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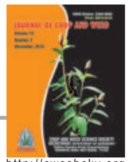

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Spacing and propagule size on yield and quality of *Curcuma aromatica* Salisb.

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ABSTRACT

A study was conducted at the Department of Agronomy fram, College of Agriculture Vellanikkara to assess the influence of spacing and propagule size on the growth, yield and quality of Curcuma aromatica from May 2021 to December 2021. The experiment design was a two-factor completely randomized block design with three replications. The factor A included three spacings (60 cm x 40 cm, 40 cm x 25 cm, and 25 cm x 25 cm). Factor B consisted of average propagule size (~ 5 g, ~ 10 g, and ~ 20 g). A closer spacing of 25 cm × 25 cm was comparable to 40 cm x 25 cm regarding plant height (123.79 cm and 118.93 cm, respectively). The shortest plants were under broader spacing of 60 cm x 40 cm. Concerning the effect of the size of propagules on the plant height of Curcuma aromatica, taller plants were obtained when large-sized propagules (20 g) were used for planting (122.21 cm). It was on par with medium-sized (10 g) propagules (117.82 cm). Six months after planting, the 60 cm × 40 cm spacing was found to have significantly more leaves (10.75) than the other two. The treatment combination of wider spacing 60 cm x 40 cm and bigger propagules (20 g) produced a higher number of tillers, rhizome length, number of rhizomes, rhizome yield per plant, and essential oil content. It was on par with 60 cm x 40 cm spacing with 10 g propagules. The per hectare yield was significantly higher in closer plant spacing of 25 cm x 25 cm (21461 Kg ha^{-1}). Compared to wider spacing, the yield increase in closer spacing was 11901 Kg ha^{-1} (124.49 %).

***Keywords**: Curcuma aromatica*, propagule size, quality, rhizome yield, spacing

Curcuma aromatica Salisb., commonly referred to as wild turmeric, is a plant in the Zingiberaceae family and belongs to the genus Curcuma. The medicinal property of Curcuma aromatica is well known since ancient times. Rhizomes are considered antibacterial and antifungal and renowned for their cosmetic use. The annual trade of *Curcuma aromatica* is between 50-100 MT $year^{-1}$ (National Medicinal Plants Board, 2022)

Despite a wide range of applications and good export potential, the cultivation of *Curcuma aromatica* has not become wide spread, mainly because of ignorance of the crop's true identity. This makes it easy for the vendors to sell any commonly available *Curcuma* species, especially *Curcuma zedoaria*, at an enhanced price as *Curcuma aromatica*. Increased demand coupled with the high rate of substitution demands urgent measures for popularizing the cultivation of *Curcuma aromatica*. Proper spacing is a crucial requirement for giving an equal chance for all plants to utilize resources and get higher production. Gopichand *et al*. (2006) assessed the effect of plant spacing on the growth and yield of *Curcuma aromatica* and reported variations in growth and yield parameters due to spacing. The amount of stored reserves existing in the tuber, corm, rhizomes or bulb at the moment of planting affects the growth and development of geophytic and other vegetatively propagated plants. By optimizing propagule size, one might reduce the need for seed rhizomes without sacrificing economic production (Padmadevi *et al*., 2012).

In this background, a study was conducted at the Department of Agronomy, College of Agriculture, Vellanikkara to assess the influence of spacing and propagule size on the growth, yield, and quality of *Curcuma aromatica.*

The field experiment was conducted at the Department of Agronomy farm, College of Agriculture, Vellanikkara, Thrissur, Kerala (latitude 13° 32'N and longitude 76° 26'E and 40 m above mean sea level) from May to December 2021. The field soil was sandy clay loam, pH was 4.7 (acidic), available N was 145 Kg ha^{-1} (low), available P was 25 Kg ha^{-1} (high), and available K was 220 Kg ha^{-1} (medium).

The trial was laid out in two factor completely randomized block design with three replications. The factor A included three spacings (60 cm x 40 cm, 40 cm x 25 cm and 25 cm x 25 cm). Factor B consisted of propagule size (~ 5 g, ~ 10 g and ~ 20 g).

A disc plough was used to plough the trial area thoroughly, and a cultivator was used to create fine tilth.

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The individual plots were prepared as per the layout plan. Planting was done on raised beds as per the spacing treatments. After planting, the beds were mulched with dried leaves. Farmyard manure @ 15 t ha^{-1} was applied as basal. It was fertilised with N: P_2O_5: K_2O @ 100: 50: 50 Kg ha^{-1}. Total phosphate was applied as basal. N and K_2O were applied in two equal split doses, one at basal and the other at two months after planting, coupled with weeding and earthing up. The crop was harvested after seven months when leaves started drying. At 6 MAP (months after planting), plant height measurements, leaf count and tiller count were made. On the day of harvest, rhizome length, rhizome number and rhizome yield were noted.

Hydro distillation method, utilizing the Clevenger equipment, was followed to ascertain the essential oil content of rhizomes at the time of harvest (AOAC, 1975). The data generated from the experiment were analyzed through analysis of variance (ANOVA) with the statistical package 'WASP 2' (ICAR GoI, https://ccari.icar.gov.in/waspnew.html).

The growth and yield characteristics of *Curcuma aromatica* were considerably influenced by variations in spacing and propagule size as well as their interaction (Table 1 and 2). A closer spacing of 25 cm x 25 cm was comparable to 40 cm x 25 cm regarding plant height (123.79 cm and 118.93 cm, respectively). The shortest plants were under broader spacing of 60 cm x 40 cm. Concerning the effect of the size of propagules on the plant height of *Curcuma aromatica*, taller plants were obtained when large-sized propagules (20 g) were used for planting (122.21 cm). It was on par with medium-sized (10 g) propagules (117.82 cm). The plant height of *Curcuma aromatica* was shortest when small-sized propagules (5 g) were used for propagation. Larger propagules contain more extensive reserves that enhance seedling growth, resulting in taller plants. A combination of closer spacing (25 cm x 25 cm) with large-sized propagules (20 g) resulted in the tallest plants, which were 27.34 cm taller than the combination of broader spacing and smaller propagules (60 cm x 40 cm and 5 g). The plant height varied significantly due to the effect of different spacings (Table 1). Kelaskar *et al*. (2020) reported a similar trend of taller *Curcuma* plants with closer spacing. Plants compete more for light, nutrients, fertilizer and space when they were spaced closer together. As a result, the plant may have changed the height of the canopy by elongating the intermodal length, which encouraged more upright growth.

At six months after planting, the 60 cm × 40 cm spacing was found to have significantly more leaves (10.75) than the other two spacings. Closer spacing resulted in lowering of the number of leaves. No significant variation was observed for the number of leaves due to variation in propagule size. The combination of wider spacing and larger propagules resulted in more leaves (11.39) and was on par with wider spacing with a propagule size of 10 g (10.85).

The number of tillers at six months after planting followed the same trend of plant height and number of leaves, with more tillers in 60 cm x 40 cm spacing (2.04). The lower count of tillers was in the closer spacing of 25 cm x 25 cm (1.38). As per Hossain *et al*. (2005), the shoot number per plant was comparatively low when planting was done closer because of insufficient space for growth, resulting in a thinner shoot and less number of shoots. Though statistically insignificant, more tillers were noticed when planting was done with large-sized propagules.

The combination of wider spacing (60 cm x 40 cm) and bigger propagules (20 g) produced a higher number of tillers (2.27) which was on par with wider spacing with 10 g propagules (2.00).

Plants that received a spacing of 60 cm x 40 cm resulted in longer rhizomes (19.05 cm) followed by 40 cm x 25 cm (18.19 cm), which were on par. Similarly, the length of harvested rhizomes increased with the size of propagules. Compared to smaller-sized propagules, the rhizome length of harvested produce increased when bigger propagules were used for planting. A longer rhizome length of 20.88 cm was achieved using propagules weighing 20 g and a spacing of 60 cm x 40 cm. It was comparable to all possible spacing combinations when used along with 20 g propagule.

The number of rhizomes at the time of harvest ranged from 26.85 to 40.93 due to plant spacing changes. The highest number of rhizomes were in 60 cm x 40 cm spacing (40.93), followed by 40 cm x 25 cm (32.08). The number of rhizomes was the highest when large-sized propagules were used as planting material (36.19). Propagule sizes of 10 g and 5 g were on par concerning the number of rhizomes (32.60 and 31.07, respectively). The interaction effect of spacing and propagule size was significant for rhizome number also. The number of rhizomes was higher in the treatment combination of 60 cm x 40 cm spacing with 20 g propagule (44.33), followed by the same spacing with 10 g propagule (42.12), which were on par.

As the number of rhizomes, the per plant rhizome yield was also highest in the wider spacing of 60 cm x 40 cm (286.82 g $plant^{-1}$), which was significantly superior to the other two spacings. The reduction in plant spacing resulted in the lowering of rhizome yield. Compared to 60 cm x 40 cm spacing, the 25 cm x 25 cm specing resulted in a yield reduction of 41.55 % (119.16 g $plant^{-1}$). The per plant rhizome yield also showed

Table 1: Effect of spacing and propagule size on growth and yield of *Curcuma aromatica*

Treatment	Plant height (at 6 MAP) (cm)	No. of leaves (at 6 MAP)	No. of tillers (at 6 MAP)	Rhizome length (at harvest) (cm)	No. of rhizomes (at harvest)	Rhizome yield plant^{-1} (g)	Rhizome yield (Kg ha^{-1})	Essential oil content (%)
Factor A : Spacing								
60 cm x 40 cm	109.30	10.75	2.04	19.05	40.93	286.82	9560	3.07
40 cm x 25cm	118.93	8.81	1.77	18.19	32.08	215.86	17269	3.24
25 cm x 25 cm	123.79	7.12	1.38	17.28	26.85	167.66	21461	3.25
LSD (0.05)	4.87	0.68	0.21	1.39	2.86	17.88	1697.97	NS
Factor B : Propagule size								
5 g	111.99	8.70	1.62	17.16	31.07	195.44	14505	2.75
10 g	117.82	8.96	1.77	18.38	32.60	233.18	16582	3.13
20 g	122.21	9.01	1.81	19.68	36.19	242.01	17203	3.68
LSD (0.05)	4.87	NS	NS	1.39	2.86	17.88	1697.97	0.20

Table 2: Interaction effect of spacing and propagule size on growth and yield of *Curcuma aromatica*

Treatment combination (Spacing x propagule size)		Plant height (at 6 MAP) (cm)	No. of leaves (at 6 MAP)	No. of tillers (at 6 MAP)	Rhizome length (at harvest) (cm)	No. of rhizomes (at harvest)	Rhizome yield plant^{-1} (g)	Rhizome yield (Kg ha^{-1})	Essential oil content (%)
60 cm x 40 cm	5 g	99.23	10.02	1.87	18.15	36.33	233.82	7794	2.58
	10 g	111.03	10.85	2.00	20.22	42.12	306.78	10219	2.88
	20 g	117.65	11.39	2.27	20.88	44.33	320.06	10669	3.75
40 cm x 25cm	5 g	115.49	8.92	1.72	17.07	29.57	193.47	15477	2.83
	10 g	118.87	8.63	1.80	17.87	32.28	224.42	17954	3.23
	20 g	122.41	8.88	1.78	19.63	34.41	229.70	18375	3.65
25 cm x 25 cm	5 g	121.25	7.18	1.27	16.25	27.31	158.15	20243	2.82
	10 g	123.55	7.40	1.52	17.07	23.42	168.55	21574	3.27
	20 g	126.57	6.77	1.37	18.53	29.83	176.28	22564	3.65
LSD (0.05)		8.43	1.18	0.36	2.40	4.96	30.97	2940.96	0.35

variation due to changes in the size of seed rhizomes. Compared to smaller propagules, bigger propagules gave better per plant yield. The per plant rhizome yield in 20 g and 10 g seed rhizomes were on par (242.01 and 233.18 g plant^{-1}, respectively). A yield reduction of 16.18 % occurred when propagule size was reduced from 10 g to 5 g. Increased yields in the treatments with large-sized propagules might have been due to the availability of adequate food stores, which enhanced the early seedling growth, leaf production and the number of tillers. According to Padmadevi *et al*. (2012), the weight of mother rhizomes was positively correlated with rhizome yield. Plants from larger seeds had a more extensive shoot base and produced a higher number of daughter rhizomes, which ultimately increased turmeric output. Both 20 g and 10 g sized propagules were equally better for improving rhizome yield. Following a report on turmeric that revealed an increase in production with an increase in the size of seed rhizomes only up to a certain level after which the yields stagnated, the yield differences between 20 g and 10 g propagules are not statistically significant (Hossain *et al*., 2005).

Wider plant spacing (60 cm x 40 cm) along with large-sized propagules (20 g) produced the higher rhizome yield per plant (320.06 g plant^{-1}) and was on par with the same spacing with 10 g propagules (306.78 g plant^{-1}). The lowest per plant yield was in the treatment combination of closer plant spacing (25 cm x 25 cm) with smaller propagules (5 g). The yield reduction in this treatment combination compared to the best treatment combination was 50.59 %.

Though the per plant yield and yield parameters were better in wider plant spacing of 60 cm x 40 cm, the per hectare yield was significantly higher in closer plant spacing of 25 cm x 25 cm (21461 Kg ha^{-1}). The increase in the rhizome yield per hectare basis under closer spacing may solely be attributed to higher plant density per unit of land area. The number of plants in 60 cm x 40 cm was 41,667, whereas in 25 cm x 25 cm, it was 1,60,000. Compared to wider spacing, the yield increase in closer spacing was 11901 Kg ha^{-1} (124.49 %). An increase in the size of the propagules increased the per hectare rhizome yield. When 20 g propagules were used as planting material, followed by 10 g, which were on par, a greater per hectare yield was attained. Growing with 5 g of propagules gave the lowest per hectare yield. All the treatment combinations with closer plant spacing resulted in higher rhizome yields. The higher yield was in 25 cm x 25 cm with 20 g propagule (22564 Kg ha^{-1}) followed by the same spacing with 10 g propagule (21574 Kg ha^{-1}) and 5 g propagule (20245 Kg ha^{-1}). According to Holliday (1960), their maximum production potential is realized when plants are grown at a wider spacing. In contrast, yield per unit area is maximum when individual plants are subjected to severe competition. In *Curcuma*, Rahman and Faruque (1974) and Shashidhar *et al.* (1997) also observed similar findings.

The essential oil content of *Curcuma aromatica* ranged from 2.58 % to 3.75 %. Spacing treatments did not affect the oil content. However, differences in propagule size were found to be the major cause of the variance. When large-sized propagules were used as planting material, the oil content was significantly higher. The 5 g propagule crop had the least amount of oil (2.75 %). With regard to the interaction effect, all treatment combinations using large-sized propagules were comparable and had higher oil content at harvest. In *Curcuma domestica* and *Curcuma aromatica*, Mohamed *et al*. (2017) observed a significant increase in the height of plants, leaves number, the width of leaves and fresh and dry yield of rhizomes with the increase in the weight of seed rhizomes. They also noticed increased total carbohydrates, essential oil, and curcumin in plants raised from heavier propagules. With the size of the propagule, the curcumin content increased. Rhizomes harvested from the largest-sized propagule of *Curcuma mangga* were found to contain up to 0.46 per cent curcumin (Waman *et al*., 2018).

The yield and yield parameters were higher when the spacing was wider (60 x 40 cm) and the propagule size was 10–20 g. However, the per-hactre yield was higher under 25 x 25 cm due to the higher plant density. Therefore, for commercial *Curcuma aromatica* production, a plant spacing of 25 cm x 25 cm and propagule sizes of 10–20 g can be advised. The oil content of the rhizomes was unaffected by spacing treatments and was significantly higher when large-sized propagules were employed as planting material.

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