was conducted at Horticulture Farm, Bhai Gurdas Degree College, Sangrur, Punjab-India between 2022 and 2023 during Rabi season. The experiment was comprised of 16 treatment combinations with four levels of NPK (0, 75, 100 and 125 % RD of NPK) and Sulphur (0, 20, 40 and 60 kg ha^{-1}). The recommended dose of NPK for cauliflower is 120 kg, 80 kg and 80 kg per ha. The present experiment consisting of the 16 treatment combinations will be carried out in Randomized Block Design (RBD). The maximum plant height at 30, 60 DAT and at harvest was (30.83, 46.57 and 58.25 cm in F3, leaf area was (868.30 cm^2) F_3, average weight of curd (449.84 g) F_3S_3, curd yield per plot (5.95 kg) 60 kg S ha^{-1},which was statistically at par with 40 kg S ha^{-1}. While minimum (3.43 kg) was recorded under control, yield of curd per plot (7.20 kg) F_3S_3, Nitrogen content (3.46 %) 125 per cent recommended, sulphur content in curd (1.27 %) was recorded under 125 per cent recommended dose of NPK (F_3), potassium content in soil (142.53 kg ha^{-1}) was recorded under 125 per cent recommended dose of NPK (F_3), net return (365016) was recorded under the treatment combination F_3S_3, maximum number of leaves per plant at 30, 60 DAT and at harvest (13.00, 18.22 and 24.96, respectively) was recorded under F_3, chlorophyll content was (1.42 mg g^{-1}) recorded under 125 per cent recommended dose of NPK (F_3), average weight of curd (371.68 g) was recorded under F_3, yield of curd per plot (5.95 kg) was recorded under F_3 followed F_2 (5.74 kg), followed F_1.

Keyword: *NPK, Harvest, Dose, Chlorophyll, Treatment.*

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botryitis* L.*)* is the most popular vegetable crop among cole crops belong to the family Cruciferae. It is being grown round the year for its white and tender curd. It is widely cultivated all over India and abroad for its special nutritive values, high productivity and wider adaptability under different ecological conditions.

In India, two separate groups of cauliflower are commonly grown *viz.* Indian or tropical types (originated in India) and the annual temperate or European type also known as 'Erfurt' or snowball type.

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The major difference in both groups is their adaptability to different temperature. The Indian types form curds at 20 to 25 ^{0}C and the temperate types require a temperature of 10to 16 ^{0}C for curd formation.

It has small thick stem, bearing whorl of leaves and branched tap root system. The main point develops into shortened shoot system whose apices make up the convex surface of curd. It is used as fried vegetable, dried vegetable, making soup and pickles. It is a fair source of vitamin-A (51 IU), vitamin-C (56 mg), riboflavin (0.10 mg), thiamin (0.04 mg), nicotinic acid (1.0 mg), calcium (33 mg), phosphorus (57 mg), potassium (138 mg), moisture (90.8 g), carbohydrates (4.0 g), protein (2.6 g), fat (0.4 g), fiber (1.2 g), and iron (1.5 mg) per 100 g of edible portion of cauliflower (Fageria et al., 2012).

Cauliflower is grown commercially on an area of about 433.9 thousand hectares with an annual production of about 85.73 lakh tonnes and productivity is about 19.8 MT/ha In India, West Bengal have maximum area, production and productivity (Anonymous, 2014). In India major cauliflower growing states are West Bengal, Bihar, Orissa, Uttar Pradesh, Assam, Haryana, Maharashtra and Rajasthan. In Rajasthan, it is grown extensively in the district of Ajmer, Alwar, Tonk, Sikar, Bundi, Bharatpur, Nagaur, Rajsamand, Ganganagar, Jaipur and Jodhpur. Total area of cauliflower in Rajasthan about 9.42 thousand ha with an annual production of about 36.61 thousand tonnes and productivity about 3.89 MT (Anonymous, 2013).

Among various essential plant nutrients, nitrogen is an essential for plant growth, development and reproduction. Protein content was increased with higher levels of nitrogen and bolting was also decreased (Bathkal & Lal, 1960). Nitrogen is associated with vigorous vegetative growth. It is helpful in large size compact curd development. The proper use of nitrogen improves the curd size, nutrient value and reduces the chances of buttoning (Markovic & Diurovaka, 1990).

Mineral nutrition does play an important role in influencing the quality of crops and it is fact that the soil health deteriorates due to continuous use of chemical fertilizers (Savci, 2012).

The soils of Rajasthan are deficient in nitrogen with a high p^H of 8.5.The application of nitrogen in soil is quite essential for proper growth and development of plant. The deficiency of nitrogen first appears on older leaves due to high mobility of the element. Its deficiency causes interveinal yellowing, development of anthocyanine pigment, rolling of leaves, chlorosis and necrosis (Yawalkar et al., 1996). Nitrogen is an essential plant nutrient, which is involved in physiological processes and enzyme activities. Farmers use urea excessively as a nitrogen fertilizer to enhance curd initiation and increase curd size in cauliflower. Nitrogen could increase production of cauliflower, but the curd quality is affected. High nitrogen contents with deficits of other nutrients could reduce the storage life of cauliflower and buttoning (Kirthisinghe, 2006).

Phosphorus is a constituent of nucleic acid, phytin and phosphorus. So, an adequate supply of phosphorus in early stage of plant life is an important in laying down the primordia for the reproductive parts of the cauliflower. It is also an essential constituent of majority of enzymes which are of great important in the transformation of energy in carbohydrate and fat metabolism and also in respiration in plants (Yawalkar et al., 1996).

Potassium imparts increased vigour and disease resistance to plant. It also regulates water conduction within the plant cell and water loss from the plant by maintaining the balance between anabolism, respiration and transpiration. Thus reduces tendency to wilt and help in better utilization of available water which ultimately help in the formation of protein and chlorophyll and quality (Rutkauskiene & Poderys, 1999).

Sulphur is an essential plant nutrient and it stands next to primary nutrients in importance. Sulphur plays a vital role in biosynthesis of certain amino acids (cysteine,

cystine and methionine) that are essential component of protein and also help in the synthesis of coenzyme-A and formation of chlorophyll and nitrogenase enzyme. Further, sulphur also provides winter hardiness and drought tolerance, control of insect pests and disease *etc*. Two natural growth regulators, thiamin and biotin contain sulphur. Sulphur occurs in glutathione that is important in oxidation reduction reaction (Kanwar, 1976). It is one of the constituents of vitamin B_1, some volatile oils and amino acids like methinine (21% S). It is involved in various metabolic and enzymatic processes in the plant (Goswami, 1988). The substantial decrease in SO_2 emission to less than 10 kg ha^{-1} of S further intensified S deficiency in plants, because as much as 30 per cent of its total amount can be absorbed from SO_2 in the air. The S cycle and its effect on plants are often compared to N (oxidation in soil and reduction in plants). The main difference is that S from organic compounds can be re-oxidised to SO_4– S in plants (Vanek et al., 2001). Nitrogen, Sulphur is highly mobile in the soil with a limited absorption capacity. Plants take it up from the soil solution mainly in the form of sulphates (Marschner, 1995). After reduction in the plant S participates in various primary and secondary compounds, such as the amino acids cysteine and methionine, vitamins B1 and H and enzymes and coenzymes (Haneklaus et al., 1997). Other Sulphur containing compounds are, *e.g.*, tripeptide glutathione (antioxidant and precursor of phyto chelatins, which are able to influence the detoxification of some heavy metals), ferredoxine, sulpho-lipids, glucosinolates and others. One of the essential amino acids, Methionin is, together with cysteine an indispensable component of proteins and their bonds play an important role in the protein structure where they often form intra or inter-chain disulphide bridges. The S content in proteins is relatively stable and in a certain proportion to N (Vanek et al., 2001).

MATERIAL AND METHODS

The experiment was carried out at the agricultural research farm, Bhai Gurdas Degree College, Punjab-India. The experimental site was uniform in topography and well-drained. This zone possesses typically sub-tropical & semi-arid climatic conditions characterized by mild winters and moderate summers associated with high relative humidity during the months of July to September with temperature range of minimum recorded up to 4 ^{0}C in December-January month and maximum go as high as 45 ^{0}C in the month of May - June . The annual rainfall of the region is 343 mm, most of which is contributed by the south west monsoon from June to September. The mean weekly meteorological parameters recorded at Agromet observatory, Agriculture farm, Sangrur during cropping periods.

The experiment consisted of 16 treatment combinations with four levels of NPK (0, 75, 100 and 125 % RD of NPK) and Sulphur (0, 20, 40 and 60 kg ha^{-1}). The recommended dose of NPK for cauliflower is 120 kg, 80 kg and 80 kg per ha respectively.

Treatments	Symbols
(A) NPK levels	
(i) Control	F_0
(ii) 75 per cent RD of NPK	F_1
(iii) 100 per cent RD of NPK	F_2
(iv) 125 per cent RD of NPK	F_3
(B) Sulphur levels	
(i) Control	S_0
(ii) Sulphur 20 kg ha^{-1}	S_1
(iii) Sulphur 40 kg ha^{-1}	S_2
(iv) Sulphur 60 kg ha^{-1}	S_3

The present experiment consisting of the 16 treatment combinations will be carried out in Randomized Block Design (RBD).

It is mid season variety of cauliflower and ideal for cooler climates of north-Indian states. The curds are medium sized, creamy white to white in colour and compact. It is ready for harvesting from December to January and average yield is 25-30 t ha^{-1}. The experimental field was thoroughly ploughed and cross ploughed with the help of mould board plough and cross harrowing was done with tractor and the soil was brought to a good tilth. The beds of 1.8 m x 1.8 m size, paths and channels were prepared as per layout. Five weeks old seedlings were transplanted on 24 October 2022, when average height of seedlings was about 10-12 cm. The distance between row to row and plant to plant was kept at 45 x 45 cm. Thus, 16 plants were accommodated in each plot. The transplanting was done in evening hours followed by light irrigation. The young seedlings were irrigated twice in a week till the seedlings were established. The crop was later on irrigated at 10 days interval. At the time of curd formation, the irrigation was given at closer intervals *i.e.* weekly interval**.** First weeding and hoeing was done at 20 days after transplanting and later on at every 15 days interval. Three hoeing and weeding were done in all Number of interculture was done after the start of curd formation. Harvesting was started when cauliflower curds became compact and off white in colour. It was done with the help of sharp sickle and observations of tagged plants were recorded. The process of harvesting started from third week of December, 2022 to third week of January, 2023.

RESULT AND DISCUSSION

The mean maximum plant height at 30, 60 DAT and at harvest was (30.83, 46.57 and 58.25 cm, respectively) observed in F_3 (125 per cent recommended dose of NPK), which was found to be significantly higher over F_0 and F_1 but it was statistically at par with F_2. The mean increase in plant height under F_2 treatment found to be 19.76 and 10.65 per cent at 30 DAT, 13.62 and 5.10 per cent at 60 DAT and 19.11 and 7.38 per cent at harvest higher over F_0 and F_1. The mean maximum leaf area was (868.30 cm^2) recorded in F_3 (125 per cent recommended dose of NPK), which was found to be significantly higher over F_0 and F_1 but it was statistically at par with F_2. The mean minimum leaf area (695.98 cm^2) was recorded in F_0 (control). The mean increase in leaf area under F_2 treatment was found to be 22.71 and 8.61 per cent higher than F_0 and F_1, respectively. The maximum average weight of curd (449.84 g) was recorded under the treatment combination F_3S_3, which was a significantly superior over to control and other treatment combination. However F_3S_3 was statistically at par with F_2S_2, F_3S_2 and F_2S_3 While minimum curd weight (148.98 g) was recorded with F_0S_0 treatment combination. The effect of different levels NPK significantly influenced the chlorophyll content. The maximum chlorophyll content was (1.42 mg g^{-1}) recorded under 125 per cent recommended dose of NPK (F_3), that was significantly superior to F_0 and F_1 but statistically at par with F_2. The mean increase of chlorophyll content under F_2 treatment was found to be 25.69 and 8.73 per cent over control and F_1, respectively. Different fertility levels significantly influenced the average weight of curd. The mean maximum average weight of curd (371.68 g) was recorded under F_3*i.e.* 125 per cent recommended dose of NPK, which was found to be significantly higher over F_0 and F_1 but statistically at par with F_2. The mean increase in average weight of curd 67.77 and 25.15 per cent at over F_0 and F_1, respectively under F_2 treatment. The maximum yield of curd per plot (5.95 kg) was recorded under F_3 followed F_2 (5.74 kg), followed F_1 (4.59 kg). While minimum (3.42 kg) was recorded under control. The maximum yield of curd per plot under the treatment F_3 was found significantly more over to F_0 and F_1 but it was statistically at par with F_2 treatment. The mean increase total yield of curd per plot under the treatment F_2 was found to be 67.84 and 25.05 per cent more than F_0 and F_1

treatment, the plant height, leaf area and number of leaves per plant under F_2 treatment (100% RD of NPK). However different fertility levels were found to be non significant to curd initiation of cauliflower. It might be due to that fluctuation in the day and night temperature during curd initiation. The maximum temperature in 3rd week was recorded 23° C however, it was 27° C in 1st week of January. Significantly increased the plant height, leaf area and number of leaves per plant might be due to the better nutritional environment in the root zone for growth and development of the plant by the application of NPK. The NPK are considered as one of the major nutrient required for proper growth and development of the plant. Besides this, nitrogen is a main constituent of protoplasm, cell nucleus, amino acids, proteins, chlorophyll and many other metabolic products (Kumhar, 2004).

Phosphorus is a constituent of nucleic acid, phytin and phospholipids. The beneficial influence of phosphorus in early stages of growth may be explained by early stimulation of root system through efficient translocation to the root of certain growth stimulation compounds formed on account of protoplasmic activity of tops in phosphorus fed plants, when enhanced absorption of nitrogen and other nutrient and their utilization. So an adequate supply of phosphorus in early stage of plant life is an important in laying down the primordial for the reproductive parts of the cauliflower (Thakur et al., 1991). The response to potassium fertilization in terms of overall improvement in growth parameters in further supported by the fact that the leaching losses of potassium were more in light textured soils. Therefore, potassium fertilization improved overall crop growth in terms of plant height, number of leaves per plant. Potassium helps in the protein and chlorophyll formation ultimately the NPK are used for better vegetative growth. The result are close conformity with the finding of Baghel and Singh (1995), Tarata et al. (1995), Tanaka and Sato (1997), Abd El All (1999), El-Shabrawy et al (1999), Patil et al. (2003), Meena (2004), Kumhar (2004), Mahmoud et al. (2007), Abd el-All and EL- Shabrawy (2013) and Yadav, (2014).

The application of 100 per cent recommended dose of NPK significantly increased the average weight of curd (g), curd yield per plot (kg), curd yield per ha^{-1} and volume of curd (CC) (Table 4.5 and 4.7). However 100 per cent recommended dose of NPK (F_2) was statistically at par to 125 per cent recommended dose of NPK (F_3) in all the above characters. This might be due to the fact that increased NPK levels, helped in the expansion of leaf area and chlorophyll content which together might have accelerated the photosynthetic rates and in turn increased the supply of carbohydrates to plants. The application of 100 per cent recommended dose of NPK favoured the metabolic and auxin activities in plant and ultimately resulted in increasing curds weight, volume of curd finally the total yield. However, potassium does not increase the yield of plant but indirectly supported to yield. These results are also in close conformity with the finding of Batel et al. (1997), El-Shabrawy et al. (1999), Rutkauskiene and Poderys (1999), Everaarst and Boou (2000), Kumhar (2004), Mahmoud et al. (2007), Yaldas et al. (2008) and Abd el-All and EL- Shabrawy (2013).

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 & 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 development of curd and resulted in increased growth and ultimately higher yield. The results are in close conformity with those of Hara et al. (1981), Shekhawat (1992), Bijania and Dixit (1996), Hunashikatti et al. (2000a), Bhagavatagoudra and Rokhade (2001) and Gautam (2012) and Gautam (2012).

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 photosynthates towards sink. The results revealed that application of 60 kg sulphur ha^{-1} significantly increased the curd yields ha^{-1} of cauliflower as compared to control and 20 kg sulphur per ha, which were found statistically at par with 60 kg S ha^{-1}. These finding corroborates with the findings of Shekhawat (1992), Dhar et al. (1999), Jamre et al. (2010), Gautam (2012) and Talukder et al. (2013).

The application of sulphur has been reported tohelp in lowering soil pH and improve not only the availability of sulphur but of other nutrient too, which resulted in increased consequently the yield. Sulphur plays a vital role in the activation of number of enzymes and carbohydrate metabolism in plant. The results are conformity with the finding of Kumhar (2004), Jamre et al. (2010), Abd el-All and EL- Shabrawy (2013) and Bairwa (2015).

CONCLUSION

On the basis of results of present investigation, it can be concluded that the combined application of 100 per cent recommended dose of NPK along with sulphur 40 kg ha^{-1} was found best to harvest a good cauliflower crop with maximum yield (207.56 q ha^{-1}), net returns (Rs. 338143 ha^{-1}) and B:C ratio (4.39), respectively. Although, application of 125 per cent recommended dose of NPK along with sulphur 60 kg ha^{-1} was found statistically at par to it because resulting saving of 25 per cent recommended dose of NPK and 20 kg sulphur ha^{-1}. Thus, application of 100 per cent recommended dose of NPK along with sulphur 40 kg ha^{-1} recommended for cauliflower crop. The results are only indicative and require further experimentation to arrive at more consistent and final conclusion.

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Author Contribution
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