

Effect of plant density and integrated nutrient management on growth, yield, quality and economics of kale (*Brassica oleracea* var. *acephala*) in temperate region*

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Kale (*Brassica oleracea* var. *acephala*) is a temperate vegetable which is grown for its tender leaf. It is often called “borecoles” which is taken from Dutch ‘Borenkool’. It can withstand drought and temperature of –10 to –15 °C. It is highly nutritious vegetable, rich in vitamins, particularly vitamin C and provitamin A and minerals. On cooking the retention of vitamin C is highest in Kale. In India, it is commercially grown in Kashmir and to a limited extent in Jammu region, Assam and Himachal Pradesh. In Jammu and Kashmir, it is a very popular vegetable, grown in all kitchen gardens and also as a commercial crop around cities and towns. Its cultivation has picked up around metropolitan cities due to increased demand in hotels. The production potential of kale can be realized by using high-yielding varieties, improved cultural practices, viable agricultural technology and judicious plant protection measures. Plant nutrition and spacing are the most important factors influencing growth, yield and quality of kale. Therefore, the present investigation was undertaken to study the performance of kale with different plant spacings along with varying levels of nutrition.

Field investigation was carried out at the experimental farm, Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences and Technology (K), Shalimar during autumn 2006 and spring 2007 to find out the optimum plant spacing and appropriate dosage of combinations of organic manures and inorganic fertilizers for maximum leaf yield and quality production of ‘Siberian kale’. The experiment was laid out in factorial randomized block design with 18 treatment combinations of 3 spacings, i.e. S₁ (30 cm × 20 cm), S₂ (30 cm × 30 cm) and S₃ (30 cm × 40 cm), and 6

nutritional levels, viz N₁ (120: 90: 60 kg NPK/ha, i.e. 100% recommended fertilizers dose), N₂ (50% recommended fertilizers dose + 10 tonnes farmyard manure/ha), N₃ (20 tonnes farmyard manure/ha), N₄ (50% recommended fertilizers dose + 3 tonnes vermicompost/ha), N₅ (6 tonnes vermicompost/ha) and N₆ (control, i.e. no manure/fertilizers). Observations were recorded on growth and yield parameters, like plant spread (cm), leaf area (cm²), number of leaves/plant, average leaf weight (g), petiole length (cm), petiole midrib weight (g), days to first picking, duration of picking, leaf weight/plant (g), leaf yield/plot (kg); and quality parameters like dry matter content (%), chlorophyll content, total carotenoids and vitamin C content (mg/100 g). The relative economics of different treatments were also worked out.

The organic manures, viz farmyard manure, vermicompost and chemical fertilizers (urea, single superphosphate and muriate of potash) were used as source of plant nutrients. Farmyard manure and vermicompost were applied as basal dose a week prior to transplanting as per the treatments and incorporated into the soil. The entire dose of phosphorus and potassium along with ½ dose of nitrogen was applied as basal dose and thoroughly mixed with soil just before transplanting. The remaining ½ dose of nitrogen was top-dressed at 30 and 45 days after transplanting.

The seeds of ‘Siberian kale’ were sown in lines 5 cm apart in the open raised nursery beds on 25 August 2006 during autumn, and on 6 February 2007 in hot beds during spring season. The seeds were covered with ash. To ensure better germination, the seed beds were covered with paddy straw till the germination was complete. Light watering was done in the morning/evening. Proper care and required cultural operations were taken up during the period of nursery raising. In autumn season, the transplanting was done on 26 September 2006 and in spring 2007 it was done on 10 March 2007. Immediately after transplanting the seedlings were watered with rose can and this was continued up to 2 days. After establishment of crop, need-based irrigation was given through channels. To maintain requisite population, gap-

*Short note

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Table 1 Performance of kale in relation to spacing and plant nutrition in temperate region of Kashmir (2006 and 2007)

Treatment	Plant spread (cm)	Leaf area (cm ²)	Leaves/plant	Average leaf weight (g)	Petiole length (cm)	Petiole mid rib weight (g)	Days to first picking	Duration of picking (days)	Leaf weight/plant (g)	Leaf yield/plot (kg)	Dry matter (%)	Total chlorophyll (mg/100 g)	Total carotenoids (mg/100 g)	Vitamin C content (mg/100 g)
<i>Spacing</i>														
S ₁	33.97	192.67	10.63	18.73	11.28	7.62	46.66	36.66	153.89	9.64	12.49	50.04	2.34	89.72
S ₂	36.38	210.17	10.93	19.86	12.62	8.68	46.25	37.50	163.37	7.36	13.30	57.09	2.49	96.57
S ₃	37.80	216.23	11.13	22.13	12.95	8.95	46.25	37.50	166.04	5.41	13.69	61.06	2.53	100.65
CD (P<0.05)	1.28	9.64	0.23	1.74	0.64	0.50	NS	NS	2.01	0.61	0.60	4.01	0.21	5.85
<i>Plant nutrition</i>														
N ₁	38.22	240.20	11.24	21.60	15.42	10.42	40.00	39.16	176.16	8.47	12.45	54.05	2.15	86.14
N ₂	39.56	220.38	12.10	22.92	13.43	9.01	42.50	42.50	181.73	8.51	13.16	57.06	2.30	85.67
N ₃	33.17	174.09	11.06	20.12	11.26	7.56	52.50	32.50	164.92	6.78	14.32	62.79	2.79	107.39
N ₄	43.17	268.36	12.65	24.14	14.16	9.46	40.00	45.00	188.93	9.68	13.27	59.92	2.73	99.02
N ₅	33.88	188.91	11.08	20.40	11.53	8.05	47.50	37.50	168.38	7.09	15.10	64.07	3.34	111.59
N ₆	28.29	146.21	7.11	12.27	7.92	6.00	55.83	26.66	86.52	4.29	10.67	38.46	1.40	74.07
CD (P<0.05)	1.81	13.63	0.99	2.46	0.90	0.71	3.05	2.89	3.91	0.86	0.85	5.68	0.35	6.10
<i>Spacing x nutrition</i>														
S ₁ N ₁	37.17	218.43	10.95	19.85	14.90	9.46	40.00	40.00	167.35	11.15	11.73	47.56	2.03	80.43
S ₁ N ₂	37.37	208.80	11.71	21.60	12.31	8.56	42.50	42.50	176.47	11.01	12.63	49.77	2.26	90.30
S ₁ N ₃	31.31	164.47	10.91	18.36	9.93	6.56	52.50	32.50	157.83	8.50	13.25	56.47	2.68	101.15
S ₁ N ₄	40.80	245.92	12.41	22.23	13.80	8.61	40.00	45.00	179.73	12.60	12.65	53.40	2.64	92.97
S ₁ N ₅	31.66	176.90	10.90	19.08	10.66	7.16	47.50	37.50	159.65	9.29	14.55	58.28	3.24	104.64
S ₁ N ₆	25.53	141.52	6.93	11.26	6.11	5.35	55.00	27.50	82.33	5.29	10.13	34.75	1.22	68.82
S ₂ N ₁	38.45	249.17	11.38	20.78	15.46	11.06	40.00	40.00	178.95	8.19	12.83	55.26	2.19	86.90
S ₂ N ₂	39.74	223.61	12.23	21.55	13.91	9.00	42.50	42.50	181.92	8.56	13.17	58.86	2.31	96.62
S ₂ N ₃	33.37	175.19	11.09	20.41	11.88	7.95	52.50	32.50	167.98	6.87	14.39	63.79	2.81	108.35
S ₂ N ₄	43.64	275.24	12.71	23.61	14.15	9.76	40.00	45.00	192.68	9.33	13.38	60.80	2.77	100.07
S ₂ N ₅	34.42	192.23	11.11	20.61	12.03	8.16	47.50	37.50	171.55	6.77	15.19	64.60	3.39	112.72
S ₂ N ₆	28.66	145.59	7.10	12.23	8.31	6.21	55.00	27.50	87.17	4.43	10.86	39.22	1.46	74.80
S ₃ N ₁	39.05	253.00	11.40	24.18	15.90	10.75	40.00	37.50	182.17	6.09	12.80	59.34	2.24	91.10
S ₃ N ₂	41.58	228.73	12.35	25.63	14.08	9.48	42.50	42.50	186.80	5.95	13.69	62.54	2.35	100.10
S ₃ N ₃	34.83	182.62	11.18	21.58	11.98	8.16	52.50	32.50	168.93	4.96	15.32	68.12	2.90	112.67
S ₃ N ₄	45.08	283.90	12.84	26.58	14.53	10.01	40.00	45.00	194.37	7.12	13.78	65.57	2.79	104.03
S ₃ N ₅	35.57	197.60	11.23	21.50	11.91	8.83	47.50	37.50	173.93	5.21	15.56	69.34	3.39	117.42
S ₃ N ₆	30.69	151.53	7.31	13.33	9.33	6.43	57.50	25.00	90.05	3.15	11.01	41.42	1.52	78.60
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.50	NS	NS	NS	NS

S₁ = 30 cm x 20 cm; S₂ = 30 cm x 30 cm; S₃ = 30 cm x 40 cm

N₁, 120: 90: 60 kg NPK/ha (100% recommended fertilizers dose); N₂, 50% recommended fertilizers dose + 10 tonnes farmyard manure/ha; N₃, 20 tonnes farmyard manure/ha; N₄, 50% recommended fertilizers dose + 3 tonnes vermicompost/ha; N₅, 6 tonnes vermicompost/ha; N₆, control (no manure/fertilizers)

filling was resorted up to 7 days after transplanting. Harvesting of kale leaves was started 40 days after transplanting and subsequently at an interval of 15 days. Four pickings were carried out in both the seasons at 40, 55, 70 and 85 days after transplanting. The experimental data were subjected to statistical analysis according to the method described by Panse and Sukhatme (1978).

Maximum growth parameters, like plant spread (37.80 cm), leaf area (216.23 cm²), number of leaves/plant (11.13) and petiole length (12.95 cm) were obtained with wider spacing of 30 cm×40 cm (Table 1). This was due to widely-spaced plants had more unit area/plant for its expansion, and low competition among the plants for moisture, nutrients and light in comparison to closer spacing. These findings are in conformity with Singh *et al.* (2003), Patil *et al.* (2003) and Pawar *et al.* (2007).

Significantly higher average leaf weight (22.13 g), petiole mid rib weight (8.95 g) and leaf weight/plant (166.04 g) were obtained with wider spacing of 30 cm×40 cm. This could be due to vigorous growth of plants owing to more availability of water, nutrients and light in comparison to closer spacings. However, higher leaf yield (9.64 kg/plot) was recorded with closer spacing of 30 cm×20 cm. This is due to the fact that

leaf/per unit area increased with the increase in plant density. Patil *et al.* (2003) reported similar findings. Pawar *et al.* (2007) reported that even though the yield/plant was lowest at closer spacing, the higher plant population/unit area compensated the yield.

There was positive increase in quality attributes with increase in plant spacing. Maximum dry matter content (13.69%), total chlorophyll (61.06 mg/100 g), total carotenoids (2.53 mg/100 g) and vitamin C content (100.65 mg/100 g) were obtained with a plant spacing of 30 cm×40 cm. The improvement in quality with low density could be due to availability of more sunlight, water, nutrients and other essential minerals and lesser competition for nutrients among plants at wider spacing. Similar results were reported by Amreesh and Atul (2003).

It was found that organic manures, inorganic fertilizers and their integration had a favourable and significant effect on growth attributes (Table 1). The maximum plant spread (43.17 cm), leaf area (268.36 cm²) and number of leaves/plant (12.65) were obtained with 50% recommended fertilizers dose + 3 tonnes vermicompost/ha; while 100% recommended fertilizers dose recorded maximum petiole length (15.42 cm).

Integration of vermicompost with inorganic sources

Table 2 Relative economics of kale production in relation to spacing and plant nutrition in temperate region

Treatment	Cost of manures/fertilizers and their application (Rs/ha)	Cost of cultivation (excluding manures/fertilizers and their application) (Rs/ha)	Total cost of cultivation (Rs/ha)	Pooled yield (tonnes/ha)	Gross returns (Rs/ha)	Net return (Rs/ha)	Additional returns over control (Rs/ha)	Net returns/ rupee investment (B: C ratio)
S ₁ N ₁	7 897	38 074	45 972	23.22	232 200	186 227	114 102	4.05
S ₁ N ₂	8 233	38 074	46 380	22.93	229 300	182 991	110 866	3.95
S ₁ N ₃	8 700	38 074	46 774	17.00	177 000	130 225	58 100	2.78
S ₁ N ₄	11 623	38 074	49 698	26.25	262 500	212 801	140 676	4.28
S ₁ N ₅	15 210	38 074	53 284	19.50	193 500	140 215	68 090	2.63
S ₁ N ₆		38 074	38 074	11.02	110 200	72 125		1.89
S ₂ N ₁	7 897	36 074	43 972	17.04	170 400	126 427	70 302	2.87
S ₂ N ₂	8 233	36 074	44 308	17.83	178 300	133 991	77 866	3.02
S ₂ N ₃	8 700	36 074	44 774	14.31	143 100	98 325	42 200	2.19
S ₂ N ₄	11 623	36 074	47 698	19.43	194 300	146 601	90 476	3.07
S ₂ N ₅	15 210	36 074	51 284	14.10	141 000	89 715	33 590	1.74
S ₂ N ₆		36 074	36 074	92.29	92 200	56 125		1.55
S ₃ N ₁	7 897	34 074	41 972	12.68	126 800	84 827	533 402	2.02
S ₃ N ₂	8 233	34 074	42 308	12.39	123 900	81 591	50 166	1.92
S ₃ N ₃	8 700	34 074	42 774	10.33	103 300	60 525	291 100	1.41
S ₃ N ₄	11 623	34 074	45 698	14.83	148 300	102 601	71 176	2.24
S ₃ N ₅	15 210	34 074	49 284	10.85	108 500	59 215	27 790	1.20
S ₃ N ₆		34 074	34 074	6.55	65 500	31 425		0.92

Sale price of kale: Rs 1 000/100 kg

S₁, 30 cm×20 cm; S₂ = 30 cm×30 cm; S₃ = 30 cm×40 cm

N₁, 120: 90: 60 kg NPK/ha (100% recommended fertilizers dose); N₂, 50% recommended fertilizers dose + 10 tonnes farmyard manure/ha; N₃, 20 tonnes farmyard manure/ha; N₄, 50% recommended fertilizers dose + 3 tonnes vermicompost/ha; N₅, 6 tonnes vermicompost/ha; N₆, control (no manure/fertilizers)

exhibited an increase in growth attributes of kale, which might be due to balanced C/N ratio, better organic matter buildup, efficient microbial activity, better root proliferation, abundant supply and availability of nutrients from soil, more translocation of nutrients to aerial parts for protoplasmic proteins and synthesis of other compounds. The higher petiole length might be due to quick and readily availability of plant nutrients from inorganic sources during early growth. Similar results have been reported by Kumar and Sharma (2004), Wani (2006) and Ghuge (2007).

The results revealed that maximum average leaf weight (24.14 g), leaf weight/plant (188.93 g) and leaf yield/plot (9.68 kg) were obtained with 50% recommended fertilizers dose + 3 tonnes vermicompost/ha, while maximum petiole mid-rib weight (10.42 g) was noticed with 100% recommended fertilizers dose. Integration of vermicompost with inorganic sources exhibited an increase in leaf yield and its related attributes. This could be due to balanced C/N ratio, more decomposition of vermicompost, more mineralization, more availability of native and applied macro and micronutrients. All this might have accelerated the synthesis of carbohydrates and its better translocation to source which might have led to improvement in leaf yield and its related attributes. Similar results have been reported by Bahadur *et al.* (2004) and Chattoo (2006).

It was observed that maximum dry matter content (15.10%), total chlorophyll (64.07 mg/100g), total carotenoids (3.34 mg/100 g) and vitamin C content (121.59 mg/100 g) were obtained with 6 tonnes vermicompost/ha which could be attributed to better and balanced nutrition, and production of growth-promoting substances by organics leading to better quality in term of dry matter, chlorophyll, carotenoids and vitamin C content. The superiority of vermicompost can be attributed to its nutritional richness as well as its stimulatory behaviour. These findings are in accordance with the findings of Bahadur *et al.* (2006), Ghuge (2007) and Sreedevi (2007).

Economic analysis revealed that kale planted at 30 cm × 20 cm spacing with 50% recommended fertilizers dose + 3 tonnes vermicompost/ha was most economical and gave the highest benefit : cost ratio of 4.28, followed kale planted at 30 cm×20 cm with 100% recommended fertilizers dose (Table 2). It can as such be perceived that more employment compared with sustained returns and optimization of resources could be obtained only if optimum use of factors of production are made. Therefore, the cultivation of kale is remunerative and economically viable under integrated nutrient management system. These results are in conformity with the findings of Meena and Paliwal (2003).

It is concluded that adoption of 30 cm×20 cm plant spacing along with application 50% recommended inorganic fertilizers + 3 tonnes vermicompost/ha gave the highest leaf yield and net returns (Rs 2 12 801/ha) and B: C ratio of 4.28.

SUMMARY

An experiment was laid out during 2006–07 with 18 treatment combinations of 3 spacing and 6 nutrition levels in a factorial randomized block design with 3 replications. Among the plant spacing, 30 cm×40 cm recorded higher plant spread (37.80 cm), leaf area (216.23 cm²), number of leaves/plant (11.13), average leaf weight (22.13 g), petiole length (12.95 cm), petiole mid-rib weight (8.95 g), leaf weight/plant (166.04 g), dry matter content (13.69%), total chlorophyll content (61.06 mg/100 g), total carotenoids (2.53 mg/100 g) and vitamin C content (100.65 mg/100 g). But significantly higher leaf yield (26.25 tonnes/ha) was recorded with a spacing of 30 cm×20 cm due to large plant population/unit area. Among the nutritional levels, 50% recommended fertilizers dose + 3 tonnes vermicompost/ha recorded significantly higher plant spread (43.17 cm), leaf area (268.36 cm²), number of leaves/plant (12.65), average leaf weight (24.14 g), duration of picking (45 days), leaf weight (188.93 g/plant) and leaf yield (26.25 tonnes/ha). The highest net returns of Rs 2 12 801 and benefit:cost ratio of 4.28 was accrued with 30 cm×20 cm plant spacing along with 50% recommended fertilizers dose + 3 tonnes vermicompost/ha.

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