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Effect of planting geometry on the growth and foliage yield of drumstick (*Moringa oleifera* L.)

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Abstract
The present investigation was conducted in Randomized Block Design with 03 replications in 09 treatments (2.5m x 1.0 m, 2.5 m x 2.5 m, 1.5 m x 1.0 m, 1.0 m x 1.0 m , 2.5 m x 2.0 m, 1.3 m x 1.0 m, 3.0 m x 2.5 m, 3.0 m x 3.0 m, 1.2 m x 1.2 m) and result concluded that the growth and yield parameter was found significantly superior in treatment T_6 (1.3 m x 1.0 m) for most of the characters i.e. stem girth (5.70 cm), number of branches/plant (16.27), number of leaflets/rachis (62.32), length of rachilla/plant (16.57 cm), leaflet length (24.10 cm), petiole length (12.54 cm), leaflet-petiole ratio (2.03), canopy spread (171.00 cm), fresh leaf weight (327.80 gm), dry leaf weight (73.55 gm), fresh leaf yield (2521.54 Kg/ha), dry leaf yield (565.74 kg/ha), dry matter percentage (22.43) and B: C ratio fresh leaves (3.04) and dry leaves (7.29).

Keywords: Planting geometry, foliage yield, Moringa and drumstick

Introduction
The drumstick (*Moringa oleifera* L) is one of the important perennial vegetables grown in India. It is popular because of its unique flavor and attractive taste. Moringa is also known as a '4F Plant' (Food, Fodder, Fuel & Fertility). Spacing is an important factor used to optimize tree growth, development and leaf yield per unit area of land, the trees should be established at the spacing that will produce maximum economic yields of crops. Many farmers are cultivate drumsticks for leafy purposes, but they are not aware of the optimum spacing. Planting at high density would increase the competition for nutrient space and light, which reduced the number of leaves per plant and the number of plants per unit area. Proper spacing is essential to get the maximum yield of Moringa leaves and better quality.

Materials and Methods
The experiment was conducted during Rabi, 2021-22 at the Instructional Farm, RABL College of Agriculture and Research Station Chhuikhadan, Dist- Khairagarh-Chhuikhadan-Gandai, Chhattisgarh, India. The experiment was laid out in Randomized Block Design with 3 replications and 9 treatments (spacing 2.5 m x 1.0 m, 2.5 m x 2.5 m, 1.5 m x 1.0 m, 1.0 m x 1.0 m, 2.5 m x 2.0 m, 1.3 m x 1.0 m, 3.0 m x 2.5 m, 3.0 m x 3.0 m, 1.2 m x 1.2 m). Drumstick (var. PKM-1) was used under present investigation. The nursery poly bag (pot mixture) filled with 1:2:1 sand: vermicompost: soil at 12x12 inches. After 30 days the plant was transplanted in the experimental field according to different spacing. The Recommended cultural packages of practice were adopted for well crop growth. The average values of each character were calculated based on randomly selected five plants in each replication and each treatment. The collected data on different parameters will be statistically analyzed by adopting the procedures suggested by Panse and Sukhatme (1995) [11].

Results and Discussion
Data Table 1 shows that the plant height ranged from 117.2 to 144.5 cm and the overall mean was 126.16 cm at the final stage of harvesting (270 days after planting). The maximum plant height 144.5 cm was recorded in T9 (1.2 m x1.2 m) (Control), whereas the minimum plant height (117.2 cm) was observed in T1 (2.5 m x 1.0 m). Saint Sauveur (1992) [7] reported that the medium and wider spacing resulted in the greatest plant height growth, while the narrow spacing recorded the lowest plant height. Data recorded at the 270 days after planting, showed that the maximum stem base diameter (9.15) was measured in T_6 (1.3 m x 1.0 m), while the

minimum stem base diameter (4.83) was found in T_1 (2.5 m x 1.0 m). Teixeira *et al.* (2010) [10] also observed by the increase in the stem base diameter was due to its continual growth during the experimental period, as the plants were cut at one meter above the ground.

Table 1 exhibited that the maximum stem girth (5.70 cm) was recorded in T6 (1.3 m x 1.0 and the minimum stem girth (2.88 cm) was noted in T5 (2.5 m x 2.0 m) at 270 days after planting. On other hand, the maximum number of branches per plant (16.27) was measured in T_6 (1.3 m x 1.0 m). Adegun and Ayodele (2015) [2] finding the total yield increased as the cutting interval was prolonged because trees release more buds after harvesting, stimulate fast regrowth and develop high leafy retention and coppicing capacity after cutting.

Table 1: Effect of different planting geometry on various growth parameters in drumstick at 270 DAP.

Tr. No.	Treatment Details (R X P)	Plant height (cm)	Stem base diameter (cm)	Stem girth (cm)	Number of branches per plant
T_1	2.5m x 1.0 m	117.20	4.83	2.99	10.27
T_2	2.5 m x 2.5 m	121.93	5.50	3.59	10.80
T_3	1.5 m x1.0 m	124.93	6.23	4.13	13.93
T_4	1.0 m x 1.0 m	126.60	7.06	5.67	14.47
T_5	2.5 m x 2.0 m	124.20	4.87	2.88	11.67
T_6	1.3 m x 1.0 m	128.87	9.15	5.70	16.27
T_7	3.0 m x 2.5 m	122.67	5.58	3.60	12.10
T_8	3.0 m x 3.0 m	124.53	5.48	3.05	13.00
T_9	1.2 m x 1.2 m (Check)	144.53	6.34	4.54	13.67
	SEm (±)	2.215	0.14	0.175	0.277
	CD (5 %)	6.699	0.425	0.23	0.838
	CV (%)	3.04	3.976	7.553	3.717

It was revealed from data recorded at 270 days after planting (Table 2), showed that the highest number of leaflets per rachis 62.32 cm and maximum length of rachilla per plant 16.57 cm was recorded in T_6 (1.3 m x 1.0 m). The highest canopy spread per plant 171.0 cm was also calculated in T_6 (1.3 m x 1.0 m). Santosa *et al.* (2021) [8] observed the plants grown with larger spacing displayed higher lateral growth, producing denser canopies, due to the lower competition among the plants. Another finding is the appropriate cutting management stimulated shoot growth and canopy size in the Guava plant Sutarno and Rosyida (2020) [9]. Data recorded at 270 days after planting (Table 2), showed that the highest leaflet length per plant (24.10) was measured in T_6 (1.3 m x 1.0 m), while the highest petiole length per plant 12.54 cm was observed in T_4 (1.0 m x 1.0 m). The highest leaflet-petiole ratio 2.03 was found in T_6 (1.3 m x 1.0 m), which was found statistical similar T_3 (1.5 m x 1.0 m) 1.99, T_9 (1.2 m x 1.2 m) 1.91 under the study (Table 2).

Table 2: Effect of different planting geometry on various leaf growth attributes in drumstick at 270 DAP.

Tr. No.	Treatment Details (R X P)	Number of leaflets per rachis	Length of rachilla per plant (cm)	Canopy spread per plant (cm)	Leaflet length (cm)	Petiole length (cm)	Leaflet-petiole ratio
T_1	2.5m x 1.0 m	26.15	10.53	124.86	14.38	9.26	1.55
T_2	2.5 m x 2.5 m	26.17	10.68	123.83	17.36	11.53	1.52
T_3	1.5 m x1.0 m	48.16	13.45	147.10	20.86	10.46	1.99
T_4	1.0 m x 1.0 m	59.97	15.53	150.38	21.71	12.54	1.73
T_5	2.5 m x 2.0 m	39.85	11.35	135.93	20.19	11.77	1.72
T_6	1.3 m x 1.0 m	62.32	16.57	171.00	24.10	11.91	2.03
T_7	3.0 m x 2.5 m	41.15	11.67	137.25	20.85	11.40	1.83
T_8	3.0 m x 3.0 m	48.07	12.17	143.83	19.79	10.96	1.80
T_9	1.2 m x 1.2 m (Check)	54.90	12.77	141.67	21.05	11.03	1.91
	SEm (±)	1.254	0.359	3.854	1.01	0.645	0.063
	CD (5 %)	3.792	1.085	11.655	3.054	N/A	0.19
	CV (%)	4.807	4.876	4.709	8.733	9.975	6.086

The higher fresh leaf weight 327.8 gm/plant was measured in T_6 (1.3 m x 1.0 m), which was found dominant among all the treatments under study (Table 3). Mabapa *et al.* (2017) [6] in their research reported an increase in biomass accumulation due to higher planting density effect on the leaf yield. The highest dry leaf weight (gm/plant) (73.55) was measured in T_6 (1.3 m x 1.0 m), which was found superior among all the treatments at 270 days after planting. A similar study conducted by Adegun and Ayodele (2015) [2] showed that the dense population of Moringa produced the highest Moringa dry leaf biomass yield compared to the spacious spacing.

Data recorded at the final stage 270 days after planting, showed that the highest fresh leaf yield (2521.45 kg per hectare) and the maximum dry leaf yield (62.32 kg per hectare) were measured in T_6 (1.3 m x 1.0 m) and the lowest fresh leaf yield (229.0 kg per hectare) and minimum dry leaf yield (26.15 kg per hectare) were found in T_2 (2.5 m x 1.0 m) (Table 3).The cutting was prolonged because trees release more buds after harvesting, stimulate fast regrowth, and develop high leafy retention and coppicing capacity after cutting during the dry season as agreed by Lazer (1981) [5]. Abdullahi and Maishanu (2021) [1]. Table 3 also exhibited that the highest dry matter percentage (%) (22.43) was noted in T_6 (1.3 m x 1.0 m). Goss (2012) [4] have also reported an increase in plant dry matter accumulation with an increase in planting density.

Table 3: Effect of different planting geometry on various yield parameters in drumstick at 270 DAP.

Tr. No.	Treatment Details (R X P)	Fresh leaf weight (gm/plant)	Dry leaf weight per plant (gm)	Fresh leaf yield (Kg/ha)	Dry Leaf yield (Kg/ha)	Dry matter percentage
T_1	2.5m x 1.0 m	152.00	30.65	608.00	122.59	20.15
T_2	2.5 m x 2.5 m	149.00	29.78	238.40	47.65	19.97
T_3	1.5 m x1.0 m	236.36	52.87	1575.75	352.47	22.37
T_4	1.0 m x 1.0 m	245.23	53.05	2452.33	530.47	21.63
T_5	2.5 m x 2.0 m	167.60	31.83	335.20	63.67	19.00
T_6	1.3 m x 1.0 m	327.80	73.55	2521.54	565.74	22.43
T_7	3.0 m x 2.5 m	188.33	37.47	251.11	49.96	19.90
T_8	3.0 m x 3.0 m	206.10	43.82	229.00	48.69	21.27
T_9	1.2 m x 1.2 m (Check)	219.37	45.18	1523.38	313.75	20.60
	SEm (±)	4.644	1.463	32.883	9.546	0.459
	CD (5 %)	14.042	4.424	99.433	28.865	1.387
	CV (%)	3.826	5.727	5.266	7.103	3.818

Selling price = 500 Rs Kg^{-1}

Economics is the most important aspect of any research upon which the recommendation depends and tests the feasibility of the technology. Until and unless a farmer is well convinced about a purposeful gain from a particular package of practices, he would not be willing to adopt the same. The cost of cultivation for fresh leaves is presented in Table 4 and data revealed that the minimum cost of cultivation (Rs 25098 ha^{-1}) was calculated for T_2 (2.5 m x 2.5 m) and maximum cost of cultivation (Rs 82584ha^{-1}) was observed for T_4 (1.0 m x 1.0 m) under study. The highest net returns of cultivation (Rs 230116 ha^{-1}) and highest B:C Ratio (3.48) were calculated for treatment T_6 (1.3 m x1.0 m) while, the lowest net return (Rs2870 ha^{-1}) and lowest B:C Ratio (0.11) was observed for T_8 (3.0 m x 3.0 m) for fresh leaves.

Table 4: Performance of planting geometry on benefit-cost ratio for fresh leaves.

Tr. No.	Treatment Details (R X P)	Cost of cultivation	Gross Return	Net Return	Benefit Cost Ratio
T_1	2.5m x 1.0 m	49443	78333	28890	0.58
T_2	2.5 m x 2.5 m	25098	29341	4243	0.17
T_3	1.5 m x1.0 m	62646	197943	135297	2.16
T_4	1.0 m x 1.0 m	82584	301848	219264	2.66
T_5	2.5 m x 2.0 m	27768	44243	16475	0.59
T_6	1.3 m x 1.0 m	75711	305827	230116	3.48
T_7	3.0 m x 2.5 m	27322	31864	4542	0.17
T_8	3.0 m x 3.0 m	26132	29002	2870	0.11
T_9	1.2 m x 1.2 m (Check)	69504	194381	124877	1.80

Selling price = 50 Rs Kg^{-1}

The cost of cultivation data for dry leaves is presented in Table 5, data revealed that minimum cost of cultivation (Rs 26348 ha^{-1}) was calculated for T_2 (2.5 m x 2.5 m) and the maximum cost of cultivation (Rs 89334 ha^{-1}) was noted for T_4 (1.0 m x 1.0 m) under study, whereas the highest net returns of cultivation (Rs 525552 ha^{-1}) were calculated for treatment T_6 (1.3 m x 1.0 m) and the lowest net return (Rs 31929 ha-1) was fond for T_2 (2.5 m x 2.5 m). Table 5 revealed that the highest B: C Ratio (6.96) was also obtained in treatment T_6 (1.3 m x 1.0 m), whereas lowest B: C Ratio 1.18 was obtained in T_7 (3.0 m x 2.5 m) for dry leaves.

Table 5: Performance of planting geometry on benefit-cost ratio for dry leaves.

Tr. No.	Treatment details	Total cost	Gross return	Net return	Benefit Cost Ratio
T_1	2.5 x 1.0 m	52818	157600	104782	1.98
T_2	2.5 x 2.5 m	26348	58277	31929	1.21
T_3	1.5 x 1.0 m	67146	445033	377887	4.62
T_4	1.0 x 1.0 m	89334	650333	471665	5.27
T_5	2.5 x 2.0 m	29018	83957	54939	1.89
T_6	1.3 X1.0 m	77411	683423	525552	6.96
T_7	3.0 X 2.5 m	28572	62363	33791	1.18
T_8	3.0 X 3.0 m	27382	61717	34335	1.25
T_9	1.2 X 1.2 m (check)	74004	398462	324458	4.38

Conclusion

The growth and yield parameter on different planting geometry was obtained significantly superior in treatment T6 (1.3 x1.0 m) for most of the parameters i.e. stem girth (5.70 cm), number of branches/plant (16.27), number of leaflets/rachis (62.32), length of rachilla/plant (16.57 cm), leaflet length (24.10 cm), petiole length (12.54 cm), leaflet-petiole ratio (2.03), canopy spread (171.00 cm), fresh leaf weight (327.80 gm), dry leaf weight (73.55 gm), fresh leaf yield (2.03 t/ha), dry leaf yield (565.74 kg/ha), dry matter percentage (22.43) and B:C ratio fresh leaves (3.04) and dry leaves (7.29).

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