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Effect of Nitrogen, Biofertilizer and Spacing on Quality and Yield 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. The data pertaining to the quality such as ash content and curd compactness and yield were recorded in field and laboratory. The results of the study revealed that the nitrogen, biofertilizers and spacing significantly influenced the yield and quality of cauliflower. The higher dose of nitrogen, biofertilizer + vermicompost and 30 cm spacing had significant positive effect on yield 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 with respect of the yield and quality of cauliflower.
Keywords: *Cauliflower, yield, crop quality, ash content, compactness, spacing, nitrogen, INM, vermicompost, biofertilizer, crop performance*

I. INTRODUCTION

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). 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 is most importance in maintaining the fertility and productivity of agricultural soils, sustaining high yield and ensuring environmental safety (Reganold and Wachter, 2016). The cauliflower (Brassica oleracea L. var. botrytis) is one of the most important cole crops grown widely throughout the country (Sharma *et al.,* 2004). Cauliflower is a heavy feeder and for better yield, the soil must be kept fertile (Narayanamma *et al.,* 2005). Plant population (spacing) is important agronomic factor which affects the quality and quantity of the produce (Singh *et al.,* 2022). 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 efficiently resulting in maximum yield per unit area per unit of time (Hossain *et al.,* 2015). 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 reacting influences on the quality of curd besides improving soil health (Kaushal and Kaushal, 2013; Bhardwaj *et al.,* 2018). The effects of nitrogen nutrition and plant population are closely associated and have well marked effect on crop performance (Narayanamma *et al.,* 2005; Singh *et al.,* 2022).

Among the nutrients, nitrogen being a major food for plants is an essential constituent of protein (build from amino acids that involves in catalysation of chemical responses and transportation of electrons) and chlorophyll (enable the process of photosynthesis) present in the plant system. Nitrogen plays a most important role in physiological processes *viz.,* dark-green color, promotes leaves, stem and other vegetative part's growth and development, moreover, it also stimulates the root growth. Nitrogen produces rapid early growth, improves fruit quality, enhances the growth of leafy vegetables, and increases protein content of fodder crops. It encourages the uptake and utilization of other nutrients including potassium, phosphorous and controls overall growth of plant (Kumar et al., 2020).

Furthermore, the productivity and quality of cauliflower is getting deteriorated due to imbalance use of fertilizers. The relationship of these factors with the use of bio- organics in cauliflower is not well understood. Considering these facts, present investigation was carried out to study the effect of nitrogen, biofertilizers and spacing on yield and quality of cauliflower.

II. 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 soil of the experimental field is rich in potassium, low in nitrogen and medium in phosphorus. The organic carbon status of the experimental soil is medium.

The field experiment

The cauliflower (cv. Snowball-16) was tested for 28 treatment combinations viz., three levels of nitrogen, three types of biofertilizers 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 seed of Snowball-16 was made available by R.B.S. College. The seedlings were raised at R.B.S. College Research Form, Bichpuri, Agra by sowing the seed in well prepared raised beds 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} ($N:P_2O_5:K_2O$, 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)
Biofertilizer (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

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. 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 other seedlings in both the years. The 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. The yield of the crop was recorded. The quality parameters such as compactness and ash content of curd were determined. The collected data were statistically analysed by using the analysis of variance technique described by Gomez and Gomez (1984).

III. RESULTS AND DISCUSSION

Yield of cauliflower

The data pertaining to the yield of cauliflower under various treatment combinations recorded during 2019-20 and 2020-21 is presented in Table 3. The higher dose of nitrogen i.e. N3-120 kg ha^{-1} recorded significantly higher yield of cauliflower followed by N2 and N1. The supply of higher amount of nitrogen influenced the yield of cauliflower. Chaurasia *et al.* (2002) also reported significantly higher yield 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 yield followed by the sole application of vermicompost @5t ha^{-1}. The application of sole azotobacter @5 kg ha^{-1} (B1) showed lowest yield of cauliflower as compared to sole vermicompost (B2) and combined application VC+azotobacter (B3). Moakala *et al.* (2015) revealed that the combined application of vermicompost and biofertilizer in broccoli recorded significantly higher yield as compared to the other treatments under study. Further, the decrease in spacing showed higher yield. Similar to the nitrogen and biofertilizer, spacing also showed significant effect on yield of cauliflower. Gupta *et al.* (2002) also reported that the reduced spacing recorded highest yield of cauliflower. The interaction of nitrogen and spacing was found significant with respect to the yield 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 yield was found lowest (N1S3). Hill *et al.* (2007) also recorded significantly higher yield 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 yield 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 yield was found lowest (B1N1).

Table 3. Effect of nitrogen, biofertilizer and spacing on yield of cauliflower (q ha^{-1})

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	236.2	189.3	176.2	231.6	181.9	169.5
N1B2	239.0	199.7	181.1	235.2	185.5	173.9
N1B3	240.3	204.4	185.8	236.0	189.5	180.9
N2B1	263.0	241.0	208.1	257.8	237.7	199.3
N2B2	267.2	243.2	209.9	262.5	240.7	205.0
N2B3	271.3	247.1	226.3	268.2	241.6	220.9
N3B1	273.1	249.8	230.4	270.2	246.3	225.1
N3B2	278.3	254.1	231.5	274.6	249.4	227.1
N3B3	283.1	256.7	233.7	281.0	252.3	229.7

Control	**105.1**			**103.2**		
Treated	**234.1**			**228.6**		
Treatment	S1	S2	S3	S1	S2	S3
N1	238.5	197.8	181.0	234.3	185.6	174.8
N2	267.2	243.7	214.7	262.8	240.0	208.4
N3	278.2	253.5	231.9	275.3	249.3	227.3
Mean	**261.3**	**231.7**	**209.2**	**257.5**	**225.0**	**203.5**
Treatment	N1	N2	N3	N1	N2	N3
B1	200.6	237.3	251.1	194.3	231.6	247.2
B2	206.6	240.1	254.6	198.2	236.1	250.3
B3	210.2	248.2	257.9	202.1	243.6	254.3
Mean	**205.8**	**241.9**	**254.5**	**198.2**	**237.1**	**250.6**
Treatment	B1	B2	B3	B1	B2	B3
S1	257.4	261.5	264.9	253.2	257.4	261.7
S2	226.7	232.3	236.1	222.0	225.2	227.8
S3	204.9	207.5	215.3	198.0	202.0	210.5
Mean	**229.7**	**233.8**	**238.7**	**224.4**	**228.2**	**233.4**

Treatments	2019-20		2020-21	
	SEM	CD at 5%	SEM	CD at 5%
N	1.18	3.53	0.73	2.19
B	1.18	3.53	0.73	2.19
S	1.18	3.53	0.73	2.19
NB	2.04	6.12	1.26	3.79
NS	2.04	6.12	1.26	3.79
BS	2.04	6.12	1.26	3.79
NBS	3.53	10.60	2.19	6.57
Control/Treated	6.11	18.33	3.79	11.36

Sharma (2002) reported that the application of nitrogen with biofertilizer showed significantly higher yield of cabbage. Islam *et al* (2021) also reported that the combined application of organic manures and inorganic fertilizers significantly increased the yield of cauliflower. The interaction of spacing and biofertilizers was also found significant and 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 yield performance (S3B1). Among all the treatment combinations studied, the yield of cauliflower was ranged 105.1-283.1 q ha^{-1} and 103.2-

281.0 q ha^{-1} during 2019-20 and 2020-21, respectively. The treatment N3B3S1 showed highest yield of cauliflower followed by the treatment N3B2S1 during both the years of study. The unfertilized control showed lowest yield followed by the treatment N1B1S3. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on yield 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 (Swami and Konyok, 2020; Kaur *et al.,* 2020; Qi *et al.,* 2021; Shivran *et al.,* 2021; Kc *et al.,* 2022).

Ash content

The ash content of 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} recorded significantly lower ash content of cauliflower followed by N2 and N1. The supply of higher amount of nitrogen influenced the ash content of cauliflower. The effect of application of biofertilizer combinations was also found significant. The combined application of vermicompost and azotobacter showed significantly lower ash content followed by the sole application of vermicompost @5t ha^{-1}. The application of sole azotobacter @5 kg ha^{-1} (B1) showed highest ash content of cauliflower as compared to sole vermicompost (B2) and combined application VC+azotobacter (B3). The interaction of nitrogen and spacing was found significant with respect to the ash content of cauliflower. The treatment combination N3S1 i.e. 100% RDF with least spacing of 30 cm showed lower ash content as compared to all other treatment combinations. The treatment receiving 50% RDF and highest spacing i.e. 50 cm showed the highest ash content (N1S3). The interaction of biofertilizers and nitrogen was found significant with respect to the ash content of cauliflower.

Table 4. Effect of nitrogen, biofertilizer and spacing on ash content (%) in cauliflower

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	4.70	4.77	4.77	4.61	4.75	4.79
N1B2	4.81	4.73	4.61	4.74	4.78	4.62
N1B3	4.77	4.66	4.72	4.77	4.68	4.67
N2B1	4.63	4.68	4.74	4.65	4.62	4.77
N2B2	4.69	4.80	4.67	4.64	4.74	4.74
N2B3	4.78	4.75	4.63	4.75	4.76	4.60
N3B1	4.76	4.65	4.76	4.78	4.67	4.66
N3B2	4.64	4.70	4.78	4.65	4.63	4.75
N3B3	4.68	4.81	4.14	4.63	4.76	4.62
Control	4.66			4.66		
Treated	4.70			4.70		
Treatment	S1	S2	S3	S1	S2	S3
N1	4.76	4.72	4.70	4.71	4.74	4.69
N2	4.70	4.74	4.68	4.68	4.71	4.70
N3	4.69	4.72	4.56	4.69	4.69	4.68
Mean	4.72	4.73	4.65	4.69	4.71	4.69
Treatment	N1	N2	N3	N1	N2	N3
B1	4.75	4.69	4.72	4.72	4.68	4.70
B2	4.71	4.72	4.71	4.71	4.70	4.68
B3	4.72	4.72	4.54	4.71	4.70	4.67
Mean	4.73	4.71	4.66	4.71	4.70	4.68
Treatment	B1	B2	B3	B1	B2	B3
S1	4.70	4.72	4.74	4.68	4.68	4.72
S2	4.70	4.74	4.74	4.68	4.72	4.74
S3	4.76	4.68	4.50	4.74	4.70	4.63
Mean	4.72	4.71	4.66	4.70	4.70	4.69

Treatments	2019-20		2020-21	
	SEM	CD at 5%	SEM	CD at 5%
N	0.01	0.04	0.01	0.04
B	0.01	0.04	0.01	0.04
S	0.01	0.04	0.01	0.04
NB	0.02	0.07	0.02	0.07
NS	0.02	0.07	0.02	0.07
BS	0.02	0.07	0.02	0.07
NBS	0.04	0.12	0.04	0.12
Control/Treated	0.07	0.21	0.07	0.21

The treatment combination B3N3 i.e. azotobacter + vermicompost and 100% RDF showed lowest ash content as compared to all other treatment combinations. The treatment receiving azotobacter @5 kg ha^{-1} and 50% RDF showed the highest ash content (B1N1). The interaction of spacing and biofertilizers was also found significant and the treatment combination S1B3 i.e. spacing 30 cm and azotobacter + vermicompost recorded lowest ash content as compared to all other treatment combinations. The treatment with highest spacing (50 cm) and receiving azotobacter @5 kg ha^{-1} showed highest ash content performance (S3B1). Among all the treatment combinations studied, the ash content of cauliflower was ranged 4.14-4.81% and 4.60- 4.79% during 2019-20 and 2020-21, respectively. The treatment N1B2S1 showed highest ash content of cauliflower followed by the treatment N2B2S2 during both the years of study. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on ash content of cauliflower.

Curd compactness

The data pertaining to the compactness 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} recorded significantly higher compactness of cauliflower followed by N2 and N1. The supply of higher amount of nitrogen influenced the compactness of cauliflower. The effect of application of biofertilizer combinations was also found significant. The combined application of vermicompost and azotobacter showed significantly higher compactness followed by the sole application of vermicompost @5t ha^{-1}. The application of sole azotobacter @5 kg ha^{-1} (B1) showed lowest compactness of cauliflower as compared to sole vermicompost (B2) and combined application VC+azotobacter (B3). The interaction of nitrogen and spacing was found significant with respect to the compactness 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 compactness was found lowest (N1S3). The interaction of biofertilizers and nitrogen was found significant with respect to the compactness 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 compactness was found lowest (B1N1). The interaction of spacing and biofertilizers was also found significant and 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 compactness performance (S3B1).

Table 5. Effect of various treatments on curd compactness (%) of cauliflower

Treatment	2019-20			2020-21		
	S1	S2	S3	S1	S2	S3
N1B1	7.51	6.83	6.26	7.52	6.80	6.18
N1B2	7.82	6.94	6.44	7.61	6.82	6.57
N1B3	7.88	6.97	6.69	7.85	7.00	6.74
N2B1	8.44	7.95	6.98	8.36	7.88	7.07
N2B2	8.46	7.97	7.15	8.50	7.99	7.12
N2B3	8.54	8.13	7.21	8.59	8.03	7.15
N3B1	8.58	8.26	7.25	8.63	8.18	7.22
N3B2	8.61	8.31	7.32	8.69	8.25	7.33
N3B3	9.41	8.35	7.48	9.40	8.33	7.46
Control	**6.13**			**6.11**		
Treated	**7.69**			**7.68**		
Treatment	S1	S2	S3	S1	S2	S3
N1	7.74	6.91	6.46	7.66	6.87	6.50
N2	8.48	8.02	7.11	8.49	7.97	7.11
N3	8.87	8.31	7.35	8.91	8.25	7.34
Mean	**8.36**	**7.74**	**6.98**	**8.35**	**7.70**	**6.98**
Treatment	N1	N2	N3	N1	N2	N3
B1	6.86	7.79	8.03	6.83	7.77	8.01
B2	7.07	7.86	8.08	7.00	7.87	8.09
B3	7.18	7.96	8.41	7.20	7.92	8.40
Mean	**7.04**	**7.87**	**8.17**	**7.01**	**7.86**	**8.17**
Treatment	B1	B2	B3	B1	B2	B3
S1	8.18	8.30	8.61	8.17	8.27	8.61
S2	7.68	7.74	7.82	7.62	7.69	7.79
S3	6.83	6.97	7.12	6.82	7.01	7.12
Mean	**7.56**	**7.67**	**7.85**	**7.54**	**7.65**	**7.84**

Treatments	2019-20		2020-21	
	SEM	CD at 5%	SEM	CD at 5%
N	0.01	0.03	0.02	0.06
B	0.01	0.03	0.02	0.06
S	0.01	0.03	0.02	0.06
NB	0.02	0.05	0.04	0.11
NS	0.02	0.05	0.04	0.11
BS	0.02	0.05	0.04	0.11
NBS	0.03	0.08	0.06	0.19
Control/Treated	0.05	0.14	0.11	0.33

Among all the treatment combinations studied, the compactness of cauliflower was ranged 3.13-9.41 and 6.11-9.40 during 2019-20 and 2020-21, respectively. The treatment N3B3S1 showed highest compactness of cauliflower followed by the treatment N3B2S1 during both the years of study. The unfertilized control showed lowest compactness followed by the treatment N1B1S3. The effect of nitrogen, biofertilizers and spacing and their interactions showed the significant effect on compactness of cauliflower. Anuja *et al.* (2023) also reported 4.47-8.36% compactness of cauliflower in their study conducted at Kanpur, Uttar Pradesh.

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