Research Article:

EFFECT OF SPACING AND NITROGEN FERTILIZER ON GROWTH, YIELD AND QUALITY OF BEETROOT (*Beta Vulgaris* L.) AT KAPILAKOT, SINDHULI, NEPAL

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ABSTRACT

A field experiment was conducted at the Horticulture Farm of the College of Natural Resource Management Kapilakot, Sindhuli, Nepal, from October 2020 to January 2021 to determine the effective spacing and optimum nitrogen fertilizer for the growth, yield, and quality of beetroot variety Madhur. The experiment was laid out in a two factorial RCBD design consisting of 15 treatment combinations replicated three times. The treatment considered three plant spacing (45 cm x 5 cm, 45 cm x 10 cm, and 45 cm x 15 cm) and five doses of N fertilizer (80 kg N ha^{-1}, 100 kg N ha^{-1}, 120 kg N ha^{-1}, 140 kg N ha^{-1} and 160 kg N ha^{-1}). The results indicated that plant spacing and nitrogen fertilizer doses significantly influenced beetroot growth, yield and quality. The number of leaves per plant (13.37), leaf breadth (11.54 cm), canopy diameter (39.65 cm), root diameter (78.63 mm), root weight plant^{-1} (186.69 gm), shoot weight plant^{-1} (156.69 gm), root dry matter (10.56 %), shoot dry matter (9.74 %), TSS (12.67 ^{0}Brix) were significantly higher in the wider spacing (45 cm x 15 cm). However, plant height (43.62 cm), leaf length (39.69 cm), root length (11.9 cm), economic yield (40.95 t ha^{-1}) and biological yield (62.95 t ha^{-1}) were significantly higher in close spacing (45 cm x 5 cm). Likewise, plant height (44.2 cm), leaves plant^{-1} (13.41), leaf length (39.79 cm), root length (12.32 cm), root diameter (72.56 mm), root weight plant^{-1} (181.32 gm), shoot weight plant^{-1} (164.43 gm), root dry matter (10.86), shoot dry matter (9.57 %), economic yield (38.14 t ha^{-1}) and biological yield (62.58 t ha^{-1}) were significantly higher in 160 kg N ha^{-1}. However, the canopy diameter (39.12 cm), TSS (13.3 ^{0}Brix) and pH (6.6) were significantly higher in plants receiving 120 kg N ha^{-1}. A plant spacing of 45 cm x 5 cm with 160 kg N ha^{-1} is the best management option for beetroot production in Sindhuli.

Key words: Beetroot, nitrogen, spacing, yield

INTRODUCTION

Beetroot (*Beta vulgaris* L.) is commonly known as Chukandar in Nepali is one of the classic winter seasons vegetable crops belong to the family Chenopodiaceae, and its pollination is naturally carried out by wind. Beetroot is famous for its nutrition and medicinal properties and is known by several common names, like garden beet, red beet, table beet, or simply beet. Beetroot is fast growing cool season biennial root crop grown as annual for its root (Irving et al., 2012). In the first year, the beet is formed by the thickening of the shoot axis section below the cotyledons, and for seed production, beets are replanted in the second year. Depending on the genotype, the beet has a round or cylindrical shape. The different ways that beetroot is used are in salads, and soups in addition to methods for their preservation such as pickling and canning. Beetroot is a good source of minerals, carbohydrates, and protein and it has high levels of vitamin B_1 and micronutrients (Cerne & Vrhovnik, 1999). Considered as a vegetable, beetroot may have many positive influences on human health.

Beetroot juice is today advocated as a stimulant for the immune system, as well as a cancer preventative and it has long been considered beneficial to the blood, heart and digestive system (Nottingham, 2004). Moreover, relatively easy cultivation and good storability without the need for costly storage equipment have increased farmers' as well as the food industry's interest in beetroot production (Clifford et al., 2015).Beetroot is a rich source of folic acid which is useful for pregnant women. It makes an excellent dietary supplement being not only rich in minerals, nutrients, and vitamins but also unique phyto-constituents, which have several medicinal properties. Several parts of this plant are used in medicinal systems such as anti-oxidant, anti-depressant, anti-microbial, antifungal, anti-inflammatory, diuretic, expectorant, and carminative. It is one of the natural foods which boosts energy in athletes as it has one of the highest nitrates and sugar containing plants (Yadav et al., 2016).

The intense red colour of beetroot derives from high concentration of betalains. Betalains are used as natural colorants by the food industry but have also received increasing attention due to possible health benefits in humans, especially their antioxidant and anti-inflammatory activities (Georgiev et al., 2010; Zielinska et al., 2009). The betalains that are mainly found in beetroot are betacyanins and betaxanthins (Gandia et al., 2016).

In Nepal, there are very few vegetables that dominate whole the country (Rawal et. al, 2016), and this nutritious vegetable is still neglected in Nepal. Being a new crop among Nepalese farmers, a major constraint for its production is poor agricultural practices including inappropriate plant density management and the optimum use of fertilizers. Very limited research has been conducted on beetroot production management in Nepal.

Plant population affects plant growth, development, and yield of the beetroot plant. Optimum spacing avoids shading effects on plants and interspace competition among nutrition, radiation water, etc. In case of close spacing, competition is greater and the development of the root is badly affected. Similarly at wider spacing, individual plants will yield more, and yield per hectare may reduce due to low plant population. Therefore, an optimum plant population must be determined at the maximum average yield per hectare (Pervez et al., 2004). Research has shown that in general, increasing a plant population increases the biological yield per unit area up to some upper limit or threshold density after which further increase in plant density either maintains the same yield or causes yield decline (Weiner, 1990). Proper spacing ensures optimum plant growth through adequate utilization of moisture, light, spacing, and nutrients.

In addition to the plant population, nitrogen fertilizer is important to produce a reliable and optimal yield of quality vegetables. Many studies have been conducted to compare the influence of nitrogen fertilizers on the growth, yield, and quality of beetroot (Cerne & Vrhovnik, 1999; Deuter & Grundy; 2004; Goh & Vityakon, 1983). An inadequate supply of available nitrogen frequently results in plants that have slow growth, depressed protein levels, poor yield, low quality produce, and inefficient water use. Badawi et al. (1995) reported that the maximum yield of beetroot was obtained when 260 kg N ha^{-1} was applied to sandy loam soil. Considering the above information, this research was carried out in the Marin Valley landscape in Sindhuli district of Nepal.

MATERIALS AND METHODS

Location of the research site

The experimental site was located in the College of Natural Resource Management, Kapilakot, Sindhuli which is situated in the Bagmati Province, Nepal at 27⁰15'N, 85⁰44'E with an elevation of 290 masl. The experiment was conducted during the winter season i.e. November 2020 to January 2021.

Soil properties

The soil samples were taken from the top (0-35cm) before the commencement of the study and analyzed in the Soil and Fertilizer Testing Laboratory of Bagmati Province, Hetauda, Makwanpur, District, Nepal to measure the total nitrogen by Macro-Kjeldahl method (Jackson, 1967) available phosphorus by Olsen's bi-carbonate, and available potash by ammonium acetate method. Organic matter was determined by Walkely and Black method, pH by Beckman Glass Electrode pH, and soil texture by hydrometer method. The soil of the experimental field was acidic (pH 5.7) containing medium organic matter (3.81 %), medium nitrogen (0.17 %), medium available phosphorous (45.59 kg ha^{-1}), and medium available potassium (148.55 kg ha^{-1}).

Agro-climatic condition of the research site

The research was conducted during the winter season at Kapilakot, Sindhuli. Maximum air temperature arranged from 23.14 °C (4^{th} week of December 2020) to 29.95 °C 1st week of November 2020 and minimum temperature ranged from 9 °C (1^{st} week of January 2021) to 16.9°C (1^{st} week of November 2020). Similarly, the average RH during the cropping period was 91.84 %. Rainfall (12.4 mm) and (13.2 mm) were recorded during 4^{th} week of December 2020 and 1^{st} week of January 2021 respectively (Fig. 1).

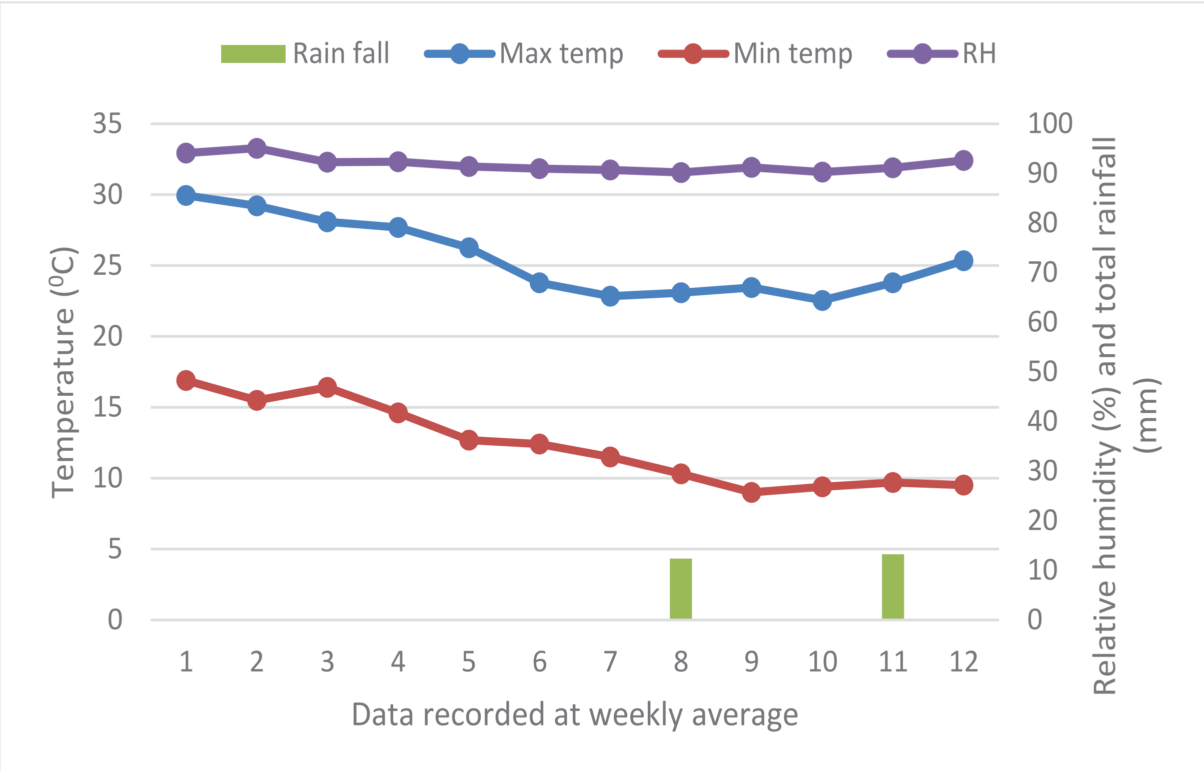

Fig. 1. Maximum temperature, minimum temperature, relative humidity and rainfall during the experimental period (November 2020 to January 2021)

Experimental details

The experiment was conducted between November 2020 to January 2021 at the experimental field of College of Natural Resource Management, Kapilakot, Sindhuli, Nepal. The experiment was conducted in a Randomized Complete Block Design. Two factors namely, three spacing and five levels of nitrogen were used in the experiment. Two factors with 15 treatments and three replications were randomized in a two factorial RCBD design. There were 96,48,32 number of plants in each experimental plot among which 44, 20, 12, and 52, 28, and 20 number of plants were experimental plants and border plants at 45 cm x 5 cm, 45 cm x 10 cm, and 45 cm x 15 cm spacing respectively. The total number of plots were 45 and individual experimental plot size was 1.8 x1.2 m (2.16 m^2).

Treatment details

Table 1. Details of the treatment used in an experiment

Spacing: (Factor A)	Nitrogen dose: (Factor B)
(S_1) 45 cm x 5 cm	(N_1) 80 kg N ha^{-1}
(S_2) 45 cm x 10 cm	(N_2) 100 kg N ha^{-1}
(S_3) 45 cm x 15 cm	(N_3) 120 kg N ha^{-1}
	(N_4) 140 kg N ha^{-1}
	(N_5) 160 kg N ha^{-1}

Table 2. Details of the treatment combinations and treatment description

S.N.	Treatment combination	Treatment details
T_1	S_1N_1	(S_1) 45 cm x 5 cm + (N_1) 80 kg N ha^{-1}
T_2	S_1N_2	(S_1) 45 cm x 5 cm + (N_2) 100 kg N ha^{-1}
T_3	S_1N_3	(S_1) 45 cm x 5 cm + (N_3) 120 kg N ha^{-1}
T_4	S_1N_4	(S_1) 45 cm x 5 cm + (N_4) 140 kg N ha^{-1}
T_5	S_1N_5	(S_1) 45 cm x 5 cm + (N_5) 160 kg N ha^{-1}
T_6	S_2N_1	(S_2) 45 cm x 10 cm + (N_1) 80 kg N ha^{-1}
T_7	S_2N_2	(S_2) 45 cm x 10 cm + (N_2) 100 kg N ha^{-1}
T_8	S_2N_3	(S_2) 45 cm x 10 cm + (N_3) 120 kg N ha^{-1}
T_9	S_2N_4	(S_2) 45 cm x 10 cm + (N_4) 140 kg N ha^{-1}
T_{10}	S_2N_5	(S_2) 45 cm x 10 cm + (N_5) 160 kg N ha^{-1}
T_{11}	S_3N_1	(S_3) 45 cm x 15 cm + (N_1) 80 kg N ha^{-1}
T_{12}	S_3N_2	(S_3) 45 cm x 15 cm + (N_2) 100 kg N ha^{-1}
T_{13}	S_3N_3	(S_3) 45 cm x 15 cm + (N_3) 120 kg N ha^{-1}
T_{14}	S_3N_4	(S_3) 45 cm x 15 cm + (N_4) 140 kg N ha^{-1}
T_{15}	S_3N_5	(S_3) 45 cm x 15 cm + (N_5) 160 kg N ha^{-1}

Details of field operations

Each plot was supplied with the recommended dose of FYM (20 t ha^{-1}), half of the nitrogen (as per treatments) and 80 kg P ha^{-1} and 40 kg K ha^{-1} were supplied during field preparation, and the remaining half of the nitrogen was supplied 30 days after seed sowing. Nitrogen was supplied through urea (46 %N) and Diammonium phosphate (DAP), phosphorous through DAP (18% N and 46 % P), and potash through murate of potash (60% potash).

Observation recorded

Growth parameters like Plant height (cm), number of leaves per plant, leaf length (cm), breath of longest leaf (cm) canopy diameter (cm), and yield parameters such as root length (cm), root diameter (mm), root weight plant $^{-1}$ (gm), shoot weight plant^{-1}(gm), economic yield (t ha^{-1}), biological yield (t ha^{-1}), root dry matter (%), shoot dry matter (%), and quality parameters like TSS (^{0} brix) and pH were recorded after harvest.

Data analysis

The collected data was compiled and subjected to analysis of variance by using Microsoft Excel. R-Studio version 4.2.3 was used for the analysis of variance of all parameters. Mean comparison was done at various levels of significance using Duncan's Multiple Range Test (DMRT). Microsoft Excel was used to construct the graphs and tables.

RESULTS

Vegetative characteristics

Plant height

The plant height of beetroot differed significantly in DMRT analysis $p<0.05$ between the three plant spacing and different nitrogen doses at final harvest (Table 3). Plant height was significantly higher (43.62 cm) at 45 cm x 5 cm spacing and the lowest plant height (38.88 cm) was obtained in wider spacing (45 cm x 15 cm). Similarly, a statistically higher plant height was recorded from 160 kg nitrogen ha^{-1} which was statistically at par with 140 kg nitrogen ha^{-1}and the lowest plant height (39.02 cm) was recorded at 80 kg nitrogen ha^{-1}. The interaction effect of plant spacing and nitrogen did not show any significant effect on plant height during the final harvest.

Number of leaves per plant

The number of leaves per plant of beetroot differed significantly between plant spacing and different nitrogen doses at final harvest (Table 3). The number of leaves per plant was significantly higher (13.37) at 45 cm x 15 cm spacing which was statistically at par with 160 kg nitrogen ha^{-1} and the lowest leaves numbers (11.7) were recorded at 45 cm x 5 cm. Likewise, statistically maximum number of leaves per plant (13.41) was recorded at 160 kg nitrogen ha^{-1} and the lowest number of leaves per plant was found (11.64) at 100 kg nitrogen ha^{-1}. The interaction between spacing and nitrogen did not show any significant effect on the number of leaves per plant at the final harvest.

Length of longest leaf

The leaf length of beetroot differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen doses at the final harvest (Table 3). Leaf length was significantly higher (39.69 cm) at 45 cm x 5 cm spacing and minimum leaf length (34.75 cm) was recorded at 45 cm x 15 cm. Similarly, statistically higher leaf length (39.79 cm) was recorded at 160 kg nitrogen ha^{-1} which was statistically at par (37.75 cm) with 140 kg nitrogen ha^{-1} and 120 kg nitrogen ha^{-1} (37.43 cm). The lowest leaf length (35.38 cm) was observed in 100 kg nitrogen ha^{-1}. The interaction between spacing and nitrogen did not show any significant effect on leaf length at the final harvest.

Breadth of longest leaf

The breadth of the longest leaf of beetroot differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen doses at the final harvest (Table 3). Leaf breadth was significantly higher (11.54 cm) at 45 cm x 15 cm spacing and narrow leaf (10.07 cm) was recorded at 45 cm x 5 cm spacing. However, nitrogen fertilizer did not show a significant effect on leaf breadth of the plant. Similarly, the interaction effect of spacing and nitrogen did not show any significant effect on leaf breadth at the final harvest.

Canopy diameter

The canopy diameter of beetroot plant was statistically significant in DMRT analysis $p<0.05$ between plant spacing and different nitrogen doses at final harvest (Table 3). Canopy diameter was significantly higher (39.65 cm) at 45 cm x 15 cm spacing and the lowest canopy diameter was recorded (36.26 cm) at 45 cm x 5 cm spacing. Similarly, the maximum plant canopy was measured (39.12 cm) at 45 cm x 10 cm spacing which was statistically at par with 140 kg nitrogen ha^{-1}(38.24 cm) and 160 kg nitrogen ha^{-1}(37.9 cm), and the lowest plant canopy diameter was recorded at 80 kg nitrogen ha^{-1}(36.41 cm). However, the interaction effect of spacing and nitrogen did not show any significant effect on canopy diameter at the final harvest.

Table 3. Effect of spacing and nitrogen fertilizer on vegetative parameters of beetroot at Kapilakot, Sindhuli, Nepal (2020-2021)

Treatments	At final harvest				
	Plant height (cm)	No. of leaves $plant^{-1}$	Leaf length (cm)	Leaf breadth (cm)	Canopy diameter (cm)
Spacing (Factor A)					
45 cm x 5 cm	43.62^{a}	11.70^{b}	39.69^{a}	10.07^{b}	36.26^{b}
45 cm x 10 cm	40.41^{b}	13.17^{a}	36.95^{b}	11.12^{a}	37.07^{b}
45 cm x 15 cm	38.88^{b}	13.37^{a}	34.75^{c}	11.54^{a}	39.65^{a}
SEM (±)	0.83	0.31	0.73	0.29	0.74
$LSD_{0.05}$	2.15***	0.81***	1.89***	0.75**	1.93**
Nitrogen doses (Factor B)					
80 kg Nitrogen ha^{-1}	39.02^{b}	12.42^{ab}	35.60^{b}	10.08	36.41^{b}
100 kg Nitrogen ha^{-1}	39.04^{b}	11.64^{b}	35.38^{b}	10.74	36.63^{b}
120 kg Nitrogen ha^{-1}	41.63^{ab}	12.90^{a}	37.43^{ab}	11.03	39.12^{a}
140 kg Nitrogen ha^{-1}	40.98^{b}	13.35^{a}	37.75^{ab}	11.26	38.24^{ab}
160 kg Nitrogen ha^{-1}	44.20^{a}	13.41^{a}	39.79^{a}	11.43	37.90^{ab}
SEM (±)	1.07	0.40	0.94	0.37	0.96
$LSD_{0.05}$	2.78**	1.04**	2.44**	ns	2.49*
Grand mean	40.97	12.74	37.13	10.91	37.66
CV, %	7.07	8.5	6.81	9.21	6.85

Note: Means with same letter within column do not differ significantly at p = 0.05 by DMRT. *significant at 5% ($p<0.05$), **significant at 1% ($p<0.01$), *** significant at 0.01% ($p<0.001$), ns- non significant, SEM (±)-standard error of mean, LSD - least significant difference, and CV-coefficient of variance.

Yield and yield attributing parameters

Root length

The root length of beetroot differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen levels (Table 4). The longest root length was recorded (11.9 cm) in 45 cm x 5 cm spacing which was statistically at par with (11.62 cm) in 45 cm x 5 cm spacing and minimum root length (11.01 cm) was observed in 45 cm x 15 cm spacing. Similarly, a statistically longer root length (12.32 cm) was recorded at 160 kg nitrogen ha^{-1} which was statistically at par with 140 kg nitrogen ha^{-1} (11.65 cm) and 120 kg nitrogen ha^{-1} (11.52 cm). The lowest root length (10.96 cm) was found in 80 kg nitrogen ha^{-1}.

Root diameter

The root diameter of beetroot differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen doses (Table 4). A significantly greater root diameter was observed (78.63 mm) at 45 cm x 15 cm spacing and the lowest root diameter (59.22 mm) was observed at 45 cm x 5 cm spacing. Similarly, the maximum root diameter (73.22 mm) was recorded at 160 kg nitrogen ha^{-1} and the lowest root diameter (66.62 cm) was found at 80 kg nitrogen ha^{-1}. The interaction effect of spacing and nitrogen did not show any significant effect on the root diameter of beetroot.

Root weight per plant

The root weight per plant was found to be statistically significant (Table 4). A significantly higher root weight per plant was observed (186.69 gm) at 45 cm x 15 cm spacing and minimum root weight (160.09 gm) was observed at 45 cm x 5 cm spacing. Similarly, the maximum root weight per plant was recorded (181.32 gm) at 160 kg nitrogen ha^{-1} which was statistically at par with 140 kg nitrogen ha^{-1} (176.78 gm) and the lowest root weight (154.62 gm) was found at 80 kg nitrogen ha^{-1}. The interaction between spacing and nitrogen did not show any significant effect on root weight.

Shoot weight per plant

The shoot weight per plant of beetroot differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen levels (Table 4). The maximum shoot weight per plant was observed (156.69 gm) at 45 cm x 15 cm spacing and minimum shoot weight (134.75 gm) was observed at 45 cm x 5 cm spacing. Likewise, the maximum shoot weight per plant (164.43 gm) was recorded at 160 kg nitrogen ha^{-1}, and the lowest shoot weight (126.62 gm) was found at 80 kg nitrogen ha^{-1}. The interaction between spacing and nitrogen did not show any significant effect on shoot weight at final harvest.

Table 4. Effect of spacing and nitrogen fertilizer on yield and yield attributing characteristics of beetroot at Kapilakot, Sindhuli, Nepal (2020-2021)

Treatment	Root length (cm)	Root diameter (mm)	Root weight $plant^{-1}$ (gm)	Shoot weight $plant^{-1}$ (gm)
Spacing (Factor A)				
45 cm x 5 cm	11.90^{a}	59.22^{c}	160.09^{b}	134.75^{b}
45 cm x 10 cm	11.62^{ab}	74.43^{b}	164.76^{b}	138.76^{b}
45 cm x 15 cm	11.01^{b}	78.63^{a}	186.69^{a}	156.69^{a}
SEM (±)	0.25	1.29	2.47	4.1
$LSD_{0.05}$	0.66*	3.34***	6.41***	10.64***
Nitrogen dose (Factor B)				
80 kg Nitrogen ha^{-1}	10.96^{b}	66.62^{b}	154.62^{d}	126.62^{d}
100 kg Nitrogen ha^{-1}	11.09^{b}	70.82^{ab}	167.27^{c}	132.60^{cd}
120 kg Nitrogen ha^{-1}	11.52^{ab}	69.90^{ab}	172.57^{bc}	144.57^{b}c
140 kg Nitrogen ha^{-1}	11.65^{ab}	72.56^{a}	176.79^{ab}	148.78^{b}
160 kg Nitrogen ha^{-1}	12.32^{a}	73.88^{a}	181.32^{a}	164.43^{a}
SEM (±)	0.33	1.66	3.19	5.3
$LSD_{0.05}$	0.86*	4.31*	8.28***	13.74***
Grand mean	11.51	70.76	170.51	143
CV, %	7.74	6.32	5.03	9.92

Note: Means with same letter within column do not differ significantly at $p = 0.05$ by DMRT. *Significant at 5% ($p<0.05$), *** significant at 0.01% ($p<0.001$), SEM (±) - standard error of mean, LSD - least significant difference, and CV-Coefficient of variance.

Economic yield and biological yield

Economic yield

The economic yield of beetroot differed significantly in DMRT analysis p<0.05 between plant spacing and different nitrogen levels (Table 5). Statistically, the highest economic yield was observed (40.95 t ha^{-1}) at 45 cm x 5 cm spacing whereas the minimum economic yield was observed (32.83 t ha^{-1}) at 45 cm x 15 cm spacing. Likewise, statistically higher economic yield (38.14 t ha^{-1}) was recorded at 160 kg nitrogen ha^{-1} which was statistically similar to 140 kg Nitrogen ha^{-1} (37.58 t ha^{-1}) and 120 kg nitrogen ha^{-1}(36.93 t ha^{-1}) and the minimum economic yield was recorded (33.49 t ha^{-1}) at 80 kg nitrogen ha^{-1}. The interaction effect of spacing and nitrogen did not show any significant effect on economic yield of the beetroot.

Biological yield

The biological yield of beetroot differed significantly in DMRT analysis p<0.05 between plant spacing and different nitrogen levels (Table 5). Statistically, higher biological weight was observed (62.95 t ha^{-1}) at 45 cm x 5 cm spacing and minimum biological yield was observed (56.7 t ha^{-1}) at 45 cm x 15 cm spacing. Similarly, a statistically higher biological yield was recorded (62.58 t ha^{-1}) at 160 kg nitrogen ha^{-1} which was statistically at par with 140 kg nitrogen ha^{-1} (60.91 t ha^{-1}) and the lowest biological yield (55.82 t ha^{-1}) was recorded at 80 kg nitrogen ha^{-1}. The interaction between spacing and nitrogen did not show any significant effect on the biological yield of the plant.

Table 5. Effect of spacing and nitrogen fertilizer on economic yield and biological yield of beetroot at Kapilakot, Sindhuli, Nepal (2020-2021)

Treatment	Economic yield (t ha^{-1})	Biological yield (t ha^{-1})
Spacing (Factor A)		
45 cm x 5 cm	40.95^{a}	62.95^{a}
45 cm x 10 cm	34.89^{b}	57.56^{b}
45 cm x 15 cm	32.83^{c}	56.70^{b}
SEM (±)	0.75	1.10
$LSD_{0.05}$	1.94***	2.87***
Nitrogen dose (Factor B)		
80 kg Nitrogen ha^{-1}	33.49^{c}	55.82^{c}
100 kg Nitrogen ha^{-1}	35.00^{bc}	57.33^{bc}
120 kg Nitrogen ha^{-1}	36.93^{ab}	58.71^{bc}
140 kg Nitrogen ha^{-1}	37.58^{a}	60.91^{ab}
160 kg Nitrogen ha^{-1}	38.14^{a}	62.58^{a}
SEM (±)	0.96	1.43
$LSD_{0.05}$	2.5**	3.71**
Grand mean	36.23	59.07
CV, %	7.17	6.5

Note: Means with same letter within column do not differ significantly at p = 0.05 by DMRT. **significant at 1% (p<0.01), *** significant at 0.01% (p<0.001), SEM (±) – standard error of mean, LSD – least significant difference, and CV-coefficient of variance.

Root dry matter

The root dry matter differed significantly in DMRT analysis p<0.05 between plant spacing and different nitrogen levels (Table 6). Statistically, the maximum root dry matter (10.56 %) was observed at 45 cm x 15 cm spacing which was statistically at par with 45 cm x 15 cm (10.44 %), and minimum root dry matter was observed (9.65 %) in 45 cm x 5 cm spacing. Similarly, statistically higher root dry matter (10.86 %) was recorded from 160 kg Nitrogen ha^{-1} which was statistically at par with 140 kg nitrogen ha^{-1} (10.68 %) and 120 kg nitrogen ha^{-1} (10.51 %). However, the lowest root dry matter was recorded (9.06 %) at 80 kg nitrogen ha^{-1}. The interaction between spacing and nitrogen did not show any significant effect on root dry matter of the plant.

Shoot dry matter

The shoot dry matter of beetroot differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen levels (Table 6). Statistically, the highest shoot dry matter (9.74 %) was found at 45 cm x 15 cm spacing and minimum shoot dry matter was observed (8.38 %) at 45 cm x 5 cm spacing. Similarly, a higher shoot dry matter (9.57 %) was recorded from 160 kg nitrogen ha$^{-1,}$ and the lowest shoot dry matter (7.9 %) was recorded at 80 kg nitrogen ha^{-1}. The interaction effect of spacing and nitrogen did not show any significant effect on shoot dry matter of the beetroot plant.

Total soluble solids (TSS)

The TSS of beetroot differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen levels (Table 6). Significantly, the highest TSS (12.67 ^{0}Brix) was found at 45 cm x 15 cm spacing which was statistically at par with 45 cm x 10 cm spacing (12.28 ^{0}Brix) and the minimum TSS was observed (11.61 ^{0}Brix) at 45 cm x 5 cm spacing. Similarly, a higher TSS (13.3 ^{0}Brix) was recorded at 120 kg nitrogen ha^{-1} which was statistically at par with 140 kg nitrogen ha^{-1} (12.77 ^{0}Brix) and the lowest TSS (10.76 ^{0}Brix) was found at 80 kg nitrogen ha^{-1}. The interaction between spacing and nitrogen did not show any significant effect on TSS of the beetroot juice.

pH

The pH of the beetroot juice differed significantly in DMRT analysis $p<0.05$ between plant spacing and different nitrogen levels (Table 6). Significantly, the highest pH (6.66) was found at 120 kg nitrogen ha^{-1} and the minimum pH was recorded (6.28) at 80 kg nitrogen ha^{-1}. However, interaction effect of spacing and nitrogen did not show any significant effect on pH of the beetroot juice.

Table 6. Effect of spacing and nitrogen fertilizer on root dry matter, shoot dry matter, total soluble solids, and pH of the beetroot at Kapilakot, Sindhuli, Nepal (2020-2021)

Treatment	Root dry matter (%)	Shoot dry matter (%)	TSS (^{0}Brix)	pH
Spacing (Factor A)				
45 cm x 5 cm	9.65^{b}	8.38^{b}	11.61^{b}	6.46
45 cm x 10 cm	10.44^{a}	9.10^{ab}	12.28^{a}	6.42
45 cm x 15 cm	10.56^{a}	9.74^{a}	12.67^{a}	6.47
SEM (±)	0.26	0.31	0.27	0.24
$LSD_{0.05}$	0.69*	0.81**	0.54**	ns
Nitrogen dose (Factor B)				
80 kg Nitrogen ha^{-1}	9.06^{c}	7.90^{b}	10.76^{d}	6.28^{b}
100 kg Nitrogen ha^{-1}	9.97^{b}	9.21^{a}	11.76^{c}	6.42^{ab}
120 kg Nitrogen ha^{-1}	10.51^{ab}	9.25^{a}	13.30^{a}	6.66^{a}
140 kg Nitrogen ha^{-1}	10.68^{ab}	9.45^{a}	12.77^{ab}	6.36^{b}
160 kg Nitrogen ha^{-1}	10.86^{a}	9.57^{a}	12.3^{bc}	6.52^{ab}
SEM (±)	0.34	0.4	0.34	0.3
$LSD_{0.05}$	0.89**	1.04*	0.7***	0.25*
Grand mean	10.22	9.08	12.18	6.45
CV, %	9.02	11.92	5.99	4.07

Note: Means with same letter within column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% ($p<0.05$), **significant at 1% ($p<0.01$), *** significant at 0.01% ($p<0.001$), SEM (±) - standard error of mean, LSD - least significant difference, ns- non significant, CV-coefficient of variance

DISCUSSION

Significantly, higher plant height and leaf length were observed in close spacing (45 x 5 cm), and shorter plant height and leaf length were obtained in wider spacing (45 x 15 cm). This might be because increased plant density limits the availability of space for lateral growth which results in increased plant height in closer spacing (Khurana et al., 1990; Pandita et al., 2005). Soil nutrients are also very important for the height of plants. So, the present research found higher dose of nitrogen increased plant height and length of the leaves (Table 3). The above findings were in accordance with Moniruzzaman et al. (2013) in carrot.

The number of leaves per plant was significantly higher in wider spacing (45 cm x 15 cm), and the lowest number of leaves was recorded in close spacing (45 cm x 5 cm) (Table 3). Maximum number of leaves was recorded with the lower plant density, which might be due to lesser competition for nutrients and light amongst the plants. Furthermore, photosynthesis goes well in plant which receives more light than less one and hence, plants at wider space tend to have more leaves. The variation in number of leaves between different nitrogen levels is due to more availability of nutrients to the crop. It may be due to the fact that nitrogenous fertilizers increase vegetative growth. Similar results were reported by Jilani et al. (2010) in radish, and Ali et al. (2006) in carrot.

The results of present study on breadth of leaves are in agreement with the findings of Hossain (2006). Due to the availability of higher amounts of plant nutrients and proper light intensity, the breadth of the leaves is increased in wider spacing.

The nitrogen level 160 kg ha^{-1} was found maximum root weight per plant (181.32 gm) and minimum was recorded in 80 kg nitrogen ha^{-1} was (154.62 gm). Higher root weight per plant at wider spacing might be due to more number of leaves and leaf area photosynthesis which increased the net assimilation efficiency in shoots and was transported to roots. The efficient utilization of these food is might have enhanced the root diameter, and root length which leads to an increase in root weight per plant. Also, plant at wider spacing have more available space and less competition for resources than plants at close spacing. This result was supported by the findings of Sinta and Garo (2021) in beetroot and Patel et al. (2015), who reported maximum root fresh weight per plant at a wider spacing of 30 cm x 30 cm in beetroot.

Results of statistical analysis revealed that highly significant effect of plant spacing on economic yield and biological yield. The close spaced (45 cm x 5 cm) plant produced a higher economic yield (40.95 t ha^{-1}) and biological yield (62.95 t ha^{-1}) and the lowest economic yield and biological yield was produced by wider spaced plant (Table 5). The higher economic yield of close spacing might be due to the accommodation of a greater number of plants per unit area than other two spacing. This finding is in line with the findings of Kadam et al., (2018) in beetroot and Gaharwar and Ughade (2017) in beetroot.

Among the nitrogen levels, 160 kg nitrogen ha^{-1} produced maximum economic yield (38.14 t ha^{-1}) and biological yield (62.58 t ha^{-}1) and minimum economic yield (33.49 t ha^{-1}) and biological yield (55.82 t ha^{-}1) was recorded in 80 kg nitrogen ha^{-1} (Table 5). This result was supported by the findings obtained by Gulser (2005) who reported that the yield of spinach was significantly influenced by an increased dose of nitrogen.

Statistically maximum TSS was recorded (13.3 ^{0}Brix) from 120 kg Nitrogen ha^{-1} and after that, TSS started declining and found (12.7 ^{0}Brix) from 140 kg nitrogen ha^{-1} and (12.3 ^{0}Brix) from 160 kg nitrogen ha^{-1} (Table 6). The decrease in TSS with the increase in nitrogen level might be due to the role of nitrogen in increasing moisture content in the root tissues. Leilah et al. (2005) also showed that TSS of sugar beet decreased from 23.87% to 23.33% and 22.78%, respectively, with an increase in nitrogen from 150 to 200 and 250 kg nitrogen ha^{-1} respectively

CONCLUSION

Based on the research, it can be concluded that close spacing of 45 cm x 5 cm was found to be optimum for beetroot production as it gave a higher economic yield. Among nitrogen doses, 160 kg nitrogen ha^{-1} produced better yield and quality compared to other nitrogen doses. Therefore, a spacing of 45 cm x 5 cm with 160 kg nitrogen ha^{-1} is considered suitable for beetroot production in Marin Valley landscape of Sindhuli.

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