

Effect of plant spacing, organic manures and inorganic fertilizers and their combinations on growth, yield and quality of lettuce (*Lactuca sativa*)*

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Lettuce (*Lactuca sativa* L.) is one of the most important leafy vegetable in temperate countries. However, it occupies an important position for its cultivation in tropical and sub-tropical countries. The cultivation of lettuce is becoming increasingly popular in Jammu and Kashmir. Its production can be increased through the development of improved, high-yielding and disease-resistant varieties and adoption of improved management practices. Among management practices, application of fertilizers with proper plant spacing to meet the nutrient requirements of the crop is undoubtedly of prime importance. Long-term fertilizer experiments on various cropping systems of different agro-ecological regions and soil types revealed that continuous use of chemical fertilizers in an imbalanced and indiscriminate manner and ignoring the application of organics had laid deleterious effect on long-term fertility and sustainability, thereby indicating deficiency of other major and micronutrients. Nutrient interactions have a key role to play in determining the course and outcome of two major issues of interest in fertilizer management. These are balanced and efficient fertilizer use. Besides balanced nutrition, appropriate plant spacing is of paramount significance in determine growth and productivity of lettuce. Since the information available on nutritional and spacing requirements of lettuce under Kashmir conditions is limited, the present investigation was therefore initiated to study the efficacy of organic manures and inorganic fertilizers alone and in combination along with ascertaining appropriate plant spacing for obtaining the maximum yield and quality under temperate conditions of Kashmir.

The present investigation was undertaken at experimental farm of Division of Olericulture of the University, Srinagar.

*Short note

Based on complete information of M Sc thesis of the first author submitted to SKUAST-K, Shalimar during 2008

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The experiment was laid out in a randomized block design (factorial) with 3 spacings, viz 45 cm × 30 cm, 45 cm × 45 cm and 45 cm × 60 cm and 6 nutrition levels, viz 120: 90: 60 kg NPK/ha, ie 100% recommended fertilizer dose, 50% recommended fertilizer dose + 10 tonnes farmyard manure/ha, 20 tonnes farmyard manure/ha, 50% recommended fertilizer dose + 3 tonnes vermicompost/ha, 6 tonnes vermicompost/ha and control (no manures/fertilizers). The characters studied were days to first harvest, plant height (cm), plant spread (cm), leaf area (cm²), number of leaves/plant, average leaf weight (g), petiole midrib weight (g), leaf weight/plant (g), leaf yield/plot (kg), dry matter (%), vitamin-C content (mg/100 g) and total carotenoids (mg/100 g).

The organic manures, viz farmyard manure, vermicompost and chemical fertilizers (urea, single superphosphate and muriate of potash) were used as source of plant nutrients. A basal dose of well rotten farmyard manure and vermicompost were applied prior to transplanting in the specific plots as per technical programme and thoroughly mixed with soil. Full dose of P and K along with dose ½ dose of N was given as a basal dose and thoroughly mixed with soil. The remaining ½ dose of the nitrogen was applied in 2 splits, first 30 days after transplanting and second 45 days after transplanting.

The raised nursery beds were prepared by working the soil into fine tilth. Well rotten farmyard manure was mixed in each bed. The 'LS 2' seeds of lettuce variety were sown in lines in the raised nursery beds on 26 August 2006 for autumn crop and on 5 February 2007 in hot beds for spring crop covered with ash. To ensure better germination the seed beds were covered with dry grass till germination was complete. Light watering was done in the morning and evening with the help of rose cane. Proper care and cultural operations like weeding, irrigation etc. were taken up during the entire period of nursery raising. During Autumn 2006 the transplanting was done on 25 September 2006, whereas during Spring 2007, transplanting was done on 7 March 2007. After crop establishment, the necessary cultural practices, like weeding and hoeing was done from time to time to keep

the plots free from weeds. Plant protection measures against rodents were carried out during growth period of the crop. Harvesting of lettuce leaves was started 40 days after transplanting with an interval of 15 days. Total 3 pickings were carried out in both the season on 40, 55 and 70 days after transplanting. Relative economics after harvest of crop was calculated on pooled basis. To test the significance of results, the experimental data were subjected to statistical analysis according to the method described by Box *et al.* (1978).

Plant spacing had a significant effect on various growth parameters, viz plant height (cm), plant spread (cm), leaf area (cm²) and number of leaves/plant. The closest plant spacing (45 cm × 30 cm) recorded maximum plant height (22.1 cm and 28.0 cm) during autumn and spring season, respectively, while the widest spacing (45 cm × 60 cm) resulted in maximum plant spread (38.8 cm and 34.8 cm), leaf area (233.4 cm² and 218.1 cm²) and number of leaves/plant (27.8 and 38.1) during autumn and spring season respectively. Since closely-spaced plants had a very little space as compared to widely-spaced plants for their lateral development with declined shoot root system, a comparatively larger root system might have improved water and nutrient absorption, thereby resulting in increased vegetative growth in the vertical direction (plant height) to compete for sunlight. On the other hand, in widely-spaced plants there was less competition for water, nutrients and sunlight, and plant had more space for their expansion which resulted in increased lateral growth and leaf area. Similarly, the increase in number of leaves/plant with increased plant spacing might be because of lesser competition among the plants and larger amount of available nutrients, sunlight and

water for luxuriant and vigorous growth under widest spacing as compare to closer spacing. The result of the present findings is also supported with the results of Abu *et al.* (2004) and Pawar *et al.* (2007).

Plant spacings were found to have a significant effect on average leaf weight, petiole midrib weight, leaf weight/plant and leaf yield/plot. The widest plant spacing (45 cm × 60 cm) recorded highest average leaf weight (17.66 g and 11.55 g), petiole midrib weight (2.93 g and 2.46 g) and leaf weight/plant (430.16 g and 449.67 g) during autumn and spring season, respectively. The increase in average leaf weight and petiole midrib weight with increase in plant spacing may be attributed to the availability of higher amount of nutrients and less competition among plants for available moisture, sunlight and space. The increase in leaf weight/plant with increase in plant spacing may be due to more number of leaves/plant, larger sized leaves and average leaf weight. This is in accordance with the findings of Abu *et al.* (2004).

The leaf yield/plot increased significantly with decrease in plant spacing. Maximum leaf yield/plot (8.35 kg and 8.81 kg) were recorded at closest spacing of 45 cm × 30 cm during autumn and spring season, respectively, while minimum leaf yield/plot was recorded at the widest spacing of 45 cm × 60 cm during both the seasons. The increase in leaf yield at closer spacing might be attributed to the increased plant population/unit area with higher number of leaves/plot. These results are in line with the earlier findings of Naik (2008).

Plant spacings were found to have significant effect on dry matter content, vitamin C content and total carotenoids. The maximum dry matter content (7.93% and 9.44%), vitamin C content (45.36 mg/100 g and 35.17 mg/100 g) and

Table 1 Effect of different plant spacing on growth, yield and quality parameters of 'LS 2' lettuce

Treatment	Days to first harvest		Plant height (cm)		Plant spread (cm)		Av. leaf area (cm ²)		No. of leaves/plant		Average leaf weight (g)	
	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007
S ₁	45.8	43.3	22.1	28.0	33.2	29.4	210.0	189.5	22.5	32.1	15.52	10.06
S ₂	45.0	42.5	19.9	24.5	37.4	33.9	226.9	213.0	27.2	36.8	17.18	11.38
S ₃	45.0	42.5	18.7	23.4	38.8	34.8	233.4	218.1	27.8	38.1	17.66	11.55
CD (P<0.05)	NS	NS	0.51	0.58	0.99	0.80	5.62	4.10	0.47	1.33	0.39	0.31
Treatment	Petiole mid rib weight (g)		Leaf weight/plant (g)		Leaf yield/plot (kg)		Dry matter content (%)		Vitamin C content (mg/100 g)		Total carotenoids (mg/100 g)	
	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007
S ₁	2.27	2.13	310.73	326.33	8.35	8.81	7.29	8.88	41.44	27.01	2.69	2.51
S ₂	2.66	2.41	409.90	427.17	7.24	7.56	7.85	9.24	44.19	33.73	3.04	2.75
S ₃	2.93	2.46	430.16	449.67	5.97	6.42	7.93	9.44	45.36	35.17	3.26	2.81
CD (P<0.05)	0.15	0.12	5.38	7.91	0.51	0.22	0.17	0.28	1.05	1.14	0.07	0.09

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

Table 2 Effect of different organic manures and inorganic fertilizers and their combination on growth, yield and quality parameters of lettuce

Treatment	Days to first harvest		Plant height (cm)		Plant spread (cm)		Av. leaf area (cm ²)		No. of leaves/plant		Average leaf weight (g)	
	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007
N ₁	40.0	40.0	24.6	30.9	43.2	33.7	250.5	224.9	30.4	37.5	18.98	11.94
N ₂	45.0	40.0	22.7	32.1	39.1	34.3	239.6	234.9	26.3	42.6	17.91	12.23
N ₃	50.0	45.0	16.8	19.2	32.4	31.0	221.1	195.2	23.3	33.2	14.91	10.50
N ₄	40.0	40.0	25.8	34.6	44.7	40.8	270.9	261.2	35.0	44.6	20.80	13.10
N ₅	45.0	40.0	17.6	20.2	33.8	32.0	224.0	205.3	23.4	33.9	14.98	10.04
N ₆	51.6	51.6	14.0	15.0	25.6	24.5	134.4	119.9	16.7	22.3	13.15	8.16
CD (<i>P</i> <0.05)	5.51	3.70	0.72	0.82	1.40	1.13	7.95	5.80	0.66	1.88	0.56	0.45

Treatment	Petiole mid rib weight (g)		Leaf weight/plant (g)		Leaf yield/plot (kg)		Dry matter content (%)		Vitamin C content (mg/100 g)		Total carotenoids (mg/100 g)	
	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007	Autumn 2006	Spring 2007
N ₁	3.40	2.91	442.61	444.22	8.57	8.24	7.10	8.46	36.00	25.38	2.46	2.24
N ₂	2.93	2.41	428.40	455.89	7.94	8.57	7.42	9.05	45.16	30.78	2.80	2.66
N ₃	2.15	1.99	384.16	413.22	6.45	7.44	8.48	10.08	54.44	37.32	3.87	3.38
N ₄	3.01	2.75	452.04	472.67	9.10	9.25	7.70	9.13	45.00	34.56	2.82	2.60
N ₅	2.38	2.27	393.51	431.44	6.61	7.76	8.76	10.38	57.72	45.62	3.88	3.43
N ₆	1.85	1.69	200.87	188.89	4.44	4.31	6.68	7.64	23.66	18.15	1.89	1.86
CD (<i>P</i> <0.05)	0.21	0.17	7.61	11.19	0.29	0.31	0.24	0.40	1.49	1.61	0.11	0.13

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)

total carotenoids (3.26 mg/100 g and 2.81 mg/100 g) were recorded during autumn and spring season, respectively, at widest plant spacing of 45 cm × 60 cm, showing an increasing trend with increase in plant spacing. This may be due to more availability of soil macro as well as micronutrients which might have led to better root proliferation, improved nutrient uptake and better accumulation of photosynthates in widest spacing as compared to closer spacing and less competition among the plants. These findings are in accordance with the findings of Naik (2008).

Data clearly indicated that nutrition levels had a significant effect on days to first harvest in lettuce. Sole application of inorganic fertilizer and their combination with organic manures reduced the number of days to first harvest as compared to the sole application of organic sources. The reduction in the number of days taken to first harvest due to NPK fertilization in conjunction with organic manures might be due to added supply of nutrients and proliferous root system developed early under balanced nutrient application resulting in better absorption of water and nutrients with improved physical environment. The minimum number of days taken to first harvest (40 days) among various nutritional treatments were recorded with treatment supplying 50% recommended fertilizer dose + 3 tonnes vermicompost/ha.

This might be due to higher concentration of P, K and enzymes in vermicompost which enhance the early maturity of leaves.

The maximum plant height (25.8 cm and 34.6 cm), plant spread (44.7 cm and 40.8 cm), leaf area (270.9 cm² and 261.2 cm²) and number of leaves/plant (35.0 and 44.6) were observed with application of 50% recommended fertilizer dose + 3 tonnes vermicompost/ha during autumn and spring season, respectively. Among sole application of vermicompost @ 6 tonnes/ha recorded highest plant height, plant spread, leaf area and number of leaves/plant. Integration of organic and inorganic sources exhibited an increase in growth related attributes of lettuce probably due to balanced C: N ratio, better organic matter build-up, 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. Superiority of vermicompost over farmyard manure in improvement of growth related character of lettuce might be attributed to its nutritional richness, quick mineralization, more availability of nitrogen and other plant nutrients. In addition, vermicompost contains growth-promoting substances thus, leading to better growth whether applied alone or in combination with inorganic

Table 3 Treatment-wise comparative economics or cost of cultivation of lettuce

Treatment	Cost on 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 income (Rs/ha)	Net income (Rs/ha)	Additional returns over control (Rs/ha)	Net returns/ Re invested (B : C ratio)
S ₁ N ₁	7 897	35 743	43 641	23.86	2 38 600	1 94 958	1 06 002	4.46
S ₁ N ₂	8 233	35 743	43 977	23.65	2 36 500	1 92 522	1 03 566	4.37
S ₁ N ₃	8 700	35 743	44 443	20.24	2 02 400	1 57 956	69 000	3.55
S ₁ N ₄	11 623	35 743	47 367	26.04	2 60 400	2 13 032	1 24 041	4.49
S ₁ N ₅	15 210	35 743	50 953	20.79	2 07 900	1 56 946	73 310	3.08
S ₁ N ₆		35 743	35 743	12.47	1 24 700	88 956		3.48
S ₂ N ₁	7 897	34 243	42 141	20.61	2 06 100	1 63 958	94 502	3.89
S ₂ N ₂	8 233	34 243	42 477	20.75	2 07 500	1 65 022	58 966	3.88
S ₂ N ₃	8 700	34 243	42 943	17.23	1 72 300	1 29 356	58 500	3.01
S ₂ N ₄	11 623	34 243	45 867	23.13	2 31 300	1 85 432	1 14 541	4.04
S ₂ N ₅	15 210	34 243	49 453	17.38	1 73 800	1 24 346	50 490	2.31
S ₂ N ₆		34 243	34 243	10.51	1 05 100	70 856		2.06
S ₃ N ₁	7 897	32 743	40 641	17.76	1 77 600	1 36958	75 202	3.36
S ₃ N ₂	8 233	32 743	40 977	16.76	1 67 600	1 26 622	64 866	3.09
S ₃ N ₃	8 700	32 743	41 443	14.01	1 40 100	98 556	36 800	2.38
S ₃ N ₄	11 623	32 743	44 367	18.76	1 87 600	1 43 232	81 441	3.22
S ₃ N ₅	15 210	32 743	47 953	15.03	1 50 300	1 02 343	40 587	2.13
S ₃ N ₆		32 743	32 743	9.45	94 500	61 756		1.88

S₁, 30 cm × 20 cm ; S₂, 30 cm × 30 cm; S₃, 30 cm × 40 cm, Sale rate of lettuce: Rs 1 000/100 kg; 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)

fertilizers. These observations are in line with the findings of Morselli *et al.* (2004) and Ghuge *et al.* (2007).

Plant nutrition exhibited a significant effect on leaf yield and its attributing characters of lettuce. Maximum values of average leaf weight (20.80 g and 13.10 g), leaf weight/plant (452.04 g and 472.67 g) and leaf yield/plot (9.10 kg and 9.25 kg) were recorded with application of 50% recommended fertilizer dose + 3 tonnes vermicompost/ha during autumn and spring season, respectively, whereas maximum petiole mid rib weight were recorded with the sole application of inorganic fertilizer 120 : 90 : 60 NPK kg/ha, ie 100% recommended fertilizer dose. Among sole application of organic sources, vermicompost @ 6 tonnes/ha recorded higher values for average leaf weight, petiole mid-rib weight, leaf weight/plant and leaf yield/plot during both the seasons.

Integration of different organic and inorganic sources exhibited significant increase in yield and its attributing characters of lettuce. This could be due to the balanced C : N ratio, more decomposition, more mineralization and more availability of macro and micronutrients. All this might have accelerated the synthesis of carbohydrates and its better translocation from sink to source resulting an improvement in yield and its attributes of lettuce.

Vermicompost proved its superiority in enhancing yield and its attributes of lettuce over farmyard manure, whether used as a sole application or in conjunction with inorganic fertilizers. This superiority could be attributed to nutritional

richness, production of growth-promoting substances, balanced C : N ratio, efficient microbial activity leading to sustainable nutrient availability and improvement in soil physical conditions. All these properties might have led to better root proliferation, better translocation of plant nutrients and accelerated carbohydrate synthesis, finally leading to better leaf yield. The higher value for petiole mid rib weight due to inorganic fertilizer could be attributed to quick release of nutrients by inorganic fertilizer in sufficient amount. Similar results were reported by Xu *et al.* (2003), and Anez and Espinoza (2003).

As far as quality in terms of dry matter, vitamin C and total carotenoids are concerned, maximum dry matter content (8.76% and 10.30%), vitamin C content (57.72 mg/100 g and 45.62 mg/100 g) and total carotenoids (3.88 mg/100 g and 3.43 mg/100 g) were recorded with the sole application of vermicompost @ 6 tonnes/ha during autumn and spring season, respectively. Among the integrated treatments of organic and inorganic fertilizers, application of 50% recommended fertilizer dose + 3 tonnes vermicompost/ha registered higher values for dry matter content, vitamin C content and total carotenoids. Improvement in quality attributes of lettuce due to sole application of organic sources and their integration with inorganic fertilizers could be attributed to better and balanced nutrition and production of growth-promoting substances by organics, which might have led to better quality. Improvement in quality of lettuce can

also be attributed to the improvement in soil physical, chemical and biological properties leading to better root proliferation, improved nutrient uptake and better accumulation of photosynthates. The superiority of vermicompost over farmyard manure might be attributed to their nutritional richness and stimulatory behaviour. These findings are in accordance with the findings of Xu *et al.* (2003) and Premuzic *et al.* (2004).

The present investigation revealed that the lettuce transplanted at 45 cm × 30 cm plant spacing with application of 50% recommended fertilizer dose + 3 tonnes vermicompost/ha was found most economical and gave the highest benefit : cost ratio of 4.28 : 1. Therefore, the cultivation of lettuce is remunerative and economically viable under integrated nutrient management system.

SUMMARY

The experiment comprised 3 plant spacings and 6 nutrition levels. Among the plant spacing, 45 cm × 60 cm recorded significantly higher values for plant spread, leaf area, number of leaves/plant, average leaf weight, petiole midrib weight, leaf weight/plant, dry matter content, vitamin C content and total carotenoids, whereas significantly highest leaf yield/plot and plant height were recorded at closest spacing of 45 cm × 30 cm due to accommodation of large plant population per unit area. Out of 6 nutrition levels, 50% recommended fertilizer dose + 3 tonnes vermicompost/ha recorded significantly higher values for plant height, plant spread, leaf area, number of leaves/plant, average leaf weight, leaf weight/plant and leaf yield/plot during both the seasons. The highest leaf weight/plant was recorded in the treatment combination of 45 cm × 60 cm plant spacing with 50% recommended

fertilizer dose + 3 tonnes vermicompost/ha, whereas maximum leaf yield (26.04 tonnes/ha) was recorded in the treatment combination of 45 cm × 30 cm plant spacing with 50% recommended fertilizer dose + 3 tonnes vermicompost/ha. While working out economics of each treatment, the highest net profit of Rs 213 032 and benefit:cost ratio of 4.49: 1 was obtained with treatment combination of 45 cm × 30 cm plant spacing with 50% recommended fertilizer dose + 3 tonnes vermicompost/ha.

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