Int.J.Curr.Microbiol.App.Sci (2021) *10*(11): 313-321

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 10 Number 11 (2021)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2021.1011.035

Effect of Different Spacing on Yield and Yield Attributing Parameters of Red Cabbage (*Brassica oleracea var. capitata f. rubra*)

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Keywords

Red Cabbage, Genotypes, planting density, Growth, Yield and Quality

Article Info

Received:
15 October 2021
Accepted:
05 November 2021
Available Online:
10 November 2021

A B S T R A C T

An experiment on Red Cabbage Genotypes planted in different planting densities was conducted during December, 2020 to February, 2021 in Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) India. The results of the present investigation, regarding the performance of six genotypes of Red Cabbage *i.e.* (CABRVAR - 1, CABRVAR - 2, CABRVAR – 3, CABRVAR – 4, CABRVAR – 5 and CABRVAR – 6) in two planting densities *i.e.* (60 x 45 cm and 60 x 60 cm) for plant growth, yield and quality of Red Cabbage, have been discussed and interpreted in the light of previous research work done in India and abroad. The experiment was conducted in 6x2 Factorial Randomized block design with 6 Genotypes of Red Cabbage obtained from different sources, were each genotype replicated thrice in different planting densities. From the present experimental findings it is found that the genotype G_2 (CABRVAR - 2) followed by G_4 (CABRVAR - 4) was found best in terms of growth, yield and quality parameters of Red Cabbage in planting density D_2 (60 x 60 cm) was best in growth and quality parameters and Density D_1 (60 x 45 cm) was best in yield parameters. In terms of economics maximum gross return, net return and benefit cost ratio was recorded was recorded in T_3 (60 x 45 cm x CABRVAR - 2).

Introduction

Red cabbage (*Brassica oleracea* var. capitata f. *rubra)* is a native crop in the Mediterranean region of Europe which belongs to the family Brassicacae and now grown all over the world as a fresh market vegetable. Red cabbage is a small, round headed type with dark red leaves. Red cabbage synthesized and accumulated anthocyanins at all the developmental stages of vegetative growth. It has been an important vegetable in USA and Europe till today but it introduction into the Indo-Pakistan subcontinent is somewhat recently. Botanically, Cabbage is a biennial crop being grown for its large edible and terminal buds. Prior to cultivation and use as food, cabbage was mainly used for medicinal purposes.

It is used as salad, boiled vegetable, cooked in curries, used in pickling as well as dehydrated vegetable. It is a rich source of carotene, proteins (0.35%), fats (0.25%), minerals like calcium (3.56%), phosphorus (19.90%), potassium, sulphur etc. and vitamins *viz.*, A, B1, B2 and C. Red cabbage is known to possess medicinal properties. It has an anticancer property due to the presence of indole-3-carbinol. An important advantage of red cabbage is the fact that it is generally consumed raw, which permits the preservation of vitamins sensitive to thermal processing and some polyphenolic compounds (Ismail *et al.,* 2004).

Yield is a complex character controlled by a large number of contributing characters and their interactions. A study of genotypes with planting density between different growth and yield characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. It would be desirable to consider the relative magnitude of association of various characters with yield, therefore proper understanding of the genotypes in different planting density helps in identifying the best genotypes with best suited density for benefiting the farmers.

Materials and Methods

The present Experiment was conducted in Factorial Randomized Block Design (FRBD) with 6 Genotypes *i.e.* G_1 (CABRVAR – 1), G_2(CABRVAR – 2), G_3(CABRVAR – 3), G_4(CABRVAR – 4), G_5(CABRVAR – 5) and G_6 (CABRVAR – 6) and 2 planting densities *i.e.*D_1 (60 x 45 cm) and D_2(60 x 60 cm) total 12 treatments, the experiment was conducted in the Research field, Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during December, 2020 to February, 2021.

Climatic condition in the experimental site

The area of Prayagraj district comes under subtropical belt in the south east of Utter Pradesh, which experience extremely hot summer and fairly cold winter. The maximum temperature of the location reaches up to 46^o C- 48^o C and seldom falls as low as 4^oC- 5^oC. The relative humidity ranges between 20 to 94 %. The average rainfall in this area is around 1013.4 mm annually. However, occasional precipitation is also not uncommon during winter months.

Results and Discussion

The present investigation entitled "Effect of different spacing on yield and yield attributing parameters of Red Cabbage (*Brassica oleracea var. capitataf.rubra*)"was carried out during December, 2020 to February, 2021 in Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) India. The results of the present investigation, regarding the effect of different spacing on red cabbage, have been discussed and interpreted in the light of previous research work done in India and abroad.

The results of the experiment are summarized below.

Growth Parameters

Interaction effect shows that in table – 1, statistically significant variation for Plant height at harvest, in different planting densities and genotypes, maximum plant height 35.20 cm, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_1G_2 (60 x 45 cm x CABRVAR - 2) with 33.31 cm, whereas minimum plant height 28.78 cm, was observed in, D_1G_6 (60 x 45 cm x CABRVAR - 2). Maximum plant height in wider spacing is

may be due to the availability of more space for plant growth, better light distribution and utilization pattern due to wider spacing. Significantly increase plant height with increased plant spacing similar results previously also reported by Purushottam, (2001), Naruka and Dhaka (2001), Sarker *et al.,* (2002) in Cabbage, Kumar *et al.,* (2007) in Broccoli and Riad *et al.,* (2009) in Cabbage.

In terms of number of leaves Interaction effect shows in table – 1, significant variation at harvest, in different planting densities and genotypes, maximum number of leaves 32.99, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_2G_4 (60 x 60 cm x CABRVAR - 4) with 31.28 leaves, whereas minimum number of leaves 26.96, was observed in, D_1G_6 (60 x 45 cm x CABRVAR - 6).

The plants grown under wider spacing received more nutrients, light and moisture around compared to plants of closer spacing, which was probably the cause of better performance in yield attributes like number of leaves per plant. Similar findings previously also reported by Purushottam, (2001), Naruka and Dhaka (2001), Sarker *et al.,* (2002) in Cabbage, Sharma *et al.,* (2005), Singh (2005) in Cauliflower, Kumar *et al.,* (2007) in Broccoli and Moniruzzaman (2011) in cabbage.

Yield and yield attributing parameters

Table – 1, shows that, Interaction effect shows that statistically significant variation for Days to 50% Head initiation in different planting densities and genotypes, minimum 70.14 days, was recorded in D_1G_2 (60 x 45 cm x CABRVAR - 2), followed by D_2G_2 (60 x 60 cm x CABRVAR - 2) with 70.85 days, whereas maximum 77.43 days, was observed in, D_2G_6 (60 x 60 cm x CABRVAR - 6). Similarly in Days to maturity in different planting densities and genotypes, minimum 76.54 days, was recorded in D_1G_2 (60 x 45 cm x CABRVAR - 2), followed by D_2G_2 (60 x 60 cm x CABRVAR - 2) with 77.21 days, whereas maximum 83.60 days, was observed in, D_2G_6 (60 x 60 cm x CABRVAR - 6).

In Head polar diameter, significant variation was noticed maximum Head polar diameter24.51 cm, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_1G_2 (60 x 45 cm x CABRVAR - 2) with 22.76 cm, whereas minimum 19.54 cm, was observed in, D_1G_1 (60 x 45 cm x CABRVAR - 1).

Similarly for Head equatorial diameter maximum Head equatorial diameter19.02 cm, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_2G_4 (60 x 60 cm x CABRVAR - 4) with 18.07 cm, whereas minimum 15.41 cm, was observed in, D_1G_6 (60 x 45 cm x CABRVAR - 6).

Maximum Head and equatorial diameter of heads in wider spacing, is might be attributed to the genetic makeup of varieties that primarily dictate the characters and do not influenced by the environment. Similar results were obtained by Dasgan and Abak (2003) in bell peppers.

Table – 2 shows that, In terms of Gross Head weight maximum significant Gross Head weight 1.46 kg, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_2G_4 (60 x 60 cm x CABRVAR - 4) with 1.35 kg, whereas minimum 1.16 kg, was observed in, D_1G_6 (60 x 45 cm x CABRVAR - 6).

This might be due to wider plant spacing found effective in utilization of land, nutrients and sunlight that has resulted in good quality of fruits and yield. The results are in conformity with findings of Dasgan and Abak (2003) in sweet pepper, Choudhary and More (2002) in Cucumber, Kumar and Rawat

(2002) in Cabbageand Singh *et al.,* (2004), Sharma *et al.,* (2005), Singh (2005) in Cauliflower, Singhal *et al.,* (2009) in Cabbage and Manasa *et al.,* (2017) in Red Cabbage. In table – 2, Interaction effect shows that statistically significant variation for Net Head weight in different planting densities and genotypes, maximum Net Head weight 1.07 kg, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_2G_4 (60 x 60 cm x CABRVAR - 4) with 0.97 kg, whereas minimum 0.80 kg, was observed in, D_1G_6 (60 x 45 cm x CABRVAR - 6).

The similar findings of increase net head weight and yield per plant with wider spacing was reported by Biradar *et al.,* (2014) in capsicum, Choudhary and More (2002) in Cucumber, Mahesh and Rawat (2002) in Cabbageand Singh *et al.,* (2004), Sharma *et al.,* (2005), Singh (2005) in Cauliflower, Singhal *et al.,* (2009) in Cabbage and Manasa *et al.,* (2017) in Red Cabbage.

In Table – 2, shows that in Marketable Head yield/plot maximum significant Marketable Head yield/plot 11.04 kg, was recorded in D_1G_2 (60 x 45 cm x CABRVAR - 2), followed by D_1G_4 (60 x 45 cm x CABRVAR - 4) with 10.59 kg, whereas minimum 7.16 kg, was observed in, D_2G_6 (60 x 60 cm x CABRVAR - 6). Similar trends was noticed in Marketable Head yield/ha maximum significant Marketable Head yield/ha 306.36 q/ha, was recorded in D_1G_2 (60 x 45 cm x CABRVAR - 2), followed by D_1G_4 (60 x 45 cm x CABRVAR - 4) with 293.73 q/ha, whereas minimum 198.88 q/ha, was observed in, D_2G_6 (60 x 60 cm x CABRVAR - 6).

Maximum yield in closer plant spacing is found effective due to accommodation of more number of plants per unit area that has resulted in more head yield. The results are in conformity with findings of Dasgan and Abak (2003) in sweet pepper, Choudhary and More (2002) in Cucumber, Kumar and Rawat (2002) in Cabbage,and Singh *et al.,* (2004), Sharma *et al.,* (2005), Singh (2005) in Cauliflower, Singhal *et al.,* (2009) in Cabbage and Manasa *et al.,* (2017) in Red Cabbage.

Quality Parameters

Table – 2, shows that in terms of Total Soluble Solid (^{o}Brix)in different planting densities and genotypes, maximum TSS5.65 ^{o}Brix, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_1G_2 (60 x 45 cm x CABRVAR - 2) with 5.24 ^{o}Brix, whereas minimum 4.61 ^{o}Brix, was observed in, D_1G_5 (60 x 45 cm x CABRVAR - 5). In terms of Ascorbic acid maximum significant Ascorbic acid 55.88 mg, was recorded in D_2G_2 (60 x 60 cm x CABRVAR - 2), followed by D_1G_2 (60 x 45 cm x CABRVAR - 2) with 53.34 mg, whereas minimum 47.33 mg, was observed in, D_1G_6 (60 x 45 cm x CABRVAR- 6).

Differences in quality parameters have also been reported by Mantur *et al.,* (2014) in cherry tomato which can be attributed to the genetic makeup of varieties that primarily dictate the characters and do not influenced by the environment. The present results are supported by the findings of Purushottam, (2001), Naruka and Dhaka (2001), Kumar and Rawat (2002) in Cabbage, Dragon *et al.,* (2007) in Broccoli and Singhal *et al.,* (2009) in Cabbage.

Economics

In table – 3, shows that the maximum Gross return Rs. 214452.00, Net return Rs. 104395.00 and B:C ratio 1.95 is recorded in T_3 (G_2D_1) followed by T_7 (G_4D_1) with Rs. 205611.00, Rs. 95554 and 1.87 Gross return, Net return and Benefit Cost Ratio respectively and minimum Gross return Rs. 139216.00, Net return Rs. 29159.00 and B:C ratio 1.26 was recorded in T_{12} (G_6D_2).

Table.1 Plant height, No. of leaves, Days to 50% Head initiation, Days to maturity, Head polar and head equatorial diameter of Red Cabbage Genotypes under different planting densities.

Plant height (cm) At Harvest

Genotypes	Planting Density D_1	D_2	Mean Genotypes
G_1	30.90	31.88	31.39
G_2	33.31	35.20	34.25
G_3	29.78	30.67	30.22
G_4	31.79	32.91	32.35
G_5	29.54	30.70	30.12
G_6	28.78	29.94	29.36
Mean nting Density	30.68	31.88	

Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.272	0.568
Factor(G)	S	0.157	0.328
Factor(D X G)	NS	0.385	N/A

Number of Leaves at harvest

Genotypes	Planting Density D_1	D_2	Mean Genotypes
G_1	27.98	29.25	28.61
G_2	31.10	32.99	32.04
G_3	27.49	28.06	27.77
G_4	30.01	31.28	30.64
G_5	27.85	29.72	28.78
G_6	26.96	27.82	27.39
Mean nting Density	28.56	29.85	

Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.233	0.487
Factor(G)	S	0.135	0.281
Factor(D X G)	NS	0.330	N/A

Days to 50% head initiation

Genotypes	Planting Density D_1	D_2	Mean enotypes
G_1	74.65	75.88	75.26
G_2	70.14	70.85	70.49
G_3	73.48	74.89	74.18
G_4	71.30	72.41	71.85
G_5	75.69	77.14	76.41
G_6	75.86	77.43	76.64
Mean Planting Density	73.52	74.76	

Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.463	0.966
Factor(G)	S	0.267	0.557
Factor(D X G)	NS	0.654	N/A

Days to maturity

Genotypes	Planting Density D_1	D_2	Mean enotypes
G_1	81.08	82.19	81.63
G_2	76.54	77.21	76.87
G_3	80.14	81.18	80.66
G_4	77.99	78.80	78.39
G_5	82.05	83.03	82.54
G_6	82.05	83.60	82.82
Mean anting Density	79.97	81.00	

Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.402	0.840
Factor(G)	S	0.232	0.485
Factor(D X G)	NS	0.569	N/A

Head polar diameter (cm)

Genotypes	Planting Density D_1	D_2	Mean enotypes
G_1	19.54	19.65	19.59
G_2	22.76	24.51	23.63
G_3	20.57	21.72	21.14
G_4	21.27	22.38	21.82
G_5	19.94	20.46	20.20
G_6	19.88	20.30	20.09
Mean nting Density	20.66	21.50	

Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.263	0.548
Factor(G)	S	0.152	0.316
Factor(D X G)	NS	0.371	N/A

Head equatorial diameter (cm)

Genotypes	Planting Density D_1	D_2	Mean Genotypes
G_1	15.62	15.76	15.69
G_2	17.47	19.02	18.24
G_3	16.39	16.87	16.63
G_4	17.19	18.07	17.63
G_5	15.55	16.33	15.94
G_6	15.41	15.97	15.69
Mean nting Density	16.27	17.00	

Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.250	0.521
Factor(G)	S	0.144	0.301
Factor(D X G)	NS	0.353	N/A

Table.2 Gross head weight, Net Head weight, marketable head yield/plot marketable head yield/ha, TSS and Ascorbic Acid (mg) of Red Cabbage Genotypes under different planting densities.

Genotypes	Gross Head weight (kg) Planting Density		
	D_1	D_2	Mean enotypes
G_1	1.17	1.20	1.18
G_2	1.34	1.46	1.40
G_3	1.23	1.29	1.26
G_4	1.28	1.35	1.31
G_5	1.19	1.22	1.20
G_6	1.16	1.21	1.18
Mean Planting Density	1.22	1.28	
Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.014	0.030
Factor(G)	S	0.008	0.017
Factor(D X G)	S	0.020	0.043

Genotypes	Net head weight (kg) Planting Density		
	D_1	D_2	Mean enotypes
G_1	0.84	0.88	0.86
G_2	0.97	1.07	1.02
G_3	0.88	0.92	0.90
G_4	0.93	0.97	0.95
G_5	0.85	0.87	0.86
G_6	0.80	0.84	0.82
Mean anting Density	0.87	0.92	
Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.012	0.026
Factor(G)	S	0.007	0.015
Factor(D X G)	NS	0.017	N/A

Genotypes	Marketable head yield/plot (kg) Planting Density		
	D_1	D_2	Mean enotypes
G_1	9.50	7.50	8.50
G_2	11.04	9.13	10.08
G_3	9.98	7.84	8.91
G_4	10.59	8.21	9.40
G_5	9.52	7.42	8.47
G_6	9.10	7.16	8.13
Mean anting Density	9.95	7.87	
Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.138	0.288
Factor(G)	S	0.080	0.167
Factor(D X G)	NS	0.195	N/A

Genotypes	Marketable head yield/ha (q) Planting Density		
	D_1	D_2	Mean enotypes
G_1	263.62	208.32	235.97
G_2	306.36	262.60	284.48
G_3	276.94	217.77	247.35
G_4	293.73	228.05	260.89
G_5	262.84	206.09	234.46
G_6	252.52	198.88	225.70
Mean Planting Density	276.00	220.28	
Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	4.946	10.324
Factor(G)	S	2.856	5.961
Factor(D X G)	NS	6.995	N/A

Genotypes	Total Soluble Solid (°Brix) Planting Density		
	D_1	D_2	Mean enotypes
G_1	4.96	4.84	4.90
G_2	5.24	5.65	5.44
G_3	4.89	5.01	4.95
G_4	5.07	5.15	5.11
G_5	4.61	4.92	4.76
G_6	4.66	4.64	4.65
Mean Planting Density	4.90	5.03	
Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.144	0.300
Factor(G)	NS	0.083	N/A
Factor(D X G)	NS	0.204	N/A

Genotypes	Ascorbic acid (mg/100g) Planting Density		
	D_1	D_2	Mean enotypes
G_1	48.58	51.94	50.26
G_2	53.34	55.88	54.61
G_3	50.92	49.25	50.08
G_4	51.56	50.45	51.00
G_5	48.19	49.03	48.61
G_6	47.33	50.73	49.03
Mean Planting Density	49.98	51.21	
Factors	F-Test	SE(d)	C.D. at 5%
Factor(D)	S	0.701	1.463
Factor(G)	S	0.405	0.845
Factor(D X G)	S	0.991	2.069

Table.3 Cost benefit ratio of Red Cabbage.

Treatment Symbol	Treatment Combinations	Total cost of cultivation/ha	Red Cabbage Yield (q) /ha	Gross return @ Rs./ha	Net Return Rs./ha	Cost Benefit Ratio
T_1	G_1D_1	110057	263.62	184534	74477	1.68
T_2	G_1D_2	110057	208.32	145824	35767	1.32
T_3	G_2D_1	110057	306.36	214452	104395	1.95
T_4	G_2D_2	110057	262.6	183820	73763	1.67
T_5	G_3D_1	110057	276.94	193858	83801	1.76
T_6	G_3D_2	110057	217.77	152439	42382	1.38
T_7	G_0D_1	110057	293.73	205611	95554	1.87
T_8	G_0D_2	110057	228.05	159635	49578	1.45
T_9	G_3D_1	110057	262.84	183988	73931	1.67
T_{10}	G_3D_2	110057	206.09	144263	34206	1.31
T_{11}	G_0D1	110057	252.52	176764	66707	1.60
T_{12}	G_0D_2	110057	198.88	139216	29159	1.26

From the present experimental findings it is concluded that the genotype G_2 (CABRVAR - 2) followed by G_4 (CABRVAR - 4) was found best in terms of growth, yield and quality parameters of Red Cabbage in planting density D_2 (60 x 60 cm) was best in growth and quality parameters and Density D_1 (60 x 45 cm) was best in yield parameters. In terms of economics maximum gross return, net return and benefit cost ratio was recorded was recorded in T_3 (60 x 45 cm x CABRVAR - 2).

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How to cite this article:

Korsa Swetha Rani, Anita Kerketta and Vijay Bahadur. 2021. Effect of Different Spacing on Yield and Yield Attributing Parameters of Red Cabbage (*Brassica oleracea var. capitata f. rubra*). *Int.J.Curr.Microbiol.App.Sci.* 10(11): 313-321.
doi: https://doi.org/10.20546/ijcmas.2021.1011.035