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 infers that 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)which could be because of wider spacing and higher nutrient doses. 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.

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

1. INTRODUCTION

The valuable decorative plant red cabbage (*Brassica oleracea* var. *capitata* f. rubra) highly nutritious vegetable. Redcabbage belongs to the cabbage subgroup Rubra a member of the Brassicaceae family. It carries the 2n=18 chromosome. 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.,* [5]. Red cabbage is known for its medicinal properties, including anti-inflammatory compounds that assist pancreatic cells in insulin secretion. Furthermore, it possesses anticancer properties, attributed to the presence of indole-3-carbinol, highlighting its significant health benefits.

Among the various factors that contribute to red cabbage's potential yield, spacing is the most crucial one. Maintaining the optimal plant population per square foot significantly impacts yield. Plant densities that are either too high or too low per unit of area have an effect on crop yields. In recent years, there has been a growing interest in utilizing close plant spacing and short rows for cabbage cultivation. By altering inter and intra row spacings, several workers observed a greater production in crops like broccoli (Agarkar *et al.* [3]).[1]

The growth and development of plants depend on three primary plant nutrients, nitrogen, phosphorus, and potassiumTo enhance nutrient utilization efficiency, it is essential to consider both the amount of fertilizer applied and the method of its application.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 fertilizer application has created a lot of interest (Ghosh *et al.*, [4]). To increase and maintain production, it is necessary 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 located 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 were S_1(45cmx30cm), S_2 (45cmx45cm) and S_3 (45cmx60cm).;Nutrient levels were N_1 (75% NPK), N_2 (100% NPK) and N_3 (125% NPK).Total 9 treatments wereS_1N_1,S_1N_2, S_1N3, S_2N_1, S_2N_2, S_2N_3, S_3N_1, S_3N_2 and $S_3N_3$are applied. Nitrogenwas applied in2splits in the form ofureaas perthetreatment. Half dose of the total nitrogen and full dose of phosphorus and potassium were 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 at the 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.;The yield parameters recorded were head volume, head circumference, head weight, head compactness, head diameter and head height,Yieldperplot and yield per hectare, were also recorded. Head volume was calculated by 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:

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

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 titration method as standard techniques.

Table 1. Initial soil properties of the experimental site

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, was analyzed by Vanado-molybdo phosphoric acid yellow colour method as described by Jackson [8] and potassium was determined by using Systronics flame photometer.

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) were observed in spacing 45 cm x 60 cm at 30, 60 DAT and at harvest respectively. 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). These findings matched with the results of Sarker *et al.*[14] 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.* [18] and Haqu**e***etal.*[7].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 compared to other treatments.It can be inferred due towide spacing of plants and adequate nutrient supply to them.

Number of days from transplanting to head initiation was significantly affected by plant spacing and nutrient levels (Table 3). Early head initiation (48.40 days) and early harvest (83.09 days) was noticed in 45cmx30cm, as compared to 45cmx60cm (51.67 days and 86.44 days, head initiation and harvest respectively). These findings are in agreement with Silatar *et al.*[17] and Thirupal *et al.* [20]. Higher plant spacing led to a longer harvesting period of days. Increased photosynthesis caused by more leaves and increased food availability lengthened the vegetative phase and delayed the onset of the reproductive phase. In plants supplemented with 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 supplemented plants. Similar results were found in Manasa *et al.* [11] and Yadav *et al.* [22]. 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 were recorded 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)									
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; S.Em± = Standard error of mean; CD= Critical Difference.

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 in agreement with the findings of Agarkar*etal.* [3] and Shamima *et al.*[15]. Wider spacing gives each plant more room and less competition between plants, that is conducive to the development of a head size. Maximum 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 results were also observed earlier by Yebirzaf *et al.*[23] and Manasa *et al.*[11].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.*[9].

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

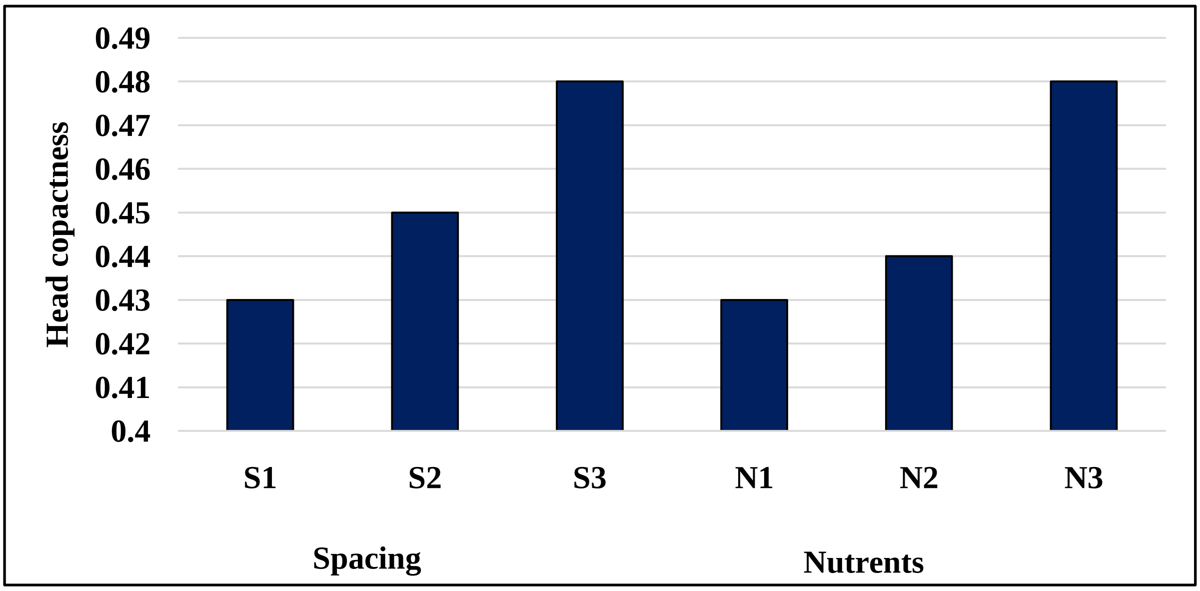
Treatment	Days taken for head initiation	Days to harvest	Head circumference (cm)	Head diameter (cm)	Head height (cm)
Spacing (S)					
S_1	48.40	83.09	33.55	11.13	11.47
S_2	49.51	84.09	37.20	11.92	12.17
S_3	51.67	86.44	39.15	12.43	12.82
F -test	*	*	*	*	*
S.Em±	0.134	0.176	0.329	0.072	0.087
CD at 5%	0.406	0.532	0.994	0.217	0.263

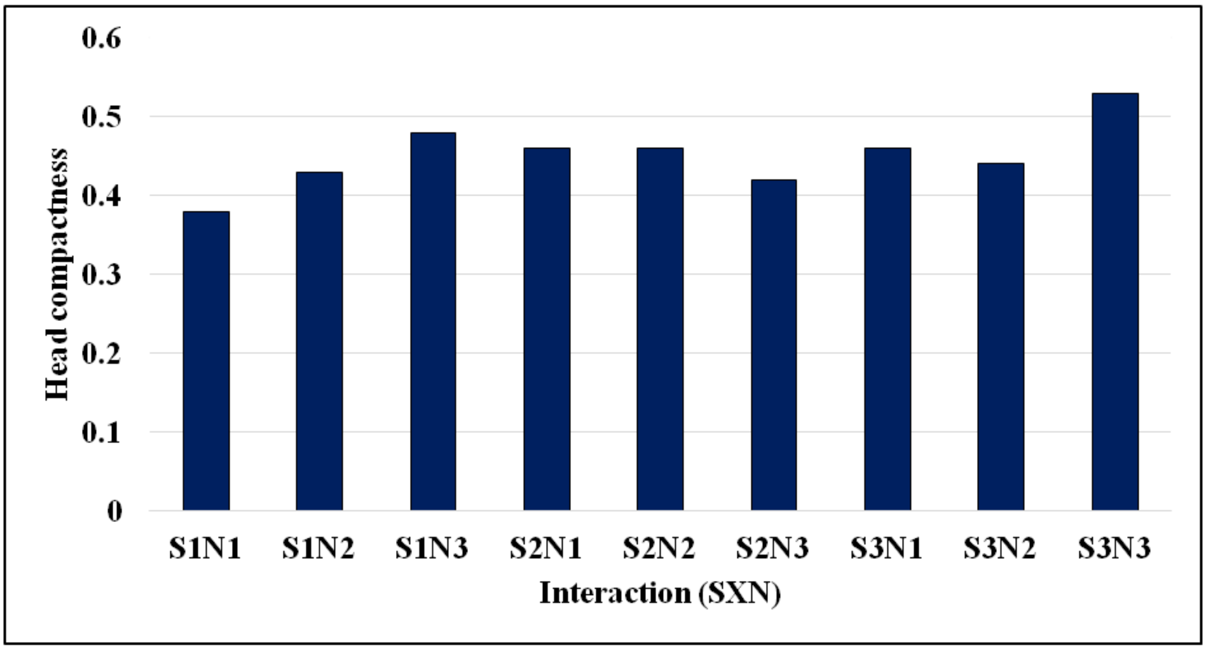
Nutrients (N)					
N_1	47.25	83.09	33.66	11.23	11.42
N_2	49.44	83.78	36.52	11.73	12.08
N_3	52.89	86.76	39.72	12.54	12.96
F -test	*	*	*	*	*
S.Em±	0.134	0.176	0.329	0.072	0.087
CD at 5%	0.406	0.532	0.994	0.217	0.263
Interaction (SXN)					
S_1N_1	45.60	82.13	31.83	10.65	11.09
S_1N_2	48.27	83.07	32.28	11.07	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; S.Em± = Standard error of mean; CD= Critical Difference.

Significant results were observed in head compactness with respect to plant spacing and nutrient levels (Fig. 1).Highest compactness (0.48) was recorded in wider spacing plants, while least compactness is observed in close spaced plants.Plant spacing has a good effect on head compactness. This may be the result of increased the available space at wider plant spacing, which encouraged the growth of compact heads. Whereas, maximum head compactness (0.48) was noticed in 125% NPKand minimum (0.43) was recorded in 75%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 (0.53) was observed in interaction effect of 45cmx60cm with 125% NPK. These resultswere in agreement with Riad*et al.*[13] in cabbage.

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 were agreed with the observations of 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 similar to those of withVerma and Nawange [21] and Manasa *et al.* [11]. Increased nutritional availability, 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 minimum was observed in 45x30cm with 75% NPK.

Higher yield per plot (61.72kg) and yield per hectare (69.26t) were recorded in closest spacing while lower yield (40.09kg/plot and 45.00t/ha were observed among plants which were widely planted (Table 4).Similar findings were found in Kaur *et al*. [10] and Silatar *et al.* [17]. The maximum yield was found to be the highest 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.* [19] and Prasad *et al.*[12]. 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*. [10].

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	Yield per plot (kg)	Yield per hectare

		head (g)		(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; S.Em± = Standard error of mean; CD= Critical Difference.

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. These results were agreement with Abhijithnaik*et al.*[2] 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; S.Em± = Standard error of mean; CD= Critical Difference.

Differentplantingspacing,nutrientlevelsandtheirinteractionssignificantlyinfluencedtheavailables oilnitrogen, phosphorus and potassium (Table6). Availablenitrogen (245.23kg/ha), phosphorus (69.49 kg/ha) and potassium (131.81 kg/ha) in soil was maximum in S_3 (45 cm x 60 cm). Lowest available nitrogen (225.81kg/ha), phosphorus (57.77kg/ha) and potassium (116.77 kg/ha) in soil wererecordedwithS_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) wererecorded 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) were noticed in N_1(75% NPK) similar findings agreement of those with Abhijithnaik *et al.,* [2]. 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 [16].

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

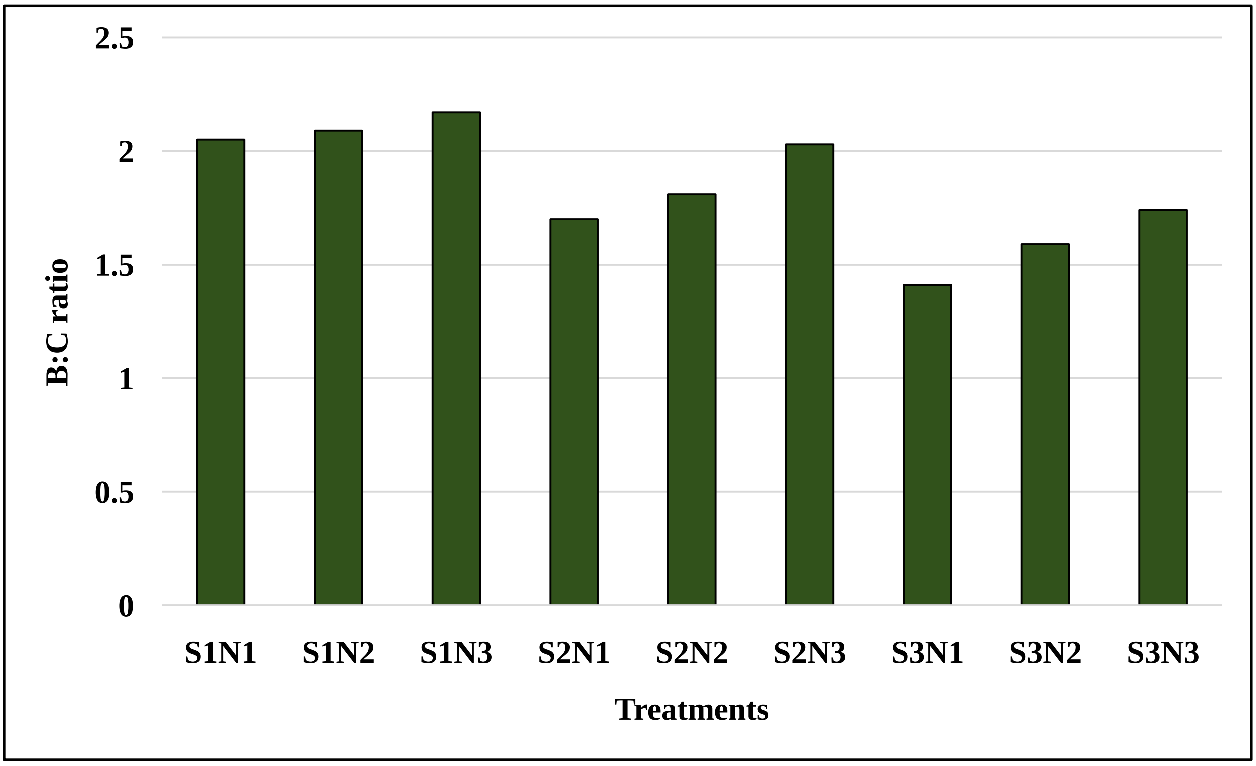
Treatment	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
Spacing (S)			
S_1	225.81	57.77	116.77
S_2	242.74	67.46	124.84

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; S.Em± = Standard error of mean; CD= Critical Difference.

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 nutrientlevels (125% NPK) resulted in improved growth and development of the plants. Conversely, closer spacing (45 cm x 30 cm) and lower nutrient levels (75% NPK) led to an earlier harvest. However, less spacing (45 cm x 30 cm) and greater nutrient levels (125% NPK) produced a larger quantitative yield per unit area.

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AUTHORS CONTRIBUTION

Tejashwini – Manuscript preparation, data collection and analysis
Dr. A. Vidya – Supervision, formulation of research and manuscript editing
Dr. Hanumantharaya, B. G. – Resource provided and manuscript editing

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