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Response of Different Levels of Nitrogen on Growth and Yield of Cauliflower (*Brassica oleracea* var. botrytis*)* Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nitrogen is the major limiting nutrient in commercial cauliflower production. The effects of six nitrogen doses (0, 70, 80, 90, 115, 130 kg N/ha) were evaluated in two cauliflower varieties (Snow Mystique and Khumal Jyapu) at the Institute of Agriculture and Animal Science, Lamjung Campus from September 2018 to January 2019. This experiment was carried out in a two factorial Completely Randomized Design with twelve treatments and five replications. FYM (25 t/ha), full dose of phosphorus (80 kg/ha) and potassium (60 kg/ha), and half dose of nitrogen were applied as a basal dose and the remaining half dose of nitrogen was applied in two equal split doses at 30 DAT and 60 DAT. The application of 130 kg N/ha gave superior results in plant height (26.32 cm),

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plant spread (4103 cm^2), leaf area (264 cm^2), stem diameter (1.96 cm), number of leaves (20.70), root length (26.26 cm), girth of curd (49.46cm) and adjusted yield (21.78 ton/ha). Similarly, the performance of the Snow Mystique variety was significantly superior as compared to Khumal Jypau in terms of growth and yield. Therefore, the combination of an optimum level of nitrogen (130 kg N/ha) and hybrid variety (Snow Mystique) could be recommended for the commercial production of cauliflower.

Keywords: Cauliflower; growth; nitrogen; yield.

1. INTRODUCTION

Cauliflower (*Brassica oleraceae* var. botrytis L. 2n= 18) is a popular vegetable crop commercially grown from terai to high hills of Nepal with area, production and productivity of 35.4 thousand ha, 528.7 thousand tons, 14.94 ton/ha respectively [1]. Cauliflower is regarded as an economically important crop of the cole group, having a high market value and the potential for off-season production in the different parts of the country. Besides its economic value, cauliflower is a good source of dietary fiber, vitamin C, and minerals [2]. While analyzing cauliflower's production trend, there has not been a satisfactory increase in the productivity of the crop in the last five years [1]. Among different factors, poor nutrient management and the use of low yielding open pollinated varieties are major limiting factors associated with the lower production of cauliflower in the country. Being a heavy feeder crop, the role of macronutrients (NPK) and micronutrients (boron, zinc, and molybdenum) is inevitable for the luxuriant growth and higher yield of cauliflower. The nitrogen requirement in cauliflower is much higher than other nutrients [3]. Nitrogen is directly related to the vegetative growth and curd development of cauliflower, as it is involved in several physiological processes and enzymatic activities. Nitrogen is integral to chlorophyll, protoplasm, proteins, nucleic acids and enzymes [4]. Thus, N should be applied at the optimum dose to avoid toxicity and deficiency and to reduce production costs.

Nitrogen deficiency checks growth and reduces the yield significantly [5]. Nitrogen deficiency in plants results in poor plant performance with stunted growth, leaf discoloration, interveinal yellowing, chlorosis, acceleration of the reproductive stage, and senescence [6]. On the other hand, the excessive application of nitrogen is not only uneconomical but also stimulates vegetative growth, induces physiological disorder, negatively affects the nutritional value by limiting the synthesis of sugar and enhancing nitrate accumulation, high nitrogen leaching from soil and environmental pollution [7-10]. High nitrogen applications have been shown to reduce the vitamin C content [11], and increasing nitrogen content from 80 to 120 kg/ha was reported to decrease the vitamin C content by seven percent in cauliflower and broccoli [12]. Similarly, the varietal response to nitrogen fertilization may be different, different varieties have specific requirements for nitrogen. Hence, a balanced dose of nitrogen application and the selection of suitable varieties are crucial for the commercial production of cauliflower. Therefore, the present study was carried out to determine the optimum level of nitrogen and a suitable variety for the commercial production of cauliflower in Lamjung, Nepal.

2. MATERIALS AND METHODS

2.1 Location and Site of the Experiment

This experiment was conducted at the Institute of Agriculture and Animal Science (IAAS) Lamjung Campus from September 2018 to January 2019. It is located at 28.13° N latitude and 84.42° E longitude. During the research period, the monthly average temperature and relative humidity were assessed using the official website of the department of hydrology and meteorology. The maximum temperature (21℃) and relative humidity (75%) were observed in September whereas the minimum temperature (5℃) and relative humidity (45%) were observed in January [13].

2.2 Design of Experiment

The experiment was designed in a two factorial completely randomized design with twelve treatment combinations and five replications. The first factor consisted of six doses of nitrogen (control, 70 kg, 80 kg, 90 kg, 115 kg and 130 kg) and the second factor consisted of two cauliflower varieties (Snow Mystique and Khumal Jyapu).

Table 1. Treatment details

S.N.	Treatments	Treatments name	Combination
1.	T1	0 kg N + Snow Mystique	N1V1
2.	T2	70 kg N + Snow Mystique	N2V1
3.	T3	80 kg N + Snow Mystique	N3V1
4.	T4	90 kg N + Snow Mystique	N4V1
5.	T5	115 kg N + Snow Mystique	N5V1
6.	T6	130 kg N + Snow Mystique	N6V1
7.	T7	0 kg N + Khumal Jyapu	N1V2
8.	T8	70 kg N + Khumal Jyapu	N2V2
9.	T9	80 kg N + Khumal Jyapu	N3V2
10.	T10	90 kg N + Khumal Jyapu	N4V2
11.	T11	115 kg N + Khumal Jyapu	N5V2
12.	T12	130 kg N + Khumal Jyapu	N6V2

Table 2. Soil analysis report

Test	Results	Remarks
pH	6.5	Slightly Acidic
N (%)	0.10	Medium
P_2O_5 (kg/ha)	8.24	Low
K_20 (kg/ha)	112.40	Medium
Organic matter (%)	2.01	Medium
Sand (%)	39.60	
Silt (%)	38.00	
Clay (%)	22.40	
Soil texture	Loamy	

2.3 Preparation of Potting Media for Transplanting

On September 25, 2018, the soil was collected from the field and submitted to the Agricultural Technology Center in Jwagal, Lalitpur, Nepal for testing (Table 2). On October 1, 2018, an estimated quantity of FYM was mixed properly with the soil. After one month, pots (top diameter: 22.5 cm, base diameter: 16.5 cm, height: 18 cm) were filled with well-prepared media (FYM and soil) and watered to the saturation point and then left for three days to allow for field capacity.

2.4 Seedling Raising

A raised bed of 15 cm height and 1 m width was made and seeds of two varieties were sown separately on 8^{th} October 2018. Line sowing with 10 cm spacing was done at a depth of 4-5 cm. The seeds were then finely covered with a thin layer of a mixture of FYM and soil and nursery beds were mulched with straw. Light irrigation was done after seed sowing. The straw mulch was removed after five days and the overhead plastic tunnel was made to protect seedlings from extreme cold and hot. Light irrigation was done at three day intervals.

2.5 Transplanting of Seedlings

Uniform size vigorous seedlings (4-5 leaf stage and 27 days old) were transplanted in the pot containing well-prepared media (soil and FYM) and recommended doses of fertilizers. Light irrigation was done immediately after transplanting.

2.6 Manure and Fertilizers Application

Nitrogen, phosphorous, and potash were applied through Urea, Single Super Phosphate (SSP) and Muriate of Potash (MOP) respectively. FYM (25 t/ha), phosphorous, and potassium (80:60 kg/ha) were applied as a basal dose. The fertilizer requirement per pot was calculated on the basis of 60×45 cm plant spacing. Half a dose of different levels of urea (0, 2.05, 2.34, 2.64, 3.37, 3.81 g pot^{-1}) was applied as a basal dose and the remaining dose of urea was applied in two equal split doses at 30 and 60 days after transplanting (DAT) by band placement. A foliar spray of boron (0.25%) was done at 30, 45, and 60 DAT and a foliar spray of molybdenum (0.2%) was done at 35 DAT.

Table 3. NPK application at basal and split dose during the experiment

Fertilizers	Basal dose (g)	Split dose (g)
Urea	0, 2.05, 2.34, 2.64, 3.37, 3.81 g pot^{-1}	At 30 DAT (0, 1.025, 1.17, 1.32, 1.68, 1.90 g pot^{-1})
		At 60 DAT (0, 1.025, 1.17, 1.32, 1.68, 1.90 g pot^{-1})
Single Super Phosphate	13.50 g pot^{-1}	
Muriate of Potash	2.70 g pot^{-1}	

2.7 Intercultural Operations

The pots were kept weed free throughout the growth period to avoid crop weed competition. Manual weeding was done at 30 and 60 DAT and earthing up was done during the second weeding. During the weeding operation split dose of nitrogen was applied.

2.8 Observations

2.8.1 Growth parameters

2.8.1.1 Plant height (cm)

The plant height was measured with the help of a measuring scale. The plant height was measured from the ground level to the growing tip of the plant.

2.8.1.2 Plant spread (cm$^{2)}$

The spreading of the plants was measured by measuring the distance between perpendicular directions at harvesting time.

2.8.1.3 Leaf area (cm^2)

The length of leaves was measured between the attachment of the petiole and the apex of the leaf and breadth was measured at the point of maximum expansion with the help of a measuring scale. The area of leaves per plant was calculated by the Montgomery equation [14].

Leaf area= $\frac{\pi}{4}$*Length*Width

2.8.1.4 Diameter of the stem (cm)

The girth of the stem was measured with the help of Vernier's caliper at the time of harvesting.

2.8.1.5 Number of leaves per plant

The total number of fully opened leaves was counted at the time of harvesting.

2.8.1.6 Root length (cm)

The root length was measured with the help of a measuring scale. The plant was uprooted and immersed in water for an hour. The soil in the root was washed away, and the length of the root was measured from the base of the plant (ground level) to the tip of the root.

2.8.2 Yield parameters

2.8.2.1 Days to curd initiation

The number of days taken to curd initiation from the date of transplanting of seedlings was observed.

2.8.2.2 Diameter of curd (cm)

After harvesting the curd, the diameter of the curd was measured horizontally with the help of scale.

2.8.2.3 Fresh weight of leaves (g)

After harvesting, the fresh weight of the leaves was measured with the help of an electrical weighing balance.

2.8.2.4 Fresh weight of curd (g)

After harvesting, the fresh weight of the curd was measured with the help of an electrical weighing balance.

2.8.2.5 Adjusted yield per hectare

The weight of curd was measured by the electrical weighing balance and yield per hectare was computed using the following formula:

$$\text{Yield per hectare} = \frac{\text{curd weight per pot (gm)} \times \text{total plant population per hectare}}{1000 \times 1000}$$

2.9 Statistical Analysis

The data were entered into Microsoft Excel 2016 and analyzed using Genestat (15th edition). The data were subjected to Analysis of Variance (ANOVA) and mean separation was carried out using Duncan's Multiple Range Test (DMRT) at 0.05 level of significance ($P < 0.05$).

3. RESULTS

3.1 Effect of Nitrogen and Varieties on Growth Parameters of Cauliflower

Analysis of variance showed that the effect of different doses of nitrogen and varieties was significant for the different growth parameters of cauliflower (Table 4). The highest mean height of the cauliflower plant was obtained in the treatment applied with 130 kg N/ha (26.32 cm) and the lowest plant height (16.10 cm) was observed in the control. Maximum plant spread was observed in the treatment with 130 kg N/ha (4103 cm^2) which was statistically at par with the treatment treated with 115 kg N/ha and 90 kg N/ha while minimum plant spread was observed in the control (627 cm^2). The leaf area of the cauliflower plant increased significantly with the application of successive doses of nitrogen. Treatment that received 130 kg N/ha had the maximum leaf area (264 cm^2) while the minimum leaf area was observed in the control treatment (35.1 cm^2). The maximum stem diameter was observed in the 130 kg N/ha (1.96 cm) and the minimum stem diameter was observed in the control (0.92 cm). The highest number of leaves per plant was recorded at 130 kg N/ha which was statistically similar to 115 kg N/ha. The lowest number of leaves per plant was observed in the control (12.70). Similarly, the root length was also maximum in the 130 kg N/ha (26.26 cm) and minimum in the control (19.50 cm). Among the varieties, the results were significant for all growth parameters except leaf area. The highest plant height (22.16 cm), plant spread (4011 cm^2), diameter of the stem (1.70 cm), number of leaves per plant (20.10) and root length (26.22 cm) were observed in the Snow Mystique.

Table 4. Effect of different levels of nitrogen and varieties on growth parameters of cauliflower

Treatments	Plant height (cm)	Plant spread (cm^2)	Leaf area (cm^2)	Diameter of stem (cm)	Number of leaves per plant	Root length (cm)
Nitrogen level (kg/ha)						
0	16.10 ^{e}	627 ^{c}	35.1 ^{d}	0.92 ^{e}	12.70 ^{d}	19.50 ^{e}
70	20.92 ^{d}	3554 ^{b}	192.2 ^{c}	1.49 ^{d}	17.50 ^{c}	22.37 ^{d}
80	21.84 ^{cd}	3762 ^{ab}	194.0 ^{c}	1.62 ^{c}	18.70 ^{bc}	22.88 ^{cd}
90	22.75 ^{bc}	3915 ^{a}	198.4 ^{bc}	1.65 ^{bc}	20.00 ^{ab}	24.17 ^{bc}
115	23.80 ^{b}	4007 ^{a}	217.2 ^{b}	1.74 ^{b}	20.50 ^{a}	25.37 ^{ab}
130	26.32 ^{a}	4103 ^{a}	264.0 ^{a}	1.96 ^{a}	20.70 ^{a}	26.26 ^{a}
LSD	1.63**	335.3**	19.41**	0.09**	1.65**	1.64**
Varieties						
Snow Mystique	22.16	4011 ^{a}	185.0	1.70 ^{a}	20.10 ^{a}	26.22 ^{a}
Khumal Jyapu	21.75	2645 ^{b}	182.0	1.40 ^{b}	16.60 ^{b}	20.57 ^{b}
LSD	0.77^{ns}	193.6**	11.21^{ns}	0.05**	0.956**	0.97**
CV	6.8	11.2	11.8	6.6	10.0	8.0
Mean	21.96	3328	183.5	1.6	18.35	23.40

*Means separation in column followed by the same letters are not significantly different at p=0.05, **= highly significant, NS= Non-significant, LSD = Least Significant Difference, CV = Coefficient of Variance*

Table 5. Effect of different levels of nitrogen on yield parameters of cauliflower

Treatments	Curd initiation days	Girth of curd (cm)	Fresh weight of leaves (g)	Fresh weight of curd (g)	Adjusted yield (t/ha)
Nitrogen level (kg/ha)					
0	48.80 [b]	15.27 [e]	33.10 [d]	28.50 [e]	1.05 [e]
70	45.10 [cd]	45.71 [d]	423.10 [c]	420.40 [d]	15.57 [d]
80	44.00 [d]	46.53 [cd]	467.70 [bc]	481.70 [c]	17.84 [c]
90	47.50 [bc]	47.66 [bc]	514.90 [b]	518.20 [bc]	19.19 [bc]
115	51.70 [a]	48.42 [ab]	524.20 [b]	557.90 [ab]	20.66 [ab]
130	53.30 [a]	49.46 [a]	592.20 [a]	588.20 [a]	21.78 [a]
LSD	2.751**	1.286**	65.81**	53.82**	1.993**
Varieties					
Snow Mystique	51.03 [a]	43.59 [a]	583.0 [a]	569.7 [a]	21.10 [a]
Khumal Jyapu	45.77 [b]	42.04 [b]	268.8 [b]	295.3 [b]	10.94 [b]
LSD	1.588**	1.160*	38.00**	31.07**	1.151**
CV	6.3	5.2	17.2	13.8	13.8
Mean	48.40	42.81	425.9	432.5	16.02

*Means separation in column followed by the same letters are not significantly different at p=0.05, **= highly significant, LSD = Least Significant Difference, CV = Coefficient of Variance*

3.2 Effect of Different Levels of Nitrogen and Varieties on Yield Parameters of Cauliflower

The yield parameters were significant for the different doses of nitrogen and varieties as shown by the analysis of variance (Table 5). The minimum number of days (44 days) taken for curd initiation was observed in treatment at 80 kg N /ha which was similar to 70 kg N/ha while the maximum number of days taken for curd initiation was 53.30 days in treatment applied with 130 kg/ha. The highest girth (49.46 cm) of curd was observed in 130 kg N/ha and the lowest girth was observed in the control (15.27 cm). The maximum fresh weight of leaves was observed in the treatment 130 kg N /ha (592.20 g) and the minimum fresh weight of leaves was observed in the control (33.1 g). The fresh weight of curd and adjusted yield were also increased with the successive dose of nitrogen. The highest adjusted yield was observed at 130 kg N/ha (21.78 ton/ha) and the lowest adjusted yield was observed in the control (1.05 ton/ha). Among varieties, the results were significant for the yield parameters. The minimum number of days (45.77 days) for curd initiation was observed in the Khumal Jyapu and the maximum girth of curd (43.59 cm), fresh weight of leaves (583.0 g), fresh weight of curd (569.7 g) and adjusted yield (21.10 ton/ha) were observed in the Snow Mystique.

4. DISCUSSION

Nitrogen application is attributed to the vegetative growth of plants and plant height increases with the increase in nitrogen levels [15]. The maximum growth under a higher dose of nitrogen might be due to increasing the photosynthetic rates and the assimilation rates, which lead to an increase in the stalk length of cauliflower. Being one of the important nutrients, with its roles in plant metabolism and development, its application boosts plant growth [16]. These findings are in agreement with those reported by [17] in broccoli, [5,18] in cauliflower, [19] in Chinese cabbage and [20] in broccoli. Plant spread is directly related to the available nitrogen in the root zone of plants. When the supply of nitrogen to the root increases, the synthesis of cytokinin also increases and ultimately more cytokinin is transferred to the leaves for their growth and expansion [21,22]. These findings are in agreement with [18] in Chinese cabbage. Nitrogen in the vegetative growth of the plant enhanced leaf number in broccoli brought about by high nitrogen fertilization [23]. The maximum growth under a higher supply of nitrogen might be due to increasing the photosynthetic and assimilation rates, which lead to increased metabolic functions in the stem diameter of cauliflower. Similar results were observed by [5,24-26] in cauliflower, [26] in broccoli. Nitrogen is an integral part of chlorophyll and a major constituent of all proteins. With the increase in nitrogen, the enzymatic reactions within a plant system operate with optimum efficiency which leads to an increase in vegetative growth, leaf area, leaf number and chlorophyll content [27].

Nitrogen promotes vegetative growth; low or high doses of nitrogen fertilizer can delay curd initiation while an optimum dose of nitrogen fertilizer can promote early curd initiation in cauliflower. It is a well-known fact that nitrogen enhances vegetative growth and increases dry matter accumulation [28]. Nitrogen increases the production of green leaves which help in the synthesis of carbohydrates, proteins and nitrogenous compounds essential for building up new tissues. Nitrogen also stimulates chlorophyll formation which in turn accelerates the rate of photosynthesis and eventually increases growth and dry matter formation. It also promotes the growth and development of plants while increasing the uptake and utilization of potassium and phosphorus [29]. However, with the increase in nitrogen, curd initiation, and maturity are delayed due to an increase in the vegetative period [30]. The increased supply of nitrogen might have accelerated the synthesis of chlorophyll and amino acids and the effective utilization of carbohydrates and other organic compounds which might have resulted in the enlargement of curd. Nitrogen has a significant impact on the production of leaf area, the duration of leaf area, and the net assimilation rate, all of which are directly related to increased yield [31]. Carbohydrate metabolism, enzyme activation, and translocation of sugars and starches also increase with the supply of an optimum level of nitrogen [32]. With the increase in yield attributing traits of plants (plant height, leaf number, leaf area, and plant spreading), the photosynthesis, net assimilation, and dry matter accumulation of plants increase. This result is supported by [3,33,34] in broccoli and [30] in cauliflower.

The hybrid varieties have greater potential to uptake and utilize nitrogen more efficiently than the open pollinated varieties [31]. Similarly, hybrid varieties contain higher amounts of chlorophyll in their leaves, promoting the accumulation of photosynthates [35]. Higher photosynthetic activity correlated with the chlorophyll content of leaves [36]. The superiority of hybrid varieties might be due to improved photosynthetic activity and efficient transportation of photosynthates to developing sink tissues which ultimately increased plant biomass and yield [37]. The better growth and performance throughout the plant's development may therefore be influenced by the better accumulation of carbohydrate and pigment components in hybrid varieties [38]. Due to superior genetic makeup, hybrid varieties exhibited accelerated maturity, more complete apical dominance, higher harvest index, superior heading quality [39], and more productive and resistant to biotic and abiotic stresses [40]. Hybrid broccoli varieties outperformed open-pollinated varieties by 40-90%, owing to the hybrids' superior quality characteristics [41].

5. CONCLUSION

Nitrogen is a crucial nutrient for the growth and yield of cauliflower. This study indicated that increasing nitrogen levels significantly improved the yield and yield-attributing traits of cauliflower. Curd yield and growth parameters of cauliflower were highest at 130 kg N/ha. Similarly, the varietal response to nitrogen was superior in the Snow Mystique variety. Thus, the application of nitrogen and selection of varieties should be judiciously managed to obtain the maximum yield of cauliflower.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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