Original Research Article

Effectof plant spacing and nutrient levels on growth and yield of red cabbage (*Brassica oleracea* var. *capitata* f.*rubra*)

ABSTRACT

An experiment was conducted to investigate the impact of plant spacing and nutrient levels on the growth and yield of red cabbage. This experiment involved three distinct spacing configurations (45cmx30cm, 45cmx45cm, and 45cmx60cm) and nutrient levels (75% NPK, 100% NPK, and 125% NPK). The experiment was designed as a Factorial Randomized Block Design (FRCBD) and carried out at the Department of Horticulture, University of Agricultural Sciences, GKVK, Bengaluru, during the 2021-22 period. This study indicatesthat spacing and nutrients promote the vegetative growth of plants. The spacing configuration of 45cm X 60cm with 125% NPK resulted in the most significant outcomes, including the highest number of leaves (28.93), maximum plant height (36.71 cm), maximum fresh weight of the head (1421.80 g) and highest head volume (1360.19 cc)because wider spacing and higher nutrient doses ~~led to proper nutrient use and larger heads~~. Conversely, the spacing configuration of 45cm X 30cm with 75% NPK demonstrated the early head initiation (45.60 days) and the most compact head formation (0.38). The highest yield per hectare (74.43 t) was achieved with the spacing configuration of 45cmx30cm using 125% NPK which improved greater availability of nutrients and, as a result, boosted the vegetative development, and larger cabbage heads. ~~which allowed red cabbage heads to store enormous amounts of food.~~

Key words: Growth, head diameter, nutrient, red cabbage, spacing, yield.

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1. INTRODUCTION

The valuable decorative plant red cabbage (*Brassica oleracea* var. *capitata* f. rubra) is a very healthy vegetable. Red cabbage is a member of the cabbage subgroup rubra and is a member of the Brassicaceae family. It carries the 2n=18 chromosomes. It is also known as purple cabbage or crimson kraut. Its juice is used to be a treatment for poisonous mushrooms. Chemicals in red cabbage serve to regulate angiogenesis and shield DNA from oxidative damage. These pathways assist in treating neoplastic sickness while angiogenesis is suppressed alone to lessen tumor formation, Hagivara *et al.*, [4]. Red cabbage contains compounds that are anti-inflammatory and help pancreatic cells excrete insulin. It is renowned for its medicinal properties as well. It has anticancer properties since indole-3-carbinol is present. It makes a distinction.

Among the various factors that contribute to red cabbage's potential yield, spacing is the most crucial one. The yield is significantly impacted by maintaining the optimal plant population per square foot. Plant densities that are either too high or too low per unit of area influence crop yields. There has been a rise in interest in using close plant spacing and short rows to produce cabbage in recent years. By altering inter and intra row spacings, several workers observed a greater production in crops like broccoli (Agarkar *et al.* [2]).

The growth and development of plants depend on the three main plant nutrients, nitrogen, phosphorus, and potassium. Both the quantity and method of fertiliser application must be consideredto increase nutrient utilization efficiency. Split fertiliser applications, which break up total fertiliser treatments into several dosages based on crop requirements, are a critical part of a nutrient management system. This method promotes optimal yields, improves nutrient utilization, and reduces losses. In addition to lowering production, unbalanced fertilizer application harms the soil health. Due to this unbalance nutrient utilization, there is a significant lag between the removal of crops and the application of fertilizer. In India, balanced NPK fertilization has created a lot of interest (Ghosh *et al.*, [3]). To increase and maintain production, it is required to apply fertilizer components, especially N, P, and K through inorganic sources in the proper quantities.

Nutrition has been discovered to have a significant impact on the growth, yield, quality, and economics of cole crops among other agronomic methods. Two barriers to raising the production of these crops are their unbalanced use and the rising cost of chemical fertilisers. Efficiency in fertiliser utilisation improves yield, preserves soil health, and lowers cultivation costs.Different spacing between cabbage plants and fertilizer applications on the effect of crop yield is the objective of the present study.

2. MATERIAL AND METHODS

Experiment was conducted at Department of Horticulture, College of Agriculture, GKVK, Bengaluru during year 2021-2022. Geographically place is in Eastern Dry Zone (Zone-5) of Karnataka state at 12^0 58''at north latitude and 77^0 35'' East longitude with an elevation of about 830 meters above mean sea level.Thesoilisredsandyloamandwelldrainedwithuniformtexture. The experiment was laid out in factorial randomized block design (FRCBD) withthree replications, considering spacing as first factor and different nutrient levels as second factor. Spacing levels are S_1(45cmx30cm), S_2 (45cmx45cm) and S_3 (45cmx60cm).;nutrient levels are N_1 (75% NPK), N_2 (100% NPK) and N_3 (125% NPK).Total 9 treatments areS_1N_1,S_1N_2, S_1N3, S_2N_1, S_2N_2, S_2N_3, S_3N_1, S_3N_2 and S_3N_3.Nitrogenwas applied in2splits in the form ofureaas perthetreatment. Half of the total nitrogen and full dose of phosphorus and potassium was applied as basal in the form of Diammonium phosphate(DAP) and Muriate of potash (MOP) respectively, at the time of field preparation along with farm yard manure(FYM).Harvestingwasdoneinthemorninghourswhenredcabbageheads were atsolidity that is at full mature stage andmarketablesize. Five plants in each plot were selected randomly andthedatawereaveragedandexpressedperplantfromthenetplotofeachreplicationineach treatment. Observations were recorded on growth parameters like plant height, plant spread, number of leaves per plant, number of days taken for head initiation and days to harvest.yield parameters head volume, head circumference, head weight, head compactness, head diameter and head height,Yieldperplot and Yield per hectare, were recorded. Head volume was calculated using the formula

Head volume= 4/3x π (1/2MD)3

MD = Mean diameter calculated from head polar (PD) and equatorial diameter (ED)

$$MD = (PD + ED) \div 2$$

Headcompactness wascalculatedusingthefollowingformula:

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$$Compactness\,rate = \frac{head\ volulme\ (\frac{3}{4}radius^{3}\ )}{head\ weight\ (g)}$$

2.1 Soil analysis

Soil samples were taken down to a depth of 0–15 cm. Composite soil samples were taken from each plot (three replications) at a depth of 0–15 cm prior to the start and end of the studies. For every plot, two sets of sub-samples were created from the three auger samples that were obtained. For physical and chemical tests, the collected materials were air dried, powdered, and placed in a clean plastic container after passing through a 2 mm (10 mesh) screen. Next, a soil sample was taken from every plot following the cabbage harvest. A composite soil sample was created based on treatment after all debris had been removed, and the soil was given the designation post soil. In the lab, the soil was air dried at ambient temperature. The initial soil's physical and chemical characteristics (Table 1)were then examined using the flame photometer, Brays No. 1 method, and Kjeldahl titeration method as standard techniques.

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Table 01. Initial soil properties of the experimental site

Comment [RY11]: Table 1

Chemical properties	
Parameter	**Value**
Ph	6.2-6.4
EC (ds/m)	0.67
N (kg/ha)	302.05
P_2O_5 (kg/ha)	80
K_2O (kg/ha)	280.30

Nitrogen uptake (kg/ha) by the plants estimated by micro- Kjeldahl method, Phosphorus will be analyzed by Vanado- molybdo phosphoric acid yellow colour method as described by Jackson (~~1973~~)[7] and potassium was determined by using Systronics flame photometer.

Comment [RY12]: Jackson (7), no where the year has been mentioned in the text, so delete the year.

2.2 Benefit: cost ratio

Itwasobtainedbydividinggrossreturnswith costofcultivation/ha.

$$B{:}C\ ratio = \frac{Gross\ return}{cost\ of\ cultivation}$$

The data obtained from this investigation were appropriately computed, tabulated and analysed using Factorial Randomized Block Design. The statistical analysis of data was done by using OPSTAT online statistical analysis software.

3. RESULTS AND DISCUSSION

3.1 Growth parameters

Plant spacing and nutrient levels showed significant results on growth parameters (Table 2). Maximum plant height (21.18 cm, 25.90 cm and 33.47 cm)and Highest plant spread (23.02cm, 49.71cm and 62.64 cm) was observed in spacing 45 cm x 60 cm at 30, 60 DAT and at harvest respectively,~~in comparison with spacing 45 cm x 30 cm~~. Also, more number of leaves was recorded in spacing 45cmx60cm (13.51, 20.76 and 25.43 at 30, 60 DAT and at harvest respectively), (Table 2). ~~Whereas, less number of leaves ((11.98, 16.79 and 21,99) was observed under spacing level 45cmx30cm at 30, 60 DAT and at harvest respectively~~. These findings matched those of Sarker *et al.*[12] and Haque *et al.*[6].This may be due to the fact that when plants are separated from one another by a greater distance, they compete less ferociously for resources and sunlight. Due to the additional sunlight and space provided by wider spacing, the crop may have produced highest plant height, plant spread and more number leaves per plant.Growth parameters were also increased significantly due to nutrient levels. Maximum plant height (21.55 cm, 26.54 cm and 34.56 cm)and plant spread (22.22cm, 50.29cm and 63.28cm at 30, 60 DAT and at harvest respectively) was recorded in 125% NPK.Whereas, 75% of NPK recorded minimum plant height and plant spread.Maximum number of leaves (13.87, 21.18 and 26.06 at 30, 60 DAT and at harvest respectively) were observed in 125%NPK and minimum number of leaves (11.93, 16.71 and 21.65 at 30, 60 DAT and at harvest respectively) were recorded in 75%NPK. Similar results were found in Singh *et al.* [16] and Haque*etal.*[5].That might be due to higher nutritional levels because more nutrients are available for growth and development, which causes higher nutrient uptake, and more growth. Interaction effect of wider plant spacing and higher nutrients levels(S_3N_3) showed significantly higher plant height, plant spread and number of leaves per plant as compare to other treatments.It was caused by the plantswidest spacing receiving an adequate amount of nutrients.

Number of days from transplanting to head initiation was significantly affected by plant spacing and nutrient levels (Table 3). Early head initiation (48.40days) and Early harvest (83.09 days) was noticed in 45cmx30cm, as compared to 45cmx60cm (51.67days and 86.44 days, head initiation and harvest respectively).These findings are agreed with Silatar *et al.*[15]. Thirupal *et al.* [18].Higher plant spacing led to a longer harvesting period of days. Increased photosynthesis ~~and dry matter digestion~~caused by more leaves and increased food availability lengthened the vegetative phase and delayed the onset of the reproductive phase.Incase of nutrient levels 75% NPK showed early head initiation and Early harvest (47.25 days and 83.09 days respectively).Whereas, late head initiation (52.89 days) and late harvest (86.76 days) were recorded in 125% NPK. Similar results were found in Manasa *et al.* [10] and Yadav *et al.* [20]. It might be because there are more nutrients available, which hastened vegetative growth and suppressed the generative phase. The significant variation was recorded due to combined effect of nutrient and plant spacing too. The early head initiation and harvest wasrecorded in treatment S_1N_1.

Table 2: Effect of plant spacing and nutrient levels on plant height (cm), number of leaves per plant and plant spread of red cabbage

Treatment	Plant height (cm)			Number of leaves			Plant spread (cm)		
	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest	30 DAT	60 DAT	At harvest
Spacing (S)									

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S_1	16.78	20.28	26.66	11.98	16.79	21.99	17.66	41.07	50.99
S_2	19.83	23.95	31.05	12.96	19.35	24.04	20.84	47.38	59.45
S_3	21.18	25.90	33.47	13.51	20.76	25.43	23.02	49.71	62.64
F - test	*	*	*	*	*	*	*	*	*
S.Em±	0.117	0.155	0.208	0.173	0.136	0.235	0.154	0.141	0.166
CD at 5%	0.353	0.470	0.629	0.523	0.410	0.711	0.464	0.427	0.501
Nutrients (N)									
N_1	17.03	20.69	26.58	11.93	16.71	21.65	18.29	41.87	52.17
N_2	19.21	22.90	30.05	12.64	19.01	23.74	21.02	46.00	57.64
N_3	21.55	26.54	34.56	13.87	21.18	26.06	22.22	50.29	63.28
F - test	*	*	*	*	*	*	*	*	*
S.Em±	0.117	0.155	0.208	0.173	0.136	0.235	0.154	0.141	0.166
CD at 5%	0.353	0.470	0.629	0.523	0.410	0.711	0.464	0.427	0.501
Interaction (SXN)									
S_1N_1	15.73	18.30	23.10	11.40	15.13	21.00	16.23	38.80	46.97
S_1N_2	16.32	19.24	25.06	12.13	17.23	22.03	18.83	40.53	50.47
S_1N_3	18.30	23.30	31.83	12.40	18.00	22.93	17.93	43.87	55.53
S_2N_1	17.14	20.57	25.83	12.20	17.73	21.73	17.50	41.67	52.40
S_2N_2	20.07	24.13	32.20	12.47	18.13	24.07	21.73	48.20	59.87
S_2N_3	22.29	27.15	35.13	14.20	22.20	26.33	23.30	52.27	66.07
S_3N_1	18.23	23.20	30.80	12.20	17.27	22.23	21.13	45.13	57.13
S_3N_2	21.23	25.33	32.90	13.33	21.67	25.13	22.50	49.27	62.57
S_3N_3	24.07	29.17	36.71	15.00	23.33	28.93	25.43	54.73	68.23
F - test	*	*	*	*	*	*	*	*	*
S.Em±	0.202	0.269	0.361	0.300	0.235	0.408	0.266	0.244	0.287
CD at 5%	0.611	0.814	1.090	0.906	0.710	1.232	0.804	0.739	0.867

S_1 = 45 cm x 30 cm, S_2 = 45 cm x 45 cm, S_3= 45 cm x 60 cm, N_1 = 75%NPK, N_2 = 100%NPK, N_3 =125%NPK

What is S.Em±

3.2Yield and quality parameters

Yield parameters were significantly influenced by plant spacing and application of nutrient levels (Table 3). Maximum head circumference,head diameter and head height (39.15cm, 12.43 cm and 12.82cm respectively) were noticed in 45cmx60cm spacing, while minimum (33.55cm,11.13cm and 11.47cm head circumference, head diameter and head height respectively) was recorded in 45cmx30cm spacing. These results were agreed with Agarkar*etal.* [2] and Shamima *et al.*[13]. Wider spacing gives each plant more room and less competition between plants, that is conducive to the development of a head size. Maximum

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head circumference (39.72cm), head diameter (12.54cm) and head height (12.96cm) were recorded in 125%NPK.Whereas, 75% NPK showed minimum head circumference (33.66 cm), head diameter (11.23cm) and head height (11.42cm).Similar findings were found in Yebirzaf *et al.*[21] and Manasa *et al.*[10].Increased nutritional availability may have expedited the production of chlorophyll and amino acids, and efficient use of carbohydrates and their organic components may have led to an increase in head size. The highest head circumference, diameter and height was found in combined effect of 45cmx60cm with 125% NPK. Nutrients and spacing influenced the head size. Similar results were reported by Joshi *et al.*[8].

Table 3: Effect of plant spacing and nutrient levels on days taken for head initiation, days to harvest, head circumference, head diameter and head height of red cabbage

Treatment	Days taken for head initiation	Days to harvest	Head circumference (cm)	Head diameter (cm)	Head height (cm)
Spacing (S)					
S_1	48.40	83.09	33.55	11.13	11.47
S_2	49.51	84.09	37.20	11.92	12.17
S_3	51.67	86.44	39.15	12.43	12.82
F -test	*	*	*	*	*
S.Em±	0.134	0.176	0.329	0.072	0.087
CD at 5%	0.406	0.532	0.994	0.217	0.263
Nutrients (N)					
N_1	47.25	83.09	33.66	11.23	11.42
N_2	49.44	83.78	36.52	11.73	12.08
N_3	52.89	86.76	39.72	12.54	12.96
F -test	*	*	*	*	*
S.Em±	0.134	0.176	0.329	0.072	0.087
CD at 5%	0.406	0.532	0.994	0.217	0.263
Interaction (SXN)					
S_1N_1	45.60	82.13	31.83	10.65	11.09
S_1N_2	48.27	83.07	32.28	11.07	11.21
S_1N_3	51.33	84.07	36.53	11.73	12.11
S_2N_1	47.27	83.07	33.58	11.45	11.39
S_2N_2	49.13	83.13	37.79	11.95	12.29
S_2N_3	52.13	86.07	40.23	12.35	12.84
S_3N_1	48.87	84.07	35.56	11.58	11.79
S_3N_2	50.93	85.13	39.48	12.18	12.75
S_3N_3	55.20	90.13	42.41	13.54	13.93
F -test	*	*	*	*	*
S.Em±	0.232	0.305	0.569	0.125	0.151
CD at 5%	0.703	0.922	1.722	0.377	0.456

S_1 = 45 cm x 30 cm, S_2 = 45 cm x 45 cm, S_3= 45 cm x 60 cm, N_1 = 75%NPK, N_2 = 100%NPK, N_3 =125%NPK

Significant results were observed in head compactness with respect to plant spacing and nutrient levels (Fig. 1).Highest head compactness (0.43) was recorded in wider spacing and lowest (0.48) was observed in closer spacing.Plant spacing has a good effect on head compactness. This may be the result of increased plant competition for nutrients and available space at closer plant spacing, which encouraged the growth of compact heads. Whereas, maximum head compactness (0.43) was noticed in 75% NPKand minimum (0.48) was recorded in 125% NPK. This can be due to the red cabbage heads receiving the ideal amount of nutrients, which led to the heads being more compact. The maximum head compactness (0.38) was observed in interaction effect of 45cmx30cm with 75% NPK. These resultswereagreement with Riad*et al.*(2009) in cabbage.

Comment [RY24]: Does not agree with Fig.1. Highest compactness (0.43) was recorded in close spacing plants, while least compactness is observed in widely spaced plants.

Comment [RY25]: The table shows SXN as 125

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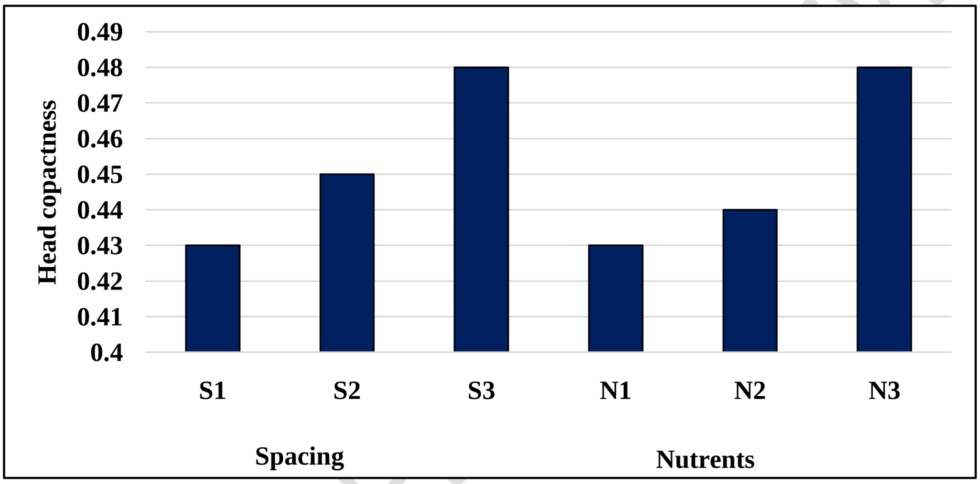
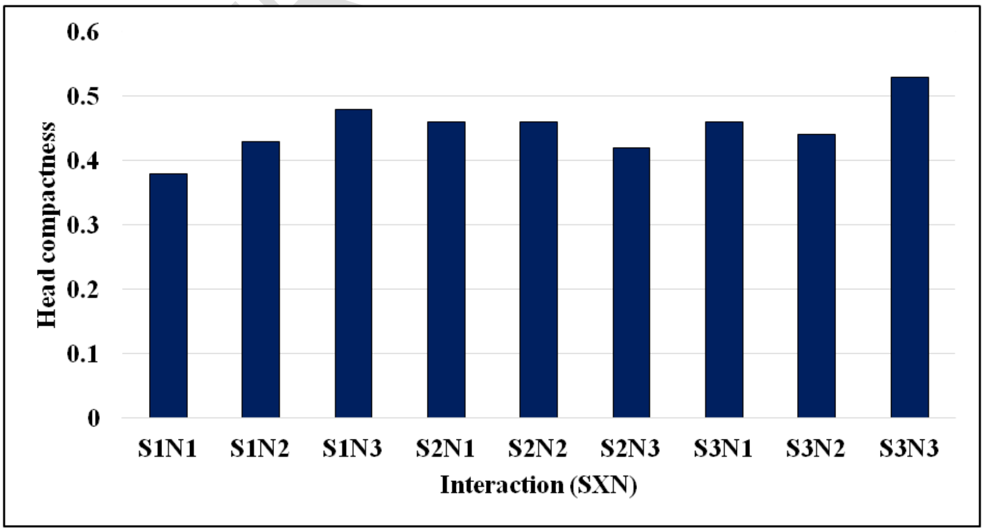
Fig.1: Effect of plant spacing, nutrient levels and interaction on head compactness of red cabbage





S_1 = 45 cm x 30 cm, S_2 = 45 cm x 45 cm, S_3 = 45 cm x 60 cm, N_1 =125:37.5:37.5 kg/ha, N_2 = 180:50:50 kg/ha and N_3 = 225:62.5:62.5 kg/ha

Significant variation in head volume was observedin plant spacing and nutrient levels. Highest head volume (1073.17cc) and fresh head weight (1214.91g) were recorded with spacing of 45cmx60cm as compared to spacing 45cmx30cm (Table 4). These findings agreed with Abed*et al.* [1]. This could be attributed to the fact that there are fewer plants per square foot, which creates more conducive growing circumstances like more room for shoot, root, and leaf growth than there would be with more tightly spaced plants.With respect to nutrients, maximum head volume (1099.04cc) and fresh weight of head (1256.18g) were recorded in highest nutrient level.Whereas, lowest nutrient level observed minimum head volume and fresh weight of head. These results were conformity with Verma and Nawange [19] and Manasa *et al.* [10]. Increased nutritional availability, ~~which~~ may have led to the production of more plant metabolites. Head volume may have increased because metabolites were more readily available to the plant.Interaction effect of 45cmx60cm spacing with 125% NPK recorded maximum head volume (1360.19) and fresh weight of head (1421.80g), while ~~where as~~minimum was observed in 45x30cm with 75% NPK.

Higher yield per plot (61.72kg) and yield per hectare (69.26t) ~~was~~ wererecorded in closest spacing a~~nd wider spacing observed for lower yield (40.09kg/plot and 45.00t/ha)~~(Table 4).Similar findings were found in Kaur *et al.* [9] and Silatar *et al.* [15]. The maximum yield was found to be thehighest at a reduced plant spacing due to having more plants per unit area and a bigger ground cover of leaf area, which improved interception of sunlight and subsequently increased assimilate production.Maximum yield (57.43kg/plot and 64.45t/ha)was observed in 125% NPK whereas, 75% NPK observed for minimum (44.62kg/plot and 56.03t/ha)yield. experimental findings were in consonance with the findings of the Sultana *et al.* [17] and Prasad *et al.*[11]. Because applying nutrients boosted plant vigour in the form of height and leaf count, which in turn increased photosynthetic efficiency and, ultimately, increased crop yield, the importance of nutrients in increasing output was well established.Combined effect of closer spacing with higher nutrient level showed highest yield (66.32kg/plot)and (74.43t/ha). These results agreed with those of Kaur *et al*. [9].

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Table 4: Effect of plant spacing and nutrient levels on head volume (cc) and fresh weight of head (g), yield per plot (kg) and yield per hectare (t) of red cabbage

Treatment	Head volume (cc)	Fresh weight of head (g)	Yield per plot (kg)	Yield per hectare (ha)
Spacing (S)				
S_1	762.47	934.69	61.72	69.26
S_2	922.45	1140.04	50.16	56.30
S_3	1073.17	1214.91	40.09	45.00
F -test	*	*	*	*
S.Em±	15.91	14.17	0.65	0.58
CD at 5%	48.11	42.83	1.97	1.75
Nutrients (N)				
N_1	764.35	951.84	44.62	50.08
N_2	894.69	1081.62	49.92	56.03
N_3	1099.04	1256.18	57.43	64.45

F -test	*	*	*	*
S.Em±	15.91	14.17	0.65	0.58
CD at 5%	48.11	42.83	1.97	1.75
Interaction (SXN)				
S_1N_1	673.73	872.20	57.63	64.68
S_1N_2	724.57	927.20	61.20	68.68
S_1N_3	889.12	1004.67	66.32	74.43
S_2N_1	782.14	979.53	43.10	48.37
S_2N_2	937.38	1098.53	48.33	54.25
S_2N_3	1047.82	1342.07	59.05	66.27
S_3N_1	837.18	1003.80	33.13	37.18
S_3N_2	1022.14	1219.13	40.23	45.16
S_3N_3	1360.19	1421.80	46.92	52.66
F -test	*	*	*	*
S.Em±	27.55	24.53	1.13	1.01
CD at 5%	83.10	74.19	3.41	3.04

S_1 = 45 cm x 30 cm, S_2 = 45 cm x 45 cm, S_3= 45 cm x 60 cm, N_1 = 75%NPK, N_2 = 100%NPK, N_3 =125%NPK

3.4 Soil analysis

Effect of plant spacing, nutrient levels and theirinteractionsignificantly influenced on uptakeofnitrogen, phosphorus and potassium (Table 5). Higher uptake of nitrogen (330.15 kg/ha), Phosphorus (29.11 kg/ha) and Potassium (166.14 kg/ha) was recorded with S_3 (45 cm x 60 cm). whereas, N_3 (125% NPK) achieved higher nitrogen (332.04 kg/ha), phosphorus (31.39 kg/ha) and potassium (167.05 kg/ha) uptake by plants. In interaction effect S_3N_3 (45 cm x 60 cm + 125% NPK) recorded higher uptake of nitrogen (375.93 kg/ha), phosphorus (35.94 kg/ha) and potassium (185.11 kg/ha). The lowest uptake of (179.87kg/ha, 76 kg/ha and 86.60 kg/ha) nitrogen, phosphorus and potassium respectively wererecordedwithcombinationofS_1N_1 (45 cm x 30 cm + 75% NPK).

Table 5: Effect of different plant spacing and nutrient levels on uptake of nutrients of red cabbage

Treatment	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)
Spacing (S)			
S_1	278.55	23.36	112.29
S_2	341.78	26.81	146.99
S_3	375.93	29.11	166.14
F -test	*	*	*
S.Em±	2.44	0.29	1.29
CD at 5%	7.38	0.88	3.90
Nutrients (N)			
N_1	228.27	20.29	112.00
N_2	293.27	27.60	146.36
N_3	332.04	31.39	167.05

F- test	*	*	*
S.Em±	2.44	0.29	1.29
CD at 5%	7.38	0.88	3.90
Interaction (SXN)			
S_1N_1	179.87	17.76	86.60
S_1N_2	226.39	25.84	112.45
S_1N_3	278.55	26.49	137.83
S_2N_1	234.14	21.17	112.71
S_2N_2	315.46	27.50	150.03
S_2N_3	341.78	31.75	178.22
S_3N_1	276.62	21.94	136.70
S_3N_2	337.90	29.45	176.60
S_3N_3	375.93	35.94	185.11
F -test	*	*	*
S.Em±	4.23	0.50	2.24
CD at 5%	12.78	1.52	6.76

S_1 = 45 cm x 30 cm, S_2 = 45 cm x 45 cm, S_3= 45 cm x 60 cm, N_1 = 75%NPK, N_2 = 100%NPK, N_3 =125%NPK

Differentplantingspacing,nutrientlevelsandtheirinteractionssignificantlyinfluencedtheavailablesoilnitrogen, phosphorus and potassium (Table6). availablesoilnitrogen (245.23kg/ha), soil phosphorus (69.49 kg/ha) and soil potassium (131.81 kg/ha) was maximum in S_3 (45 cm x 60 cm). Lowest available soil nitrogen (225.81kg/ha), soil phosphorus (57.77kg/ha) and soil potassium (116.77 kg/ha) wasrecordedwithS_1(45 cm x 30 cm). Significantly higher amount of available soil nitrogen (248.42 kg/ha), soil phosphorus (70.88 kg/ha) and soil potassium (130.86 kg/ha) wasrecorded with an application of N_3 (125% NPK). Whereas, lowest available soil nitrogen (226.44kg/ha), soil phosphorus (58.47 kg/ha) and soil potassium (119.14 kg/ha) was noticed in N_1(75% NPK). The interaction effect of S_3N_3 (45 cm x 60 cm + 125% NPK) recorded highest available soil nitrogen(252.71kg/ha), soil phosphorus (75.74 kg/ha) and soil potassium (140.81 kg/ha). Different planting spacing and nutrient levels significantly influencedavailable soil nitrogen, phosphorus and potassium in red cabbage. These resultswereinagreementwiththefindingsofSharma and Arya [14].

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Table 6: Effect of different plant spacing and nutrient levels on available nutrients after harvest of red cabbage

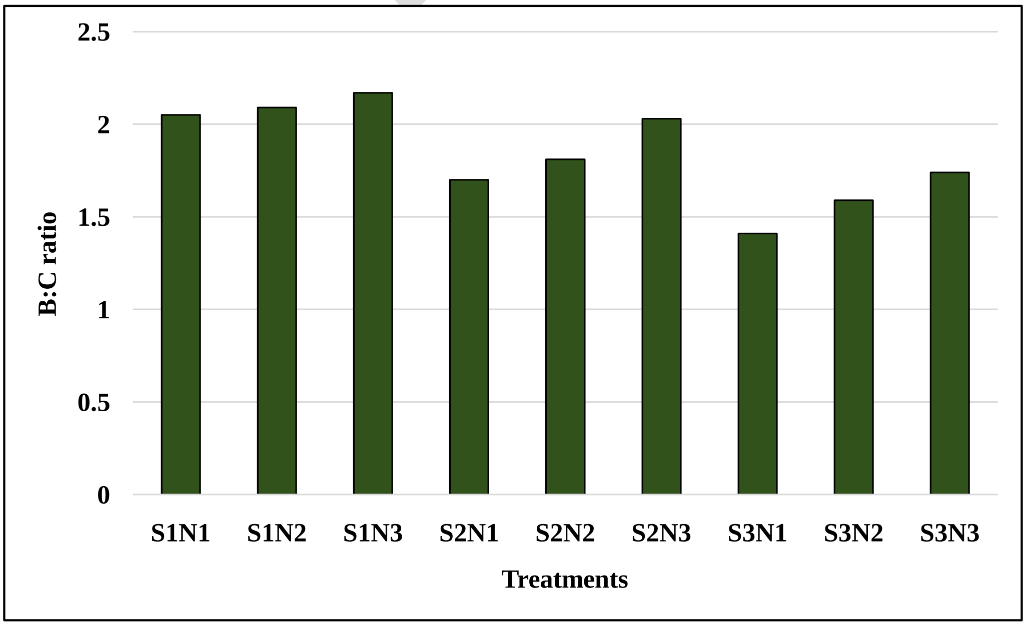
Treatment	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
Spacing (S)			
S_1	225.81	57.77	116.77
S_2	242.74	67.46	124.84
S_3	245.23	69.49	131.81
F -test	*	*	*
S.Em±	1.49	0.39	0.67
CD at 5%	4.49	1.19	2.01
Nutrients (N)			
N_1	226.44	58.47	119.14

N_2	238.91	65.36	123.42
N_3	248.42	70.88	130.86
F -test	*	*	*
S.Em±	1.49	0.39	0.67
CD at 5%	4.49	1.19	2.01
Interaction (SXN)			
S_1N_1	210.95	52.07	111.34
S_1N_2	223.99	57.05	116.41
S_1N_3	242.49	64.18	122.57
S_2N_1	232.23	59.98	120.59
S_2N_2	245.93	69.66	124.73
S_2N_3	250.07	72.73	129.19
S_3N_1	236.15	63.35	125.48
S_3N_2	246.82	69.37	129.13
S_3N_3	252.71	75.74	140.81
F -test	*	*	*
S.Em±	2.57	0.68	1.15
CD at 5%	7.78	2.06	3.48

S_1 = 45 cm x 30 cm, S_2 = 45 cm x 45 cm, S_3= 45 cm x 60 cm, N_1 = 75%NPK, N_2 = 100%NPK, N_3 =125%NPK

Inthepresentstudy,themaximumgrossreturns,netreturnsandB: C ratio (2.17) were realized with S_1 (45 cm x 30 cm) and supplied with N_3 (125% NPK) (Fig. 2). This was mainlydue to higher head yield as compared to other plant spacing and nutrient levels.

Fig.2: Effect of plant spacing, nutrient levels on benefit cost ratio of red cabbage



S_1 = 45 cm x 30 cm, S_2 = 45 cm x 45 cm, S_3 = 45 cm x 60 cm, N_1 =125:37.5:37.5 kg/ha, N_2 = 180:50:50 kg/ha and N_3 = 225:62.5:62.5 kg/ha

4. CONCLUSION

According to the experimental results of the study, the wider spacing (45 cm 60 cm) and higher level of nutrients (125% NPK) resulted in improved growth and development of the plant. Closer spacing (45 cm x 30 cm) and lower levels of nutrients (75% NPK) led to an earlier harvest, but less spacing (45 cm x 30 cm) and greater levels of nutrients (125% NPK) produced a larger quantitative yield per unit area.

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