

Growth and yield responses of broccoli cultivars to different rates of nitrogen in western Chitwan, Nepal

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ABSTRACT

A field experiment was conducted with the objective to determine the optimum rate of nitrogen (N) fertilizer for effective growth and yield of two varieties of broccoli in southern plain of Nepal. The experiment was laid out with two-factorial completely random block design (RCBD) comprising two varieties of broccoli (Calabrese and Green Sprouting) and five N rates (0, 50, 100, 150 and 200 kg ha⁻¹) with three replication in each treatment combinations. The effects of variety and N rate on total curd yield were significant but the interaction effect was non-significant. Green Sprouting produced 11% higher total curd than Calabrese. Similarly, curd production increased N rate up to 200 kg ha⁻¹ reaching a maximum of 14.47 t ha⁻¹. This indicated that optimum level of N could be beyond the rates tested in this study, which needs further experimentation.

Keywords: *Brassica oleracea* L. *italica*; Curd Yield; Growth; Varieties

1. INTRODUCTION

Broccoli (*Brassica oleracea* L. *italica*) is a comparatively newer winter vegetable crop in Nepal [1]. Although broccoli stands in the 17th position in terms area of cultivation covering 141 hectares with 9 t/ha productivity in Chitwan district its production is mostly limited to kitchen garden level [2]. However, commercial cultivation of broccoli has started in recent years in southern plain including Chitwan district with limited governmental support.

For commercial cultivation, it is important to deter-

mine fertilizer [including nitrogen (N)] requirement of broccoli varieties. Nitrogen is an essential plant nutrient, which has a crucial role in growth and developments of crops. Although role and importance of nitrogen fertilizer in crop cultivation is reported very frequently, nitrogen fertilizer requirement of broccoli cultivated in southern plain of Nepal is not documented yet. We therefore conducted a field experiment with the objective to determine optimum rate of N fertilizer for effective growth and yield of two varieties of broccoli in southern plain of Nepal.

2. MATERIALS AND METHODS

The field experiment was conducted at horticulture farm of Institute of Agriculture and Animal Sciences, Rampur, Chitwan (27°39'N, 84°19'E, and 190 m above sea level) during a growing season of broccoli (17 October 2006-6 February 2007). The climate of the study area is subtropical type that receives average annual precipitation of 2500 mm with 74% falling in summer (from June to September). Winter season is generally dry with occasional rainfall and generally remains foggy with minimum sunshine hours. The soil is classified as sandy loam with pH 5.17, organic matter 3.43%, total nitrogen 0.12%, available phosphorus 244 kg/ha and available potassium 122 kg/ha.

The experiment was carried out in two factorial randomized complete block design (RCBD) with two broccoli cultivars (Calabrese and Green Sprouting) and five rates of N (0, 50, 100, 150 and 200 kg/ha which are referred to as N₀, N₅₀, N₁₀₀, N₁₅₀, N₂₀₀, respectively) with 3 replications in each treatment combination. The individual plot size was 3 × 2.5 m. There were 5 rows in each plot and 5 plants in each row with row to row distance of 60 cm and plant to plant distance of 50 cm.

Raised nursery beds were prepared for both varieties

where seeds were sown on 17 October 2006. Uniform sized seedlings with 3 - 4 leaves were selected and transplanted in the prepared experimental plots on 14 November 2006. The experimental plots were well prepared by harrowing 3 times and weeds and debris were removed manually. Farmyard manure (FYM) at rate of 20 t ha⁻¹ was well mixed at equal amount in each plot before transplanting. Beside FYM, all the plots were fertilized with 80 kg ha⁻¹ phosphorus (P) and 40 kg ha⁻¹ potassium (K) through single super phosphate (SSP) and muriate of potash (MOP), respectively. Also, Borax was applied at the rate of 2.2 kg boron ha⁻¹ at the time of field preparation. Mineral N fertilizer was applied in the form of urea in all plots except N₀. Half dose of N and full doses of P, K and boron were used as basal dose at the time of transplanting. A light irrigation was given after transplanting of the seedlings. General intercultural operations and plant protection measures were followed as per requirement of the plants. First weeding, earthing up and side dressing with 1/4 amount of N was done at 25 days after transplanting (DAT) while remaining 1/4 amount of N was applied at 40 DAT *i.e.* before curd initiation stage. Irrigation was given as and when needed.

Measurements were taken in inner 9 plants while the remaining 16 plants were considered as border plants. Five plants were randomly selected as sample plants from those nine plants. The measurements taken were plant height, number of leaves, days to heading, days to first harvest, days to last harvest, terminal curd yield, auxiliary curd yield, total curd yield, and length and diameter of terminal and auxiliary curd.

Statistical analysis was done using MSTAT-C (version 2.0, Michigan State University, Michigan, USA). Means were separated with Duncan's Multiple Range Test (DMRT) at 5% level of significance [3].

3. RESULTS AND DISCUSSION

3.1. Plant Height

Calabrese was significantly taller ($P < 0.05$) than Green Sprouting (**Table 1**). In general, plant height increased with increased N rate. Similar positive response of nitrogen fertilization in plant height of broccoli was also observed by El-Shikha *et al.* [4]. Interaction effects of varieties and N rate on the plant height were non-significant ($P > 0.05$) at the beginning of growth (**Table 2**).

Table 1. Effect of varieties and N rates on plant height and leaf number per plant at different days after transplanting (DAT).

Treatments	Plant Height (cm)			Number of Leaves		
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
Varieties						
Calabrese	21.80 ^a	38.91 ^a	61.75 ^a	6.37 ^a	10.10 ^a	12.67 ^a
Green Sprouting	12.14 ^b	20.93 ^b	37.57 ^b	4.93 ^b	7.493 ^b	11.19 ^b
Mean	16.80	29.92	49.66	5.65	8.8	11.93
SEM±	0.28	0.34	0.54	0.10	0.10	0.19
LSD _{0.05}	0.84	1.00	1.61	0.28	0.29	0.55
CV%	6.43	4.35	4.23	6.52	4.28	6.00
N Rates						
N ₀	16.12 ^b	27.38 ^d	42.57 ^d	5.667 ^{ab}	7.97 ^c	10.83 ^b
N ₅₀	16.25 ^b	28.97 ^c	48.45 ^c	5.20 ^b	8.50 ^b	11.13 ^b
N ₁₀₀	16.92 ^{ab}	30.05 ^{bc}	50.37 ^{bc}	5.63 ^{ab}	8.70 ^b	12.37 ^a
N ₁₅₀	17.67 ^a	31.33 ^{ab}	51.37 ^b	5.93 ^a	9.33 ^a	12.80 ^a
N ₂₀₀	17.90 ^a	31.87 ^a	55.53 ^a	5.83 ^a	9.50 ^a	12.50 ^a
Mean	16.80	29.92	49.66	5.65	8.80	11.93
SEM±	0.45	0.53	0.857	0.15	0.15	0.29
LSD _{0.05}	1.32	1.56	2.546	0.45	0.46	1.23
CV%	6.43	4.35	4.23	6.52	4.28	6.00

Means within the column followed by the same letter are not significantly different at 5% level of significance by DMRT. N₀ = 0 kg·N/ha, N₅₀ = 50 kg·N/ha, N₁₀₀ = 100 kg·N/ha, N₁₅₀ = 150 kg·N/ha, N₂₀₀ = 200 kg·N/ha.

Table 2. Interaction effect of varieties and N rates on plant height and leaf number per plant at different days after transplanting (DAT).

Treatments	Plant Height (cm)			Number of Leaves		
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT
V ₁ N ₀ (T1)	20.40	35.07	51.93 ^d	6.47	8.93 ^c	11.53
V ₁ N ₅₀ (T2)	20.70	37.63	60.00 ^c	5.73	9.60 ^b	11.60
V ₁ N ₁₀₀ (T3)	21.80	39.40	62.73 ^{bc}	6.27	9.87 ^b	13.33
V ₁ N ₁₅₀ (T4)	23.13	40.57	64.20 ^b	6.93	10.93 ^a	13.73
V ₁ N ₂₀₀ (T5)	22.97	41.87	69.87 ^a	6.47	11.20 ^a	13.13
V ₂ N ₀ (T6)	11.83	19.70	33.20 ^g	4.87	7.00 ^c	10.13
V ₂ N ₅₀ (T7)	11.80	20.27	36.90 ^f	4.67	7.40 ^{de}	10.67
V ₂ N ₁₀₀ (T8)	12.03	20.70	38.00 ^{ef}	5.00	7.53 ^{de}	11.40
V ₂ N ₁₅₀ (T9)	12.20	22.10	38.53 ^{ef}	4.93	7.73 ^d	11.87
V ₂ N ₂₀₀ (T10)	12.83	21.87	41.20 ^e	5.20	7.80 ^d	11.87
Mean	16.8	29.92	49.66	5.65	8.80	11.93
SEM±	0.63	0.75	1.21	0.21	0.22	0.41
LSD _{0.05}	ns	ns	3.60	ns	0.65	ns
CV%	6.43	4.35	4.23	6.52	4.28	6.00

Means within the column followed by the same letter are not significantly different at 5% level of significance by DMRT. N₀ = 0 kg·N/ha, N₅₀ = 50 kg·N/ha, N₁₀₀ = 100 kg·N/ha, N₁₅₀ = 150 kg·N/ha, N₂₀₀ = 200 kg·N/ha.

At 45 DAT, the tallest plants were observed in Calabrese at N₂₀₀ whereas the shortest plants were observed in Green Sprouting at N₀.

3.2. Number of Leaves per Plant

Calabrese had significantly higher ($P < 0.05$) number of leaves than Green Sprouting (**Table 1**). Similarly, effect of N rate was also significant at all observation dates. Significantly higher numbers of leaves were observed at N₁₅₀ as compared to N₅₀ and N₀ at 15 and 45 DAT. The highest number of leaves was observed at N₂₀₀ while the lowest number of leaves was obtained at N₀ at 30 DAT. Similar positive response of N fertilization in leaf numbers was also observed in other studies [5-7]. Interactive effect of varieties and N rate was non-significant except at 30 DAT (**Table 2**). Calabrese had the highest number of leaves per plant at N₂₀₀ while Green Sprouting had the lowest number of leaves per plant at N₀ at 30 DAT.

3.3. Days to Heading, and First and Last Harvest

The broccoli varieties differed significantly ($P < 0.05$) in terms of days to heading, days to first and last harvest (**Table 3**). Calabrese produced head 26 days earlier and consequently the first and last harvest of the variety was

Table 3. Effect of varieties and N rates on days to heading, first harvest and last harvest.

Treatments	Days to Heading	Days to First Harvest	Days to Last Harvest
Varieties			
Calabrese	45.13 ^b	55.81 ^b	71.54 ^b
Green Sprouting	71.47 ^a	81.19 ^a	87.46 ^a
Mean	58.30	68.50	79.50
SEM±	0.59	0.39	0.29
LSD _{0.05}	1.75	1.15	0.86
CV%	3.91	2.19	1.41
N Rates			
N ₀	60.50	69.96 ^a	82.17 ^a
N ₅₀	58.83	67.83 ^b	78.43 ^c
N ₁₀₀	56.83	67.31 ^b	78.35 ^c
N ₁₅₀	57.17	68.24 ^{ab}	78.06 ^c
N ₂₀₀	58.17	69.15 ^{ab}	80.50 ^b
Mean	58.30	68.50	79.50
SEM±	0.93	0.61	0.46
LSD _{0.05}	ns	1.82	1.36
CV%	3.91	2.19	1.41

Means within the column followed by the same letter are not significantly different at 5% level of significance by DMRT. N₀ = 0 kg N/ha, N₅₀ = 50 kg N/ha, N₁₀₀ = 100 kg N/ha, N₁₅₀ = 150 kg N/ha, N₂₀₀ = 200 kg N/ha.

significantly earlier than Green Sprouting. This is important as broccoli produced in early of the growth season can fetch higher price in the market. Effect of N rate on days to heading was non-significant ($P > 0.05$). However, there effect of N rate was significant ($P < 0.05$) for the number of days from transplanting to first and last harvest. The broccoli varieties took slightly longer to reach the date of the first and last harvest at N_0 . In the absence of N application plants had slower rate of growth at N_0 whereas N fertilization had stimulated vegetative growth in other treatments. This slower rate of plant growth might be the cause of delayed curd initiation and subsequently more number of days to harvest [8,9]. The interaction effect of varieties and N rate on the days to heading, and the first and the last harvest were non-significant ($P > 0.05$).

3.4. Length and Diameter of Terminal and Auxiliary curds

Highly significant variation between the varieties in the length and diameter of terminal curd was noticed (Table 4). Calabrese had significantly longer terminal

Table 4. Effect of varieties and N rates on length and diameter of terminal and auxiliary curd.

Treatments	Terminal Curd		Auxiliary Curd	
	Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)
Varieties				
Calabrese	19.89 ^a	7.29 ^b	12.93 ^a	3.61 ^a
Green Sprouting	17.16 ^b	12.56 ^a	9.907 ^b	3.27 ^b
Mean	18.53	9.92	11.42	3.44
SEM±	0.19	0.20	0.12	0.10
LSD _{0.05}	0.57	0.58	0.35	0.31
CV%	4.01	7.63	3.96	11.60
N Rates				
N_0	17.29 ^c	7.70 ^c	9.90 ^c	2.67 ^d
N_{50}	17.90 ^{bc}	9.48 ^b	10.80 ^d	3.08 ^{cd}
N_{100}	18.56 ^{ab}	10.54 ^a	11.38 ^c	3.50 ^{bc}
N_{150}	19.46 ^a	10.47 ^a	12.07 ^b	3.74 ^{ab}
N_{200}	19.44 ^a	11.42 ^a	12.95 ^a	4.22 ^a
Mean	18.53	9.92	11.42	3.44
SEM±	0.30	0.31	0.19	0.16
LSD _{0.05}	0.90	0.92	0.55	0.48
CV%	4.01	7.63	3.96	11.60

Means within the column followed by the same letter are not significantly different at 5% level of significance by DMRT. $N_0 = 0$ kg N/ha, $N_{50} = 50$ kg N/ha, $N_{100} = 100$ kg N/ha, $N_{150} = 150$ kg N/ha, $N_{200} = 200$ kg N/ha.

and auxiliary curds. Green Sprouting had wider terminal curds but Calabrese had wider auxiliary curds. Likewise, the effect of N rate on the length and diameter of both terminal and auxiliary curd was observed highly significant. In general, length and diameter of terminal and auxiliary curds increased with increased N rate. Similar response of proportionate increase of length and diameter of head of broccoli with N rate was also observed in other studies [6,10].

Interaction effect of varieties and N rate was non-significant ($P > 0.05$) for the length of terminal curd and auxiliary curds. The interaction effect was however significant ($P < 0.05$) for the diameter of terminal curd. The widest curd diameter was in Green Sprouting at N_{200} while the smallest curd diameter was observed in Calabrese at N_0 .

3.5. Terminal, Auxiliary and Total Curd Yield

Green Sprouting produced higher terminal cut but auxiliary curd yield was higher in Calabrese (Table 5). Thus, Green Sprouting produced 11% higher ($P > 0.05$)

Table 5. Effect of varieties and N rates on yield of terminal, auxiliary and total curd yield of broccoli.

Treatments	Yield (t/ha)		
	Terminal Curd	Auxiliary Curd	Total Curd
Varieties			
Calabrese	4.54 ^b	5.17 ^a	9.70 ^b
Green Sprouting	8.25 ^a	2.57 ^b	10.81 ^a
Mean	6.39	3.87	10.26
SEM±	0.23	0.18	0.31
LSD _{0.05}	0.67	0.52	0.92
CV%	13.67	17.60	12.50
N Rates			
N_0	3.53 ^d	1.68 ^c	5.23 ^d
N_{50}	5.85 ^c	2.96 ^d	8.80 ^c
N_{100}	6.88 ^{bc}	3.87 ^c	10.72 ^b
N_{150}	7.12 ^b	4.94 ^b	12.06 ^b
N_{200}	8.58 ^a	5.89 ^a	14.47 ^a
Mean	6.39	3.87	10.26
SEM±	0.36	0.28	0.74
LSD _{0.05}	1.06	0.83	1.55
CV%	13.67	17.60	12.50

Means within the column followed by the same letter are not significantly different at 5% level of significance by DMRT. $N_0 = 0$ kg N/ha, $N_{50} = 50$ kg N/ha, $N_{100} = 100$ kg N/ha, $N_{150} = 150$ kg N/ha, $N_{200} = 200$ kg N/ha.

total curd. The effect of N rate on the yield of terminal curd was highly significant. The highest rate of N fertilizer (N₂₀₀) produced the highest amount of terminal, auxiliary and total curd. The increment in the yield of curd with the increased N rate application may be due to the production of higher amount of photosynthates available for the enlargement of the curds. Increment in the curd yield from increased N rate was also observed in previous studies [6,11-13]. This indicated that optimum level of N could be beyond the rates tested in this study. Interaction of varieties with different N rates on terminal and total curd yield were non-significant. But, it was significant on auxiliary curd yield. Green Sprouting with N₀ produced the lowest auxiliary curd yield while Calabrese with N₂₀₀ produced the highest auxiliary curd.

4. CONCLUSION

The aim of the current study was to optimize nitrogen nutrition of two broccoli cultivars cultivated at western Chitwan, Nepal. Green Sprouting produced 11% higher total curd than Calabrese. Total curd production increased with increased N rate in both cultivars reaching a maximum of 14.47 t ha⁻¹ at N rate of 200 kg ha⁻¹. The results indicated that optimum level of N could be beyond 200 kg ha⁻¹, which needs further experimentation.

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