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Effect of plant geometry and organic manures on growth and yield of Radish (*Raphanus sativus* L.)

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Abstract
The present investigation entitled "Effect of plant geometry and organic manures on growth and yield of Radish (*Raphanus sativus* L.)" was conducted during 2020-2021 at the Campus for Research and Advanced Studies, Dhablan, GSSDGS Khalsa College, Patiala. The experiment was laid out in a randomized block design with three replications. The soil of the field was of clayey texture having slightly alkaline pH (7.9), medium in organic carbon (0.59%), medium in available nitrogen (262 kg ha^{-1}), medium in available phosphorus (21.4 kg ha^{-1}) and medium in available potassium (137 kg ha^{-1}). The growth and yield of radish were significantly influenced by T_9 (60 x 7.5 + Vermicompost @ 5 t ha^{-1}. The maximum plant height (35.62 cm) was recorded from the treatment T_3 which was at par with T_6 (34.44 cm). The maximum leaf length at 20 DAS (14.24 cm) was observed with treatment T_3 (30 x 7.5 + Vermicompost @ 5 t ha^{-1}) which was at par with T_6 (13.23 cm) and minimum leaf length was found with T_{10} control (7.41 cm). The highest root yield was recorded in the treatment T_9 (60 x 7.5 + Vermicompost @ 5 t ha^{-1}). The maximum root yield was recorded in T_9 (330.78 q ha^{-1}) which was at par with T_6 (329.60 q ha^{-1}).

Keywords: Plant spacing, varieties, growth, Raphanus sativus, Raphanos

Introduction
Radish (*Raphanus sativus* L.) is one of the most popular root vegetable crops in both tropical and temperate regions. It belongs to the family Cruciferae and the chromosome number of this crop is 2n=18. Radish is basically a cool season crop. The word Radish is derived from "Radix" the Latin word that means root. The Latin word 'Raphanos' means 'easily reared'. It is an important kitchen garden and cash crop. Radish is grown throughout the country and throughout the year. It is a short-duration crop and takes 30-60 days to reach maturity. It is a highly cross-pollinated crop. The edible part of a radish is a modified root (fusiform) which develops from the primary root and hypocotyls. It has some medicinal value like 100 g edible roots contain 93.7 percent water, 4.2 carbohydrates, 1.1 percent fat, 0.03 mg niacin, 25 mg vitamin C, and 30 mg calcium. The radish leaves are rich in minerals and vitamins A, B and vitamin C. *Mougri/monogram* or rat-tailed radish (*Raphanus caudatus* L.) does not form fleshy roots (Dhaliwal 2018) [2]. The cultivation of crops depends upon plant spacing and different genotypes. It is a well-established fact that plant spacing has a significant impact on the growth and yield of crops. Optimal plant spacing may help the farmer to achieve more returns per unit area because of the coherent utilization of light, nutrients and water by the plants. Increasing the plant density reduced the curd size but increased the total curd. Plants grown at distance spacing received more sunlight and nutrients, moisture, soil aeration and increased the curd size, curd weight and number of leaves $plant^{-1}$ (Gogoi, *et al*. 2016) [11].

Materials and Methods
The field Studies "Effect of plant geometry and organic manures on growth and yield of Radish (*Raphanus sativus* L.) under different plant spacing on growth and yield parameters" were conducted at the Campus for Research and Advanced Studies Dhablan, GSSDGS Khalsa College, Patiala, during the *rabi* season of the 2020-21. The soil of the experimental field was clay with a pH 7.3. The experiment was laid out in the randomized block design (RBD) with 10 treatments and 3 replications. In each plot, 5 plants were selected randomly and tagged for recording different observations at different growth stages. The plant height of each plant was recorded from the base to the tip of the plant. The data were recorded from each plot at monthly intervals i.e., 20, 30, 40 DAS and at harvesting.

The samples for various parameters were collected from the plots. The weight of harvested crop was recorded from the net plot area and expressed in quintals per hectare after subtracting the root yield.

Results and Discussion

Plant height is an important parameter of radish plant growth during the growth and development period. The treatment combination in this study showed significant results on the 20, 30, and 40 DAS and at harvest. The maximum plant height at 20 DAS (16.15 cm) was observed with treatment T_3 (30 x 7.5 + Vermicompost @ 5 t ha^{-1}) which was at par with T_6 (15.11 cm) and minimum plant height was found with T_{10} control (8.24 cm). The maximum plant height at 30 DAS (24.28 cm) was observed with T_3 which was at par with T_6 (23.18 cm) and the lowest plant height obtained from T_{10} control (16.56 cm). At 40 DAS the maximum plant height was observed with T_3 (32.65 cm) which was at par with T_6 (31.64 cm). The minimum plant height (23.70 cm) was recorded in T_{10}. Similarly, at the time of harvesting, the maximum plant height (35.62 cm) was recorded from the treatment T_3 which was at par with T_6 (34.44 cm). The lowest plant height was obtained from the T_{10} control (26.13 cm).

The effect of plant geometry and vermicompost showed maximum plant height and appropriate results as compared to control at different DAS due to the fact that wider plant spacing minimizes competition for nutrition, light, radiation, water and vegetative growth in early plantings stages, resulting in more photosynthetic translocation from leaves to roots. The increase in plant height with the application of vermicompost due to higher nutritional composition and increasing the water holding capacity of soil Rajan and Mahalakshmi (2007) [7]. Vermicompost is a pure organic fertilizer or soil enhancer produced from animal manure and crop residues through the action of earthworms. The effect of different treatment combinations on leaf length at 20, 30, and 40 DAS and at harvest of radish was significant. The maximum leaf length at 20 DAS (14.24 cm) was observed with treatment T_3 (30 x 7.5 + Vermicompost @ 5 t ha^{-1}) which was at par with T_6 (13.23 cm) and minimum leaf length was found with T_{10} control (7.41 cm). The maximum leaf length at 30 DAS (23.77 cm) was observed with T_3 which was at par with T_6 (22.73 cm) and the lowest leaf length obtained from T_{10} control (15.98 cm). At 40 DAS the maximum leaf length was observed with T_3 (27.60 cm) which was at par with T_6 (26.44 cm). The minimum leaf length (20.32 cm) was recorded in the T_{10} control. Similarly, at the time of harvesting the maximum leaf length (29.51 cm) was recorded from the treatment T_3 which was at par with T_6 (28.51 cm). The lowest leaf length was obtained from the T_{10} control (21.66 cm).

All the treatments were influenced the leaf length at every stage of growth differently. The increase in leaf length due to wider plant spacing which minimizes competition for light, nutrition, radiation, water and vegetative growth in early plantings stages, results in more photosynthetic translocation from leaves to roots. Vermicompost plays an important role in good plant growth because it improves the physical condition of soil as well as nutrient availability for plants. The vegetative parameters like leaf length were greatly influenced by organic manures also. The treatment 60x 7.5 + Vermicompost @ 5 t ha^{-1} has recorded the best results in the case of a number of leaves $plant^{-1}$. The maximum number of leaves at 20 DAS (9.50) was observed with treatment T_9 (60 x 7.5 + Vermicompost @ 5 t ha^{-1}) which was at par with T_6 (8.95) and a minimum number of leaves were found with T_{10} control (4.85). Similarly, the maximum number of leaves at 30 DAS (11.90) were observed with T_9 which was at par with T_6 (11.37) and the lowest number of leaves were obtained from the T_{10} control (6.93). At 40 DAS the maximum number of leaves were observed with T_9 (13.65) which was at par with T_6 (12.63). The minimum number of leaves (8.81) were recorded in T_{10}. Similarly, at the time of harvesting, the maximum number of leaves (14.85) were recorded from the treatment T_9 which was at par with T_6 (13.83). The lowest number of leaves were obtained from the T_{10} control (9.98).

The number of leaves per plant influenced by the treatment 60x 7.5 + Vermicompost @ 5 t ha^{-1} at different stages i.e. 20, 30, 40 DAS and at harvest time. The number of leaves increased with wider spacing due to the availability of more nutrients, water light, and less competition have resulted more number of leaves Chhetri *et al*. (2019) [1]. With the application of vermicompost, the vegetative parameters like the number of leaves increased with the integration of NPK. Vermicompost plays an important role in good plant growth because it improves the physical condition of soil as well as nutrient availability for plants. Due to nutrient composition and it may also be due to the rapid elongation and multiplication of cells in the presence of an adequate quantity of nitrogen. Similar results in growth parameters were observed by Uddain *et al*. (2010) and Kumari, *et al*. (2012) [9, 5] in radish who found that vegetative parameters increased with organic manure application this may be due to the effect of macro and micronutrient on growth parameters which increased the photosynthetic activity, chlorophyll formation, nitrogen metabolism and nitrogen helps in greater assimilation of food material by the plant which resulted in greater meristematic activities of cell which ultimately increases number of leaves. Due to the higher uptake of nutrients i.e. iron and magnesium from the soil and decrease in bulk density and increase water holding capacity and an increase in the porosity of the soil. The result of the present study are in accordance with the findings of previous workers on organic manure i.e. Ghimire *et al*. (2020) and Kushwah *et al*. (2020) in radish [3, 6].

The highest root yield was recorded in the treatment T_9 (60 x 7.5 + Vermicompost @ 5 t ha^{-1}). The maximum root yield was recorded in T_9 (330.78 q ha^{-1}) which was at par with T_6 (329.60 q ha^{-1}). The minimum root yield was observed from treatment T_{10} control (104.21 q ha^{-1}). It is recorded that the root yield of radishes increased in different way with vermicompost application and wider plant spacing resulted maximum root yield which attributes to the optimum plant population and individual characteristics of plant slant Sharma *et al*. (2013) [8]. The yield or root is directly influenced by the availability of nutrients to the plants. The above result was compiled with Yassen *et al*. (2019) [10] in cauliflower and Kumar *et al*. (2018) [4] in radish.

Table 1: Effect of plant geometry and organic manures on plant height (cm) of radish (*Raphanus sativus* L)

Treatments	Plant height (cm)			
	20 DAS	30 DAS	40 DAS	At harvesting
T_1 : 30 x 7.5 + FYM @ 20 tha^{-1}	11.14	19.67	25.80	28.51
T_2 : 30 x 7.5 + Poultry Manure @ 5 tha^{-1}	12.46	20.88	27.74	30.87
T_3 : 30 x 7.5 + Vermicompost @ 5 tha^{-1}	16.15	24.28	32.65	35.62
T_4 : 45 x 7.5 + FYM @ 20 tha^{-1}	11.91	20.25	26.14	29.95
T_5 : 45 x 7.5 + Poultry Manure @ 5 tha^{-1}	13.08	21.10	28.31	31.77
T_6 : 45 x 7.5 + Vermicompost @ 5 tha^{-1}	15.11	23.18	31.64	34.44
T_7 : 60 x 7.5 + FYM @ 20 tha^{-1}	10.84	18.98	24.64	27.61
T_8 : 60 x 7.5 + Poultry Manure @ 5 tha^{-1}	11.18	20.68	26.52	29.32
T_9 : 60 x 7.5 + Vermicompost @ 5 tha^{-1}	13.38	22.34	30.75	32.2
T_{10} : Control	8.24	16.56	23.70	26.13
SE (m) ±	0.43	0.62	0.44	0.54
CD (P=0.05)	0.98	1.41	1.01	1.23

Table 2: Effect of plant geometry and organic manures on leaf length (cm) of radish (*Raphanus sativus* L.)

Treatments	Leaf length (cm)			
	20 DAS	30 DAS	40 DAS	At harvesting
T_1 : 30 x 7.5 + FYM @ 20 tha^{-1}	9.21	17.57	22.80	24.53
T_2 : 30 x 7.5 + Poultry Manure @ 5 tha^{-1}	11.76	19.47	24.32	26.53
T_3 : 30 x 7.5 + Vermicompost @ 5 tha^{-1}	14.24	23.77	27.60	29.51
T_4 : 45 x 7.5 + FYM @ 20 tha^{-1}	10.98	18.71	23.43	25.61
T_5 : 45 x 7.5 + Poultry Manure @ 5 tha^{-1}	11.98	20.87	25.38	27.19
T_6 : 45 x 7.5 + Vermicompost @ 5 tha^{-1}	13.23	22.73	26.44	28.51
T_7 : 60 x 7.5 + FYM @ 20 tha^{-1}	9.94	17.01	22.50	24.65
T_8 : 60 x 7.5 + Poultry Manure @ 5 tha^{-1}	11.18	19.84	24.63	26.58
T_9 : 60 x 7.5 + Vermicompost @ 5 tha^{-1}	12.17	21.70	25.41	27.49
T_{10} : Control	7.41	15.98	20.32	21.66
SE (m)±	0.48	0.46	0.45	0.45
CD (P=0.05)	1.09	1.04	1.03	1.02

Table 3: Effect of plant geometry and organic manures on number of leaves plant^{-1} of radish (*Raphanus sativus* L.)

Treatments	No. of leaves plant^{-1}			
	20 DAS	30 DAS	40 DAS	At harvesting
T_1 : 30 x 7.5 + FYM @ 20 tha^{-1}	5.37	7.28	9.18	10.20
T_2 : 30 x 7.5 + Poultry Manure @ 5 tha^{-1}	6.15	8.51	10.15	11.88
T_3 : 30 x 7.5 + Vermicompost @ 5 tha^{-1}	7.84	9.78	11.95	12.61
T_4 : 45 x 7.5 + FYM 20 tha^{-1}	5.98	8.08	10.02	10.98
T_5 : 45 x 7.5 + Poultry Manure @ 5 tha^{-1}	7.35	9.58	11.98	12.64
T_6 : 45 x 7.5 + Vermicompost @ 5 tha^{-1}	8.95	11.37	12.63	13.83
T_7 : 60 x 7.5 + FYM @ 20 tha^{-1}	6.75	8.82	10.84	11.57
T_8 : 60 x 7.5 + Poultry Manure @ 5 tha^{-1}	7.85	9.45	11.88	12.05
T_9 : 60 x 7.5 + Vermicompost @ 5 tha^{-1}	9.50	11.90	13.65	14.85
T_{10} : Control	4.85	6.93	8.81	9.98
SE (m) ±	0.33	0.23	0.46	0.44
CD (P=0.05)	0.76	0.52	1.04	1.01

Table 4: Effect of plant geometry and organic manures on root yield (q ha^{-1}) of radish (*Raphanus sativus* L.)

Treatments	Root Yield (q ha^{-1})
T_1 : 30 x7.5 + FYM @ 20 t ha^{-1}	185.65
T_2 : 30 x 7.5 + Poultry Manure@ 5 t ha^{-1}	200.75
T_3 : 30 x 7.5 + Vermicompost @5 t ha^{-1}	235.71
T_4 : 45 x 7.5 + FYM @ 20 t ha^{-1}	255.71
T_5 : 45 x 7.5 + Poultry Manure @ 5 t ha^{-1}	245.46
T_6 : 45 x 7.5 + Vermicompost @ 5 t ha^{-1}	329.60
T_7 : 60 x 7.5 + FYM @ 20 t ha^{-1}	239.53
T_8 : 60 x 7.5 + Poultry Manure @ 5 t ha^{-1}	242.62
T_9 : 60 x 7.5 + Vermicompost @ 5 t ha^{-1}	330.78
T_9 : 60 x 7.5 + Vermicompost @ 5 t ha^{-1}	104.21
SE (m) ±	0.52
CD (P=0.05)	1.18

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