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Effect of planting geometry and plant nutrition on growth, yield and quality of red cabbage (*Brassica oleracea* var. *capitata f. rubra*) under shade house condition

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Abstract: The field experiment was carried out at College of Agriculture, Vijayapur, University of Agricultural Sciences, Dharwad during *kharif* 2015 on Red cabbage hybrid Redma RZ F_1 hybrid. There were nine treatment combinations comprising of three spacing (S_1: 45 cm x 30 cm, S_2: 45 cm x 45 cm and S_3: 45 cm x 60 cm) and three levels of fertilizer (F_1,150:100:125 F_2,175:125:150 and F_3,200:150:175 kg N, P_2O_5 and K_2O ha^{-1}). The significantly higher red cabbage head yield of 36.0 t ha^{-1} and net returns of 4, 20,719 ha^{-1} with B: C ratio of 2.4. was achieved with the closer spacing of 45 cm x 30 cm. Application of fertilizer at the rate of 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} (F_3) produced significantly higher plant height (23.3 cm), plant spread (51.9 cm), number of leaves (22.3), head diameter (10.9 cm), head weight (665.5 g), head yield (30.4 t ha^{-1}) and highest net return of ₹ 3, 47, 614 ha^{-1} with B: C ratio of 2.3. Interaction effect of spacing and fertilizer levels (S x F) revealed that, a spacing of 45 cm x 30 cm (S_1) along with 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} (F_3) resulted in significantly higher head yield of red cabbage (40.5 t ha^{-1}), net returns (5, 07,680 ha^{-1}) and B:C ratio (2.68) compared to rest of the interactions.

Key words: Economics, Plant nutients, Red cabbage, Shade house, Spacing

Introduction

Red Cabbage (*Brassica oleracea* var. *capitata f. rubra.*) leaves are dark red or purple coloured. It is being found in Northern Europe, Northern America and China. It is a cool season crop but adapted to a wide range of climate and soils. In a 100g edible portion, red cabbage contains about 90 percent water, 6.9 g total carbohydrates, besides it is a rich source of Iron, Vitamin A, Vitamin C and high in fiber and very low in Sodium. Red cabbage is a rich and relatively cheap source of anthocyanin pigment. As red cabbage is newly introduced crop to India, yet to gain popularity and its consumption is still lower than that of white cabbage. During the period of growth and development of plant, the nutrients and plant population play a vital role for functioning of the normal physiological activities. Proper spacing and plant population can be of greater help for improving the growth and yield of red cabbage**.** In view of this, and to revalidate the spacing and fertilizer requirement for red cabbage a study was undertaken to know the effect of different spacing, nutrient management and their interactions on growth, yield and quality of red cabbage.

Material and methods

The field experiment was carried out at College of Agriculture, Vijayapur, University of Agricultural Sciences, Dharwad. during *kharif* 2015 to study the effect of planting geometry and plant nutrition on growth, yield and quality of red cabbage (*Brassica oleracea* var. *capitata f. rubra*) under shade house condition. The red cabbage hybrid was used. The soil type was medium deep black. The soil available N, P_2O_5 and K_2O contents were 313.25, 19.06 and 350.49 kg ha^{-1}, respectively. The experiment was laid out in complete randomized block design with factorial concept. There were nine treatment combinations comprising of three spacing (S_1, 45 cm x 30 cm, S_2, 45 cm x 40 cm and S_3, 45 cm x 60 cm) and three levels of fertilizer (F_1,150:100:125, F_2,175:125:150 and F_3,200:150:175 kg N, P_2O_5 and K_2O ha^{-1}) and were analyzed for growth, yield and quality of red cabbage.

As per the spacing, seedlings were transplanted and fertilizer treatments were imposed. The fertilizers were applied according to the treatments 15 cm away from the main stem in ring form. Half the dose of nitrogen and full P_2O_5 and K_2O as basal dose and remaining nitrogen was given as top dressing of 30 days after transplanting. The crop was raised successfully by adopting proper cultural practices and plant protection measures (Anon., 2015) and it was harvested at its physiological maturity. The data were statistically analysed as per the procedure given by Gomez and Gomez (1984).

Results and discussion

Significant variation in plant height, plant spread, and number of open leaves per plant, head diameter, head weight, head yield, gross returns, net returns and benefit cost ratio was observed with different levels of spacing and fertilizer levels (Table 1, 2 and 3). Irrespective of spacing, significantly higher head yield (30.4 t ha^{-1}) was recorded with the application of higher dose of 200:150:175 kg N P_2O_5 and K_2O ha^{-1} which was on par with the application of 175:125:150 kg N, P_2O_5 and K_2O ha^{-1} (28. t ha^{-1}). Fertilizer level of 150:100:125 kg N, P_2O_5 and K_2O ha^{-1} recorded significantly lower head yield (26.8 t ha^{-1}).

The increased head yield due to application of 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} (F_3) might be due to the availability of optimum level of nutrients in the soil and maximum uptake of nutrients by the crop resulting in increased vegetative growth of plant which ultimately influenced increased yield and yield attributes. The poor head yield obtained with 150:100:125 kg N, P_2O_5 and K_2O ha^{-1} (F_1) was due to lower uptake of nitrogen, phosphorus and potassium which emphasing the need for more nutrients for higher head yield of red cabbage.

Table 1. Growth parameters of red cabbage as influenced by spacing and fertilizer levels

Spacing\	Plant height (cm)				Plant spread (cm)				Number of open leaves plant^{-1}			
Fertilizer Levels	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	23.6	22.4	21.8	22.6	44.4	50.9	53.9	49.7	20.6	21.3	21.9	21.3
F_2	24.0	22.9	22.4	23.1	47.4	51.6	54.5	51.2	20.9	21.4	22.5	21.6
F_3	24.2	23.1	22.6	23.3	47.8	53.3	54.6	51.9	21.1	21.5	24.3	22.3
Mean	23.9	22.8	22.3		46.5	51.9	54.3		20.8	21.4	22.9	
For comparison of		S.Em±		C.D. (P=0.05)		S.Em±		C.D. (P=0.05)		S.Em±		C.D. (P=0.05)
Spacing (S)		0.18		0.53		0.36		1.07		0.25		0.74
Fertilizer level (F)		0.18		0.53		0.36		1.07		0.25		0.74
Interaction (S x F)		0.31		NS		0.62		NS		0.42		NS

Note:NS- Non significant

S_1: 45 cm x 30 cm S_2: 45 cm x 45 cm S_3: 45 cm x 60 cm

F_1:150:100:125 kg N, P_2O_5 and K_2O ha^{-1} F_2:175:125:150 kg N, P_2O_5 and K_2O ha^{-1} F_3:200:150:175 kg N, P_2O_5 and K_2O ha^{-1}

Table 2. Yield and yield parameters of red cabbage as influenced by spacing and fertilizer levels

Spacing\	Head diameter (cm)				Head weight (g)				Head yield (t ha^{-1})			
Fertilizer Levels	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	9.9	10.3	10.7	10.3	516.7	617.2	706.7	613.5	31.6	25.9	23.1	26.8
F_2	10.1	10.4	10.9	10.4	536.0	621.8	710.0	622.6	35.8	26.1	23.5	28.5
F_3	10.2	10.5	12.0	10.9	625.3	642.8	728.3	665.5	40.5	26.9	23.9	30.4
Mean	10.1	10.4	11.2		559.3	627.3	715.0		36.0	26.3	23.5	
For comparison of		S.Em±		C.D. (P=0.05)		S.Em±		C.D. (P=0.05)		S.Em±		C.D. (P=0.05)
Spacing (S)	0.08	0.25	8.03	24.06	0.65	1.96						
Fertilizer level (F)	0.08	0.25	8.03	24.06	0.65	1.96						
Interaction (S x F)	0.15	0.44	13.90	41.68	1.13	3.39						

S_1: 45 cm x 30 cm S_2: 45 cm x 45 cm S_3: 45 cm x 60 cm

F_1:150:100:125 kg N, P_2O_5 and K_2O ha^{-1} F_2:175:125:150 kg N, P_2O_5 and K_2O ha^{-1} F_3:200:150:175 kg N, P_2O_5 and K_2O ha^{-1}

Table 3. Economic analysis of red cabbage cultivation as influenced by spacing and fertilizer levels

Spacing	Gross return (₹ ha^{-1})				Net return (₹ ha^{-1})				BC ratio			
Fertilizer Levels	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1	632000	518000	462000	536000	335993	271478	240220	282564	2.13	2.10	2.08	2.10
F_2	716000	522000	470000	570000	417813	273297	246039	312383	2.40	2.10	2.10	2.20
F_3	810000	538000	478000	608000	508352	285837	250579	348256	2.68	2.13	2.10	2.30
Mean	720000	526000	470000		420719	276871	245613		2.41	2.11	2.09	
For comparison of		S.Em±		C.D. (P=0.05)		S.Em±		C.D. (P=0.05)		S.Em±		C.D. (P=0.05)
Spacing (S)		13055		39138		13055		39138		0.05		0.14
Fertilizer level (F)		13055		39138		13055		39138		0.05		0.14
Interaction (S x F)		22611		67789		22611		67789		0.08		0.24

S_1: 45 cm x 30 cm S_2: 45 cm x 45 cm S_3: 45 cm x 60 cm

F_1:150:100:125 kg N, P_2O_5 and K_2O ha^{-1} F_2:175:125:150 kg N, P_2O_5 and K_2O ha^{-1} F_3:200:150:175 kg N, P_2O_5 and K_2O ha^{-1}

Significant and higher yield of red cabbage due to the application of 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} could be attributed to the significant increase in the yield components *viz.,* head weight (665.5 g) and head diameter (10.9 cm). This improvement in yield components could be attributed to the increased vegetative growth of the plant as evidenced by plant height (23.3 cm), plant spread (51.9 cm) and number of open leaves per plant (22.3). This was due to better translocation of food material to the top as well as rapid elongation and multiplication of cells in the presence of large amount of nitrogen as its concentration was increased in the cell sap in the form of protein, amides and amino acids in the growth region of meristematic tissues. Higher dose of fertilizers might have increased the photosynthetic capacity and auxin levels in the plant. Greater photosynthesis and higher amount of dry matter production due to more number of leaves resulted from better absorption of nutrients from the rhizosphere of plant which might have increased the head and leaf size. The similar results were obtained by Sharma and Sharma (2010) and Prasad *et al.* (2009) in Chinese cabbage, Singh and Singh (2006) in cabbage and Sharma *et al.* (2004) in red cabbage.

Economic parameters for red cabbage production differed considerably with fertilizer levels. The significantly higher net return (₹ 3,48,256 ha^{-1}) was recorded with fertilizer application of 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} (F_3) compared to other lower levels. Though, the cost of cultivation was more (2, 60,411 ha^{-1}) with higher level of fertilizer, the higher net returns obtained

could be attributed to higher gross income (₹ 6,08,000 ha^{-1}) derived from higher head yield (30.4 t ha^{-1}). The increased trend of net returns with application of increased dose of fertilizer was also observed in cabbage by Sharma and Sharma (2010) and Naik and Gupta (2010) in kale. It is noteworthy that, higher BC ratio (2.30) was recorded with application of 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} (F_3) compared to lower fertilizer levels.

Head yield of red cabbage was significantly higher (36.0 t ha^{-1}) with closer spacing of 45 x 30 cm (74,074 plants ha^{-1}) compared to 45 x 45 cm (49,383 plants ha^{-1}) and 45 x 60 cm (37,037 plants ha^{-1}) which was 26.3 t ha^{-1} and 23.5 t ha^{-1}, respectively. The increase in head yield may be due to more number of plants (74,074 plants ha^{-1}) and increased plant height (23.9 cm). Consequently, the increase in plant height at narrow spacing might be due to competition for solar energy.

Further, significantly higher head weight of 715 g obtained with wider spacing of 45 x 60 cm may be attributed to wider plant spread (54.3 cm), more number of open leaves per plant (22.9), and head diameter (11.2 cm). The plants in wider row spacing also enjoyed more space and resources resulting in better performance of individual plants. The higher yield observed with closer spacing was in accordance with the earlier findings in cabbage, where closer spacing resulted in higher number of plant population (plant density) as reported by Prakash *et al.* (2014), Turbin *et al*. (2014) and Singh and Singh (2006). On the contrary, poor head yield at wider spacing of 45 x 60 cm might be due to lesser plant population (50% of the recommended).

It is evident from the investigation that the significantly higher net return (4,20,719 ha^{-1}) was realized with closer spacing of 45 cm x 30 cm as compared to wider spacing. The benefit cost ratio (B:C) was also significantly higher (2.41) with closer spacing of 45 x 30 cm followed by 45 x 45 cm (2.11) and 45 x 60 cm (2.09) spacing. The increased net returns was attributed to higher gross income (₹ 7, 20,000 ha^{-1}) obtained from higher head yield of 36.0 t ha^{-1}. A similar trend with respect to net returns and BC ratio was also observed at closer spacing in cabbage by Sharma *et al.* (2004), Sharma and Sharma (2010), and Naik and Gupta (2010) in kale.

Interaction effect of spacing and fertilizer levels (S x F) revealed that, a spacing of 45 x 30 cm (S_1) along with 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} (F_3) resulted in significantly higher head yield (40.5 t ha^{-1}) of red cabbage compared to other interactions. This yield increase was due to significantly higher performance of individual factors of S_1 and F_3. Interaction of closer spacing and higher fertilizer level (S_1F_3) realized the significantly higher net returns (5, 08,352 ha^{-1}) and B:C ratio (2.68) which was mainly due to significantly higher head yield (40.5 t ha^{-1}) and realization of higher gross income (₹ 8,10,000 ha^{-1}).

Conclusion

The planting geometry of 45 x 30 cm along with fertilizer application of 200:150:175 kg N, P_2O_5 and K_2O ha^{-1} (F_3) recorded significantly higher head yield (40.5 t ha^{-1}) which can be recommended for commercial red cabbage cultivation in Northern Karnataka under shade house condition.

Appendix I. Prices of inputs and outputs

Particulars	Price (₹)
Inputs	
Seedlings	2 / Seedling
FYM	750 /t
Shade house	300 /m^2
Fertilizers	
Urea (50 kg)	290 /50kg
DAP (50 kg)	1230 /50kg
MOP (50 kg)	887 /50kg
Plant protection chemicals	
Chlorpyriphos	170 /500 ml
Regent	290 /250 ml
Malathian	170 /500 ml
Coragen	900 /60ml
Labour wages	
Men	235 /day
Women	235 /day
Outputs	
Red cabbage	20 /kg

Appendix II. Treatement-wise details of cost of cultivation (₹ ha^{-1}) of red cabbage perhectare basis

Treatment	Seedling	Fertilizer	FYM	Labour	Plant protection chemical	Depreciation cost of shade house	Total cost of cultivation
S_1 F_1	148454	10353	18750	16450	2000	100000	296007
S_1 F_2	148454	12534	18750	16450	2000	100000	298187
S_1 F_3	148454	15994	18750	16450	2000	100000	301648
S_2 F_1	98969	10353	18750	16450	2000	100000	246522
S_2 F_2	98969	12534	18750	16450	2000	100000	248703
S_2 F_3	98969	15994	18750	16450	2000	100000	252163
S_3 F_1	74227	10353	18750	16450	2000	100000	221780
S_3 F_2	74227	12534	18750	16450	2000	100000	223961
S_3 F_3	74227	15994	18750	16450	2000	100000	227421

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