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Interactive effect of integrated nutrient management and spacing on growth of cauliflower

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Abstract

The present field experiment was conducted at the Agriculture Farm of Raja Balwant Singh College, Agra (Uttar Pradesh) during two consecutive years i.e. 2019-20 and 2020-21. The cauliflower (cv. Snowball-16) was tested for 28 treatment combinations viz., three levels of nitrogen (60, 90 and 120 kg ha⁻¹), three types of biofertilizers (Azotobacter, Vermicompost and Azotobacter + Vermicompost) and three spacing (30, 40 and 50 cm) in a factorial randomized block design (FRBD) replicated thrice including one unfertilized control. The seed beds each measuring 3.0 × 1.0 m were prepared and seeds of cauliflower were sown. The healthy and vigorous seedlings of about 4-5 weeks were planted in the well-prepared field at the specified spacing according to the treatments during evening hours. Three plants were selected at random in each net plot and observations pertaining to the crop growth such as plant height, number of leaves, width of largest leaf, and length of longest leaf and diameter of stem at the base were recorded. The recorded data were statistically analyzed by using the analysis of variance technique to judge the effect of various treatment combinations. The results of the study revealed that the nitrogen, biofertilizers and spacing significantly influenced the growth of cauliflower. The higher dose of nitrogen, biofertilizer + vermicompost and 30 cm spacing had significant positive effect on growth of cauliflower. Further, the various interactions of nitrogen, biofertilizer and spacing were also found significant. The interaction of all the three factors showed that the treatment receiving the 100% RDF, biofertilizer + vermicompost and 30 cm spacing (N3B3S1) was found superior as compared to the other combinations studied.

Keywords: Cauliflower, spacing, nitrogen, INM, vermicompost, biofertilizer, crop performance

Introduction

The cauliflower (*Brassica oleracea* L. var. botrytis) is one of the most important cole crops grown widely throughout the country (Sharma *et al.*, 2004) ^[18]. It is mostly grown during winter season in the plains for its white tender curds formed by the shortened flower parts. Its edible curd is made-up of abortive flowers, the stalks of which are fleshy and loosely crowded. It is herbaceous annual for vegetable production and biennial for seed production. Cauliflower is a heavy feeder and for better yield, the soil must be kept fertile. In recent era, intensification of agriculture, indiscriminate use of chemical fertilizers and pesticides have adversely affected the soil fertility, biodiversity, quality of the produce, human health and increased soil acidity thus impairing soil physical conditions (Pereira, 2017) ^[16]. Reduced organic matter creates micronutrient deficiencies and increases plant susceptibility to pest and diseases. Proper and regular use of liquid fertilizers in conjunction with organic manures, green manures, legume crop residues in cropping system and microbial inoculants are of most importance in maintaining the fertility and productivity of agricultural soils, sustaining high yield and ensuring environmental safety (Reganold and Wachter, 2016) ^[17].

Plant population (spacing) is another important agronomic factor which affects the quality and quantity of the produce (Singh *et al.*, 2022) ^[20]. A large spacing would enable the plants to express their growth and yield potentialities to the maximum extent. The extra performance of individual plant at wider spacing may not be able to compensate the loss in yield due to reduction in plant population. On the contrary, tonnage may increase at closer spacing but at the cost of the quality of curd due to competition for food, air, space, and light. The best plant population would be such that the plants are able to convert radiant energy into chemical energy

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Efficiently resulting in maximum yield per unit area per unit of time (Hossain *et al.*, 2015) ^[9]. There is a considerable variation in the nitrogen requirement of the cauliflower. The plant spacing and combinations of various doses of nitrogen with bio-organics included in the study will certainly play important role in the maximization of production of curd and exercise far reaching influences on the quality of curd besides improving soil health (Kaushal and Kaushal, 2013; Bhardwaj *et al.*, 2018) ^[1, 11].

The effects of nitrogen nutrition and plant population are closely associated and have well marked effect on crop performance (Singh *et al.*, 2022) ^[20]. Furthermore, the productivity of cauliflower is low due to imbalance use of fertilizers and lack of technical know-how for its cultivation. The relationship of these factors with the use of bio-organics in cauliflower is not known at all for the studied region. Therefore, present experiment was carried out to study the effect of nitrogen management on growth of cauliflower.

Materials and Methods

Experimental site

The present field experiment was conducted at the Agriculture Farm of Raja Balwant Singh College, Agra (Uttar Pradesh) during two consecutive years i.e. 2019-20 and 2020-21. The study site is situated 27°10' N and 70°50' E latitude and at 168.4 m above the mean sea level. The study site is located about 11 kilometres away in south-west of Agra city on Agra-Bharatpur Road in the state of Uttar Pradesh. The farm is well equipped

with all necessary facilities for cultivating vegetable crops. The soil of the experimental site is sandy-loam in texture with 62.12%, 18.72% and 19.16% of sand, silt and clay, respectively. The data pertaining to various chemical components clearly exhibit that soil of the experimental field was rich in potassium, low in nitrogen and medium in phosphorus. The organic carbon status of the experimental soil was found medium.

The field experiment

The cauliflower (cv. Snowball-16) was tested for 28 treatment combinations viz., three levels of nitrogen, three types of bio fertilizers and three spacing in a Factorial Randomized Block Design (FRBD) replicated thrice. The details of the experiment and various treatment combinations studied are presented in Table 3.4 and 3.5. The factors, treatments, notations, and design of the experiment were common in both the cropping years. The size of gross plot and net plot was 2.5 m x 6.0 m. The experiment was carried out on cauliflower Cv. "Snowball-16". The seed of Snowball-16 was made available by R.B.S. College. The seedlings were raised at R.B.S. College Research Farm, Bichpuri, Agra by sowing the seed in well prepared raised beds measuring 3 m X 1 m X 0.25 m on 28.8.2019 and 6.9.2020. The normal cultural operations such as watering, weeding, plant protection etc. were performed as usual, for raising healthy seedlings. The transplanting was done on 6.10.2019 and 12.10.2020.

Table 1: Experimental details

Particulars	Details
Design	Factorial Randomized Block Design (FRBD)
Treatment	28
Replications	03
Total plots	84
Plot size	2.5 m×6.0 m
Fertilizers dose	120:40:60 kg ha ⁻¹ (N:P2O5:K2O, respectively)
Crop variety	Snowball-16
Spacing	3 (50×30 cm, 50×40 cm and 50×50 cm)
Biofertilizers	3 (Azotobacter, Vermicompost and Azotobacter + Vermicompost)
Nitrogen	3 (60 kg ha ⁻¹ , 90 kg ha ⁻¹ and 120 kg ha ⁻¹)

Table 2: Treatment details

Factor	Treatment	Details
Nitrogen (N)	N1	60 kg ha ⁻¹ (50% RDF)
	N2	90 kg ha ⁻¹ (75% RDF)
	N3	120 kg ha ⁻¹ (100% RDF)
Bio fertilizer (B)	B1	Azotobacter @ 5kg ha ⁻¹
	B2	Vermicompost @ 5t ha ⁻¹
	B3	Azotobacter @ 5kg ha ⁻¹ + Vermicompost @ 5t ha ⁻¹
Spacing (S)	S1	50 × 30 cm
	S2	50 × 40 cm
	S3	50 × 50 cm

Application of manure and fertilizers

The biofertilizer, azotobacter @ 5kg ha⁻¹ and vermicompost @ 5t ha⁻¹ was applied as basal dose as per the designed treatments. Nitrogen at the rate of 120, 90 and 60 kg ha⁻¹ and phosphorus at the rate of 40 kg ha⁻¹ through urea and single super phosphate, respectively were applied in the present experiment. Super phosphate, half amount of nitrogen and full quantity of K₂O at the rate of 60 kg/ha through MOP were applied as basal doses. The remaining quantity of nitrogen through urea was applied as top dressing at 30 days and 45 days after transplanting.

Raising of seedlings

The seed beds each measuring 3.0 m X1.0 m were prepared and sieved farm yard manure was applied. 100 g of seeds of

cauliflower cv. "Snowball-16" was sown on 28.8.2019 and next year on 6.9.2020 in lines 5.0 cm apart and covered with a layer of sieved leaf mould. The seed beds were watered thrice a day during first week and twice a day during second week and afterwards once a day depending on weather conditions. The seedlings were hardened by reducing the frequency of watering and exposing them to full sunlight for one week before transplanting. The weeds were removed by hand whenever required.

Transplanting of seedlings

The seedlings of about 4-5 weeks were lifted carefully and those found healthy, vigorous and uniform in growth were planted in the well-prepared field at the specified spacing according to the

treatments during evening hours of 06/10/2019 and 12/10/2020. The seedlings were transplanted with the help of 'khurpe' by manual labour. Transplanting was followed by flood irrigation. In order to maintain uniform stand of the crop the gaps created due to casualty were replaced by planting another seedlings in both the years. The date-wise account of various post transplanting operations such as Irrigation, gap filling, top dressing of urea, weeding and hoeing and harvesting were carried out as and when required during both the years.

Observations recorded

Three plants were selected at random in each net plot and observations pertaining to the crop growth such as plant height,

number of leaves, width of largest leaf, length of longest leaf, diameter of stem at the base were recorded.

Statistical analysis

All data related to pre and post-harvest study of crop collected were statistically analyzed by using the analysis of variance technique (Gomez and Gomez, 1984) ^[6].

Results and Discussion

Number of alive plants in plot

The data pertaining to the number of alive plants in a plot under various treatment combinations recorded during 2019-20 and 2020-21 is presented in Table 3.

Table 3: Effect of nitrogen, bio fertilizer and spacing on number of alive plants

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	99.0	96.4	94.9	99.0	95.9	94.4
N1B2	99.0	96.5	95.2	99.1	96.3	94.6
N1B3	99.1	96.8	96.2	99.1	96.6	95.7
N2B1	99.5	99.2	96.8	99.5	99.2	97.0
N2B2	99.5	99.2	97.3	99.5	99.2	97.4
N2B3	99.5	99.3	97.4	99.5	99.3	97.5
N3B1	99.5	99.5	97.7	99.5	99.5	97.9
N3B2	99.5	99.5	98.0	99.5	99.5	98.0
N3B3	99.5	99.5	98.3	99.5	99.5	98.2
Control	83.6			82.0		
Treated	98.2			98.1		
Treatment	S1	S2	S3	S1	S2	S3
N1	99.0	96.5	95.4	99.1	96.3	94.9
N2	99.5	99.2	97.2	99.5	99.2	97.3
N3	99.5	99.5	98.0	99.5	99.5	98.0
Mean	99.4	98.4	96.9	99.4	98.3	96.8
Treatment	N1	N2	N3	N1	N2	N3
B1	96.8	98.5	98.9	96.4	98.6	99.0
B2	96.9	98.7	99.0	96.7	98.7	99.0
B3	97.3	98.7	99.1	97.1	98.8	99.1
Mean	97.0	98.6	99.0	96.7	98.7	99.0
Treatment	B1	B2	B3	B1	B2	B3
S1	99.4	99.4	99.4	99.4	99.4	99.4
S2	98.4	98.4	98.5	98.2	98.3	98.5
S3	96.5	96.8	97.3	96.4	96.7	97.2
Mean	98.1	98.2	98.4	98.0	98.1	98.3
Treatments	2019-20		2020-21			
	SEM	CD at 5%	SEM		CD at 5%	
N	0.09	NS	2.04		NS	
B	0.09	NS	2.04		NS	
S	0.09	NS	2.04		NS	
NB	0.15	NS	3.53		NS	
NS	0.15	NS	3.53		NS	
BS	0.15	NS	3.53		NS	
NBS	0.26	NS	6.12		NS	
Control/Treated	0.44	NS	10.59		NS	

In the year 2019-20, the higher dose of nitrogen i.e. N3-120 kg ha⁻¹ showed higher alive plants (99.0%) in plot followed by N2 (98.6%) and N1 (97.0%). However, the effect was not found statistically significant. Similarly, the effect of application of bio fertilizer combinations was also found at par. Further, the decrease in spacing showed decreasing alive plants in plots. But similar to the nitrogen and bio fertilizer, spacing also showed non-significant effect on number of alive plants of cauliflower in experimental plots. It has been observed that the interactions of all kind did not influence the number of alive plants in cauliflower in plots significantly. Similar observations were recorded in second year of the study i.e. 2020-21.

Number of fully opened leaves

The data pertaining to the number of fully opened leaves in cauliflower under various treatment combinations recorded during 2019-20 and 2020-21 is presented in Table 4. The higher dose of nitrogen i.e. N3-120 kg ha⁻¹ showed significantly higher number of opened leaves in cauliflower plants followed by N2 and N1. The supply of higher amount of nitrogen influenced the opening of leaves in cauliflower. Chaurasia *et al.* (2002) ^[3] also reported significantly better growth of chilli upon application of increasing dose of N. The effect of application of biofertilizer combinations was also found significant. The combined application of vermicompost and azotobacter showed

significantly higher number of fully opened leaves followed by the sole application of vermicompost @5t ha⁻¹. The application of sole azotobacter @5 kg ha⁻¹ showed least number of fully opened leaves. Moakala *et al.* (2015) [13] revealed that the combined application of vermicompost and biofertilizer in broccoli significantly influenced the growth as compared to the other treatments under study. Further, the decrease in spacing showed increased number of fully opened leaves. Similar to the nitrogen and biofertilizer, spacing also showed significant effect on number of fully opened leaves in cauliflower. Gupta *et al.* (2002) [7] also reported that the reduced spacing improves the

performance of cauliflower. It has also been observed that the interactions of all kind showed significant influence on the number of fully opened leaves in cauliflower.

The interaction of nitrogen and spacing was found significant with respect to the number of fully opened leaves in cauliflower. The treatment combination N3S1 i.e. 100% RDF with least spacing of 30 cm found superior as compared to all other treatment combinations. The treatment receiving 50% RDF and highest spacing i.e. 50 cm showed poor performance as the number of fully opened leaves was found least under the same (N1S3).

Table 4: Effect of nitrogen, biofertilizer and spacing on number of fully opened leaves in cauliflower

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	20.8	19.5	18.0	20.2	18.6	18.0
N1B2	21.0	19.6	18.5	20.3	18.8	18.2
N1B3	21.0	19.6	19.1	20.4	19.1	18.5
N2B1	22.2	21.2	20.2	21.8	20.4	19.3
N2B2	22.4	21.3	20.3	22.1	20.6	19.6
N2B3	22.7	21.3	20.5	22.3	20.9	19.7
N3B1	22.8	21.5	20.6	22.3	21.2	19.9
N3B2	23.2	21.6	20.7	22.4	21.4	20.0
N3B3	23.4	21.9	20.8	22.6	21.7	20.1
Control	13.0			14.1		
Treated	20.9			20.4		
Treatment	S1	S2	S3	S1	S2	S3
N1	20.9	19.6	18.5	20.3	18.8	18.2
N2	22.4	21.2	20.3	22.1	20.7	19.5
N3	23.1	21.7	20.7	22.5	21.4	20.0
Mean	22.2	20.8	19.8	21.6	20.3	19.3
Treatment	N1	N2	N3	N1	N2	N3
B1	19.4	21.2	21.6	18.9	20.5	21.1
B2	19.7	21.3	21.8	19.1	20.8	21.3
B3	19.9	21.5	22.0	19.3	21.0	21.5
Mean	19.7	21.3	21.8	19.1	20.8	21.3
Treatment	B1	B2	B3	B1	B2	B3
S1	21.9	22.2	22.4	21.4	21.6	21.8
S2	20.7	20.8	20.9	20.1	20.3	20.6
S3	19.6	19.8	20.1	19.1	19.3	19.4
Mean	20.7	20.9	21.1	20.2	20.4	20.6
Treatments	2019-20		2020-21			
	SEM	CD at 5%	SEM	CD at 5%		
N	0.04	0.11	0.03	0.09		
B	0.04	0.11	0.03	0.09		
S	0.04	0.11	0.03	0.09		
NB	0.06	0.18	0.05	0.15		
NS	0.06	0.18	0.05	0.15		
BS	0.06	0.18	0.05	0.15		
NBS	0.11	0.32	0.09	0.26		
Control/Treated	0.18	0.54	0.15	0.45		

Hill *et al.* (2007) [8] recorded significantly better growth parameters of cauliflower upon application of higher dose of N with least spacing. The interaction of biofertilizers and nitrogen was found significant with respect to the number of fully opened leaves in cauliflower. The treatment combination B3N3 i.e. azotobacter + vermicompost and 100% RDF was found superior as compared to all other treatment combinations. The treatment receiving azotobacter @5 kg ha⁻¹ and 50% RDF showed poor performance as the number of fully opened leaves was found least in this treatment (B1N1). Sharma (2002) [19] also reported that the application of nitrogen with biofertilizer significantly improves the growth of cabbage. The interaction of spacing and biofertilizers was also found significant with respect to the number of fully opened leaves in cauliflower. The treatment combination S1B3 i.e. spacing 30 cm and azotobacter + vermicompost was found superior as compared to all other

treatment combinations. The treatment with highest spacing (50 cm) and receiving azotobacter @5 kg ha⁻¹ showed poor performance as the number of fully opened leaves was found least in this treatment (S3B1).

Among all the treatment combinations studied, the number of fully opened leaves in cauliflower was ranged 13.0-23.4 and 14.1-22.6 during 2019-20 and 2020-21, respectively. The treatment N3B3S1 showed highest number of fully opened leaves in cauliflower followed by the treatment N3B2S1 during both the years of study. The unfertilized control showed least number of fully opened leaves followed by the treatment N1B1S3. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on number of fully opened leaves in cauliflower. The results of research work reported earlier with sole and combined application of nitrogen, biofertilizer, vermicompost and spacing found in line with the

findings of present investigation (Sharma, 2002; Chaurasia *et al.*, 2002; Gupta, 2002; Choudhary *et al.*, 2003; Hill *et al.*, 2007; Moakala *et al.*, 2015; Kc *et al.*, 2022) [3, 4, 7, 8, 12, 13, 19].

Length of longest leaf

The data pertaining to the length of longest leaf of cauliflower under various treatment combinations recorded during 2019-20 and 2020-21 is presented in Table 5. The higher dose of nitrogen

i.e. N3-120 kg ha⁻¹ showed significantly higher length of longest leaf of cauliflower plants followed by N2 and N1. The supply of higher amount of nitrogen influenced the length of longest leaf of cauliflower. The effect of application of biofertilizer combinations was also found significant. The combined application of vermicompost and azotobacter (B3) showed significantly higher length of longest leaf followed by the sole application of vermicompost @5t ha⁻¹ (B2).

Table 5: Effect of nitrogen, biofertilizer and spacing on length of longest leave (cm) in cauliflower

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	49.1	43.2	41.2	48.9	44.0	37.9
N1B2	49.3	44.7	42.3	49.2	44.3	40.9
N1B3	49.5	45.0	42.8	49.4	45.2	42.8
N2B1	53.6	49.6	45.1	53.5	49.7	45.4
N2B2	55.2	49.8	45.4	54.6	50.0	46.4
N2B3	56.2	49.9	48.1	55.8	50.1	46.8
N3B1	56.5	50.2	48.5	56.4	50.5	47.9
N3B2	56.9	51.3	48.6	56.8	51.0	48.2
N3B3	57.3	52.7	48.9	57.6	52.4	48.6
Control	25.0			25.8		
Treated	49.3			49.0		
Treatment	S1	S2	S3	S1	S2	S3
N1	49.3	44.3	42.1	49.2	44.5	40.5
N2	55.0	49.8	46.2	54.6	49.9	46.2
N3	56.9	51.4	48.7	56.9	51.3	48.3
Mean	53.7	48.5	45.7	53.6	48.6	45.0
Treatment	N1	N2	N3	N1	N2	N3
B1	44.5	49.4	51.7	43.6	49.5	51.6
B2	45.4	50.1	52.3	44.8	50.3	52.0
B3	45.8	51.4	53.0	45.8	50.9	52.9
Mean	45.2	50.3	52.3	44.7	50.3	52.2
Treatment	B1	B2	B3	B1	B2	B3
S1	53.1	53.8	54.3	52.9	53.5	54.3
S2	47.7	48.6	49.2	48.0	48.4	49.2
S3	44.9	45.4	46.6	43.7	45.2	46.1
Mean	48.6	49.3	50.0	48.2	49.0	49.9
Treatments	2019-20		2020-21			
	SEM	CD at 5%	SEM	CD at 5%		
N	0.19	0.57	0.11	0.32		
B	0.19	0.57	0.11	0.32		
S	0.19	0.57	0.11	0.32		
NB	0.33	0.99	0.18	0.55		
NS	0.33	0.99	0.18	0.55		
BS	0.33	0.99	0.18	0.55		
NBS	0.57	1.71	0.32	0.96		
Control/Treated	0.98	2.95	0.55	1.66		

The application of sole azotobacter @5 kg ha⁻¹ (B1) showed least length of longest leaf of cauliflower. The interaction of nitrogen and different organic manures/biofertilizers were also studied by Chaudhary *et al.* (2015) [2] and Kc *et al.* (2022) [12]. Choudhary *et al.* reported significantly better performance of cabbage while Kc *et al.* observed similar results in cauliflower. Further, the decrease in spacing showed increased length of longest leaf. Similar to the nitrogen and biofertilizer, spacing also showed significant effect on length of longest leaf of cauliflower. It has also been observed that the interactions of all kind showed significant influence on the length of longest leaf of cauliflower. The interaction of nitrogen and spacing was found significant with respect to the length of longest leaf of cauliflower. The treatment combination N3S1 i.e. 100% RDF with least spacing of 30 cm found superior as compared to all other treatment combinations. The treatment receiving 50% RDF and highest spacing i.e. 50 cm showed poor performance as the length of longest leaf was found least under the same (N1S3). Hill *et al.* (2007) [8] recorded significantly better growth parameters of cauliflower upon application of higher dose of N

with least spacing. The interaction of biofertilizers and nitrogen was found significant with respect to the length of longest leaf of cauliflower. The treatment combination B3N3 i.e. azotobacter + vermicompost and 100% RDF was found superior as compared to all other treatment combinations. The treatment receiving azotobacter @5 kg ha⁻¹ and 50% RDF showed poor performance as the length of longest leaf was found least in this treatment (B1N1). The interaction of spacing and biofertilizers was also found significant with respect to the length of longest leaf of cauliflower. The treatment combination S1B3 i.e. spacing 30 cm and azotobacter + vermicompost was found superior as compared to all other treatment combinations. The treatment with highest spacing (50 cm) and receiving azotobacter @5 kg ha⁻¹ showed poor performance as the length of longest leaf was found least in this treatment (S3B1). Among all the treatment combinations studied, the length of longest leaf of cauliflower was ranged 25.0-57.3 cm and 25.8-57.6 cm during 2019-20 and 2020-21, respectively. The treatment N3B3S1 showed highest length of longest leaf of cauliflower followed by the treatment N3B2S1 during both the

years of study. The unfertilized control showed least length of longest leaf followed by the treatment N1B1S3. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on length of longest leaf of cauliflower. The results of Moakala *et al.* (2015) ^[13] and Kc *et al.* (2022) ^[12] are also similar with respect to the crop growth and interaction of various factors.

Width of longest leave

The data pertaining to the width of longest leaf of cauliflower under various treatment combinations revealed that the higher dose of nitrogen i.e. N3-120 kg ha⁻¹ showed significantly higher width of longest leaf of cauliflower plants followed by N2 and N1. The supply of higher amount of nitrogen influenced the width of longest leaf of cauliflower (Table 6). The effect of application of biofertilizer combinations was also found significant. The combined application of vermicompost and azotobacter (B3) showed significantly higher width of longest leaf followed by the sole application of vermicompost @5t ha⁻¹ (B2). The application of sole azotobacter @5 kg ha⁻¹ (B1) showed least width of longest leaf of cauliflower. Further, the decrease in spacing showed increased width of longest leaf. Similar to the nitrogen and biofertilizer, spacing also showed significant effect on width of longest leaf of cauliflower. It has also been observed that the interactions of all kind showed

significant influence on the width of longest leaf of cauliflower. The interaction of nitrogen and spacing was found significant with respect to the width of longest leaf of cauliflower. The treatment combination N3S1 i.e. 100% RDF with least spacing of 30 cm found superior as compared to all other treatment combinations. The treatment receiving 50% RDF and highest spacing i.e. 50 cm showed poor performance as the width of longest leaf was found least under the same (N1S3). The interaction of biofertilizers and nitrogen was found significant with respect to the width of longest leaf of cauliflower. The treatment combination B3N3 i.e. azotobacter + vermicompost and 100% RDF was found superior as compared to all other treatment combinations. The treatment receiving azotobacter @5 kg ha⁻¹ and 50% RDF showed poor performance as the width of longest leaf was found least in this treatment (B1N1). The interaction of spacing and biofertilizers was also found significant with respect to the width of longest leaf of cauliflower. The treatment combination S1B3 i.e. spacing 30 cm and azotobacter + vermicompost was found superior as compared to all other treatment combinations. The treatment with highest spacing (50 cm) and receiving azotobacter @5 kg ha⁻¹ showed poor performance as the width of longest leaf was found least in this treatment (S3B1). Among all the treatment combinations studied, the width of longest leaf of cauliflower was ranged 13.0-23.2 cm during 2019-20 and 2020-21.

Table 6: Effect of nitrogen, biofertilizer and spacing on width of longest leave (cm) in cauliflower

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	20.9	19.3	18.5	20.9	19.3	18.5
N1B2	21.0	19.7	18.8	21.0	19.3	18.7
N1B3	21.0	19.8	19.2	21.0	19.4	19.1
N2B1	22.2	21.2	19.8	22.1	21.1	19.8
N2B2	22.5	21.2	20.0	22.5	21.2	20.0
N2B3	22.7	21.3	20.6	22.7	21.3	20.4
N3B1	22.7	21.3	20.7	22.7	21.3	20.6
N3B2	23.0	21.7	20.8	22.9	21.7	20.7
N3B3	23.2	21.9	20.9	23.2	21.9	20.8
Control	13.0			13.0		
Treated	21.0			20.9		
Treatment	S1	S2	S3	S1	S2	S3
N1	21.0	19.6	18.9	21.0	19.3	18.7
N2	22.4	21.2	20.2	22.4	21.2	20.1
N3	23.0	21.7	20.8	23.0	21.6	20.7
Mean	22.1	20.8	19.9	22.1	20.7	19.8
Treatment	N1	N2	N3	N1	N2	N3
B1	19.6	21.1	21.6	19.5	21.0	21.6
B2	19.8	21.2	21.8	19.7	21.2	21.8
B3	20.0	21.5	22.0	19.9	21.5	22.0
Mean	19.8	21.3	21.8	19.7	21.2	21.8
Treatment	B1	B2	B3	B1	B2	B3
S1	21.9	22.2	22.3	21.9	22.1	22.3
S2	20.6	20.9	21.0	20.6	20.7	20.9
S3	19.7	19.9	20.2	19.6	19.8	20.1
Mean	20.7	21.0	21.2	20.7	20.9	21.1
Treatments	2019-20		2020-21			
	SEM	CD at 5%	SEM		CD at 5%	
N	0.04	0.13	0.03		0.10	
B	0.04	0.13	0.03		0.10	
S	0.04	0.13	0.03		0.10	
NB	0.07	0.22	0.06		0.17	
NS	0.07	0.22	0.06		0.17	
BS	0.07	0.22	0.06		0.17	
NBS	0.13	0.38	0.10		0.29	
Control/Treated	0.22	0.65	0.17		0.50	

The treatment N3B3S1 showed highest width of longest leaf of cauliflower followed by the treatment N3B2S1 during both the years of study. The unfertilized control showed least width of longest leaf followed by the treatment N1B1S3. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on width of longest leaf of cauliflower. In previous studies, Muhammad *et al.* (2007) ^[14] observed higher growth of cabbage with increasing levels of nitrogen application. Chaurasia *et al.* (2002) ^[3] reported significantly better growth of chilli upon application of increasing dose of N. Choudhary *et al.* (2003) ^[4] found significantly higher growth of crop with the application vermicompost. Similarly, Kaur *et al.* (2015) ^[10] also reported better performance of cabbage under vermicompost application. Choudhary *et al.* (2015) ^[2] found significantly higher growth of cabbage crop with the combined application of nitrogen, vermicompost and biofertilizers. Hill *et al.* (2007) ^[8] recorded significantly better growth parameters of cauliflower upon application of higher dose of N with least spacing. The results of present study are in conformity with these findings.

Plant height 60 DAS

The data pertaining to the plant height of cauliflower under

various treatment combinations recorded during 2019-20 and 2020-21 is presented in Table 6. The higher dose of nitrogen i.e. N3-120 kg ha⁻¹ showed significantly higher plant height of cauliflower plants followed by N2 and N1. The supply of higher amount of nitrogen influenced the plant height of cauliflower. The effect of application of biofertilizer combinations was also found significant. The combined application of vermicompost and azotobacter (B3) showed significantly higher plant height followed by the sole application of vermicompost @5t ha⁻¹ (B2). The application of sole azotobacter @5 kg ha⁻¹ (B1) showed least plant height of cauliflower. Further, the decrease in spacing showed increased plant height. Similar to the nitrogen and biofertilizer, spacing also showed significant effect on plant height of cauliflower. It has also been observed that the interactions of all kind showed significant influence on the plant height of cauliflower. The interaction of nitrogen and spacing was found significant with respect to the plant height of cauliflower. The treatment combination N3S1 i.e. 100% RDF with least spacing of 30 cm found superior as compared to all other treatment combinations. The treatment receiving 50% RDF and highest spacing i.e. 50 cm showed poor performance as the plant height was found least under the same (N1S3).

Table 7: Plant height (cm) of cauliflower determined at 60 DAT

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	60.8	55.4	51.1	60.1	54.1	51.3
N1B2	61.1	55.8	52.7	60.4	54.6	51.6
N1B3	61.1	55.9	54.8	60.4	55.5	53.9
N2B1	66.1	61.9	56.9	65.0	60.5	56.4
N2B2	66.9	62.0	57.7	65.7	61.1	56.9
N2B3	67.2	63.3	58.5	66.4	61.9	57.7
N3B1	67.3	64.1	59.5	66.4	63.2	58.5
N3B2	69.9	65.2	59.8	69.2	64.1	58.9
N3B3	71.2	65.7	60.7	70.5	64.4	59.7
Control	31.0			30.8		
Treated	61.2			60.3		
Treatment	S1	S2	S3	S1	S2	S3
N1	61.0	55.7	52.9	60.3	54.7	52.3
N2	66.7	62.4	57.7	65.7	61.2	57.0
N3	69.5	65.0	60.0	68.7	63.9	59.1
Mean	65.7	61.0	56.9	64.9	59.9	56.1
Treatment	N1	N2	N3	N1	N2	N3
B1	55.8	61.6	63.6	55.2	60.6	62.7
B2	56.5	62.2	65.0	55.5	61.3	64.1
B3	57.3	63.0	65.9	56.6	62.0	64.9
Mean	56.5	62.3	64.8	55.8	61.3	63.9
Treatment	B1	B2	B3	B1	B2	B3
S1	64.7	65.9	66.5	63.9	65.1	65.8
S2	60.5	61.0	61.6	59.3	59.9	60.6
S3	55.8	56.7	58.0	55.4	55.8	57.1
Mean	60.3	61.2	62.1	59.5	60.3	61.2
Treatments	2019-20		2020-21			
	SEM	CD at 5%	SEM	CD at 5%		
N	0.14	0.42	0.11	0.33		
B	0.14	0.42	0.11	0.33		
S	0.14	0.42	0.11	0.33		
NB	0.24	0.72	0.19	0.57		
NS	0.24	0.72	0.19	0.57		
BS	0.24	0.72	0.19	0.57		
NBS	0.42	1.25	0.33	0.99		
Control/Treated	0.72	2.16	0.57	1.70		

The interaction of biofertilizers and nitrogen was found significant with respect to the plant height of cauliflower. The treatment combination B3N3 i.e. azotobacter + vermicompost and 100% RDF was found superior as compared to all other treatment combinations. The treatment receiving azotobacter @5 kg ha⁻¹ and 50% RDF showed poor performance as the plant height was found least in this treatment (B1N1). The interaction of spacing and biofertilizers was also found significant with respect to the plant height of cauliflower. The treatment combination S1B3 i.e. spacing 30 cm and azotobacter + vermicompost was found superior as compared to all other treatment combinations. The treatment with highest spacing (50 cm) and receiving azotobacter @5 kg ha⁻¹ showed poor performance as the plant height was found least in this treatment (S3B1). Among all the treatment combinations studied, the plant height of cauliflower was ranged 31.0-71.2 cm and 30.8-70.5 cm during 2019-20 and 2020-21, respectively. The treatment N3B3S1 showed highest plant height of cauliflower followed by the treatment N3B2S1 during both the years of study. The unfertilized control showed least plant height followed by the treatment N1B1S3. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on plant height of cauliflower.

Diameter of stem

The data pertaining to the diameter of stem of cauliflower under various treatment combinations recorded during 2019-20 and

2020-21 is presented in Table 6. The higher dose of nitrogen i.e. N3-120 kg ha⁻¹ showed significantly higher diameter of stem of cauliflower plants followed by N2 and N1. The supply of higher amount of nitrogen influenced the diameter of stem of cauliflower. Chaurasia *et al.* (2002) [3] reported significantly better growth of chilli upon application of increasing dose of N. Muhammad *et al.* (2007) [14] also observed higher growth of cabbage with increasing levels of nitrogen application. The effect of application of biofertilizer combinations was also found significant. The combined application of vermicompost and azotobacter (B3) showed significantly higher diameter of stem followed by the sole application of vermicompost @5t ha⁻¹ (B2). The application of sole azotobacter @5 kg ha⁻¹ (B1) showed least diameter of stem of cauliflower. Moakala *et al.* (2015) [13] revealed that the combined application of vermicompost and biofertilizer in broccoli significantly influenced the growth as compared to the other treatments under study. Devi *et al.* (2017) [5] also reported better performance of okra with the treatment vermicompost + azotobacter. Further, the decrease in spacing showed increased diameter of stem. Similar to the nitrogen and biofertilizer, spacing also showed significant effect on diameter of stem of cauliflower. It has also been observed that the interactions of all kind showed significant influence on the diameter of stem of cauliflower. Gupta *et al.* (2002) [7] also reported that the reduced spacing improves the performance of cauliflower.

Table 8: Diameter of stem (cm) of cauliflower

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	2.23	2.08	1.92	2.25	2.11	1.92
N1B2	2.26	2.11	1.98	2.27	2.12	1.96
N1B3	2.27	2.15	2.04	2.29	2.16	2.08
N2B1	2.35	2.29	2.17	2.39	2.30	2.17
N2B2	2.37	2.30	2.18	2.41	2.33	2.18
N2B3	2.38	2.30	2.20	2.43	2.34	2.19
N3B1	2.39	2.31	2.21	2.44	2.34	2.20
N3B2	2.40	2.34	2.22	2.47	2.35	2.21
N3B3	2.41	2.35	2.22	2.50	2.36	2.24
Control	1.35			1.39		
Treated	2.24			2.26		
Treatment	S1	S2	S3	S1	S2	S3
N1	2.25	2.11	1.98	2.27	2.13	1.99
N2	2.36	2.30	2.18	2.41	2.32	2.18
N3	2.40	2.33	2.21	2.47	2.35	2.22
Mean	2.34	2.25	2.13	2.38	2.27	2.13
Treatment	N1	N2	N3	N1	N2	N3
B1	2.08	2.27	2.30	2.09	2.29	2.33
B2	2.12	2.28	2.32	2.12	2.30	2.35
B3	2.15	2.29	2.33	2.18	2.32	2.37
Mean	2.12	2.28	2.31	2.13	2.30	2.35
Treatment	B1	B2	B3	B1	B2	B3
S1	2.32	2.34	2.35	2.36	2.38	2.41
S2	2.23	2.25	2.27	2.25	2.27	2.28
S3	2.10	2.13	2.15	2.10	2.12	2.17
Mean	2.22	2.24	2.26	2.24	2.26	2.29
Treatments	2019-20		2020-21			
	SEM	CD at 5 %	SEM		CD at 5 %	
N	0.00	0.01	0.00		0.01	
B	0.00	0.01	0.00		0.01	
S	0.00	0.01	0.00		0.01	
NB	0.01	0.02	0.00		0.01	
NS	0.01	0.02	0.00		0.01	
BS	0.01	0.02	0.00		0.01	
NBS	0.01	0.04	0.01		0.02	
Control/Treated	0.02	0.06	0.01		0.04	

The interaction of nitrogen and spacing was found significant with respect to the diameter of stem of cauliflower. The treatment combination N3S1 i.e. 100% RDF with least spacing of 30 cm found superior as compared to all other treatment combinations. The treatment receiving 50% RDF and highest spacing i.e. 50 cm showed poor performance as the diameter of stem was found least under the same (N1S3). Hill *et al.* (2007)^[8] recorded significantly better growth parameters of cauliflower upon application of higher dose of N with least spacing. The interaction of biofertilizers and nitrogen was found significant with respect to the diameter of stem of cauliflower.

The treatment combination B3N3 i.e. azotobacter + vermicompost and 100% RDF was found superior as compared to all other treatment combinations. The treatment receiving azotobacter @5 kg ha⁻¹ and 50% RDF showed poor performance as the diameter of stem was found least in this treatment (B1N1). Choudhary *et al.* (2015)^[2] found significantly higher growth of cabbage crop with the combined application of nitrogen, vermicompost and biofertilizers. The interaction of spacing and biofertilizers was also found significant with respect to the diameter of stem of cauliflower. The treatment combination S1B3 i.e. spacing 30 cm and azotobacter + vermicompost was found superior as compared to all other treatment combinations. The treatment with highest spacing (50 cm) and receiving azotobacter @5 kg ha⁻¹ showed poor performance as the diameter of stem was found least in this treatment (S3B1).

Among all the treatment combinations studied, the diameter of stem of cauliflower was ranged 1.35-2.41 cm and 1.39-2.50 cm during 2019-20 and 2020-21, respectively. The treatment N3B3S1 showed highest diameter of stem of cauliflower followed by the treatment N3B2S1 during both the years of study. The unfertilized control showed least diameter of stem followed by the treatment N1B1S3. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on diameter of stem of cauliflower. The results of research work reported earlier with sole and combined application of nitrogen, biofertilizer, vermicompost and spacing found in line with the findings of present investigation (Sharma, 2002; Chaurasia *et al.*, 2002; Gupta, 2002; Choudhary *et al.*, 2003; Hill *et al.*, 2007; Moakala *et al.*, 2015; Kc *et al.*, 2022)^[3, 4, 7, 8, 12, 13, 19].

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