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Original Research

Effect of Different Rhizome Types and Sizes on Growth and Yield of Turmeric (*Curcuma longa* L.)

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ABSTRACT

Curcuma longa L. is known as spice crop and have important medicinal properties due to presence of bioactive compounds. This study was carried out to determine the effect of mother and finger rhizomes size on growth and yield of turmeric. Rhizomes with three different sizes were used viz., T_1: mother rhizome 15-25 g, T_2: mother rhizome 25-35 g, T_3: mother rhizome 35-45 g, T_4: finger rhizome <10 g, T_5: finger rhizome 15-25 g and T_6: finger rhizome 25-35 g. This experiment was arranged according to randomized complete block design with three replications. Results showed that treatment T_3 (mother rhizome 34-45 g) produced maximum plant height (82.57 cm), stem diameter (17.39 mm), number of tillers (10.31), number of leaves (16.04), leaf area (73.21 cm^2), total number of rhizomes (28.01), number of primary rhizome (11.70), number of secondary rhizome (21.45), yield per plant (345.06 g/plant), rhizome length (25.93 mm), rhizome diameter (22.53 mm), and 8.11% curcumin content while the seedling emergence percentage was non-significant for all the treatments.

Keywords: *Turmeric, Curcuma longa, rhizome size, rhizome type, rhizome yield, curcumin.*

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INTRODUCTION

Curcuma longa L. (Turmeric) is an herbaceous perennial crop that belongs to the family Zingiberaceace and comprises about 70 different species. It is valued for its underground orange-coloured rhizome and known as vegetatively propagated spice crop (Olojede et al., 2009). Because of its brilliant yellow colour, turmeric is also known as "Indian saffron." The herbal role of turmeric is traced to about 600 BC in Assyrian. India is the major producer and exporter of turmeric which contributes 78%, China 8%, Myanmar 4%, Nigeria, and Bangladesh 6% to the worldwide production of turmeric (Archana et al., 2013; Paul et al., 2016).

From ancient times turmeric is used in herbal medicines but over time turmeric is used at large scale for different purposes such as colouring agent for food, cosmetics, dyes even in medicines due to its antioxidant properties (Nasirujjaman et al., 2005). Turmeric's antioxidant properties have been proven to be a health-protective approach that should be taken on a regular basis (Tahira et al., 2010). Contents of turmeric such as volatile oils and curcuminoids are helpful for treatments of cancer, tumour and helpful to liver and function of kidney (Li et al., 2011). Turmeric is used by large number of people to improve the health and to fight with diseases (Sirisidthi et al., 2016). The main secondary metabolite in turmeric rhizome is curcumin and other contents are essential oils, carbohydrates, and proteins. Currently, turmeric is proved as an easily available source of new medicine due to the presence of curcuminoids (Corcolon et al., 2015).

In the oleoresin of turmeric, 30-55% curcuminoids and 15-25% of volatile oils are present and these oils are responsible for aroma while the yellow colour of the rhizome is due to the presence of curcuminoids. Curcumin has been reported to exhibit antispasmodic, antibacterial, antioxidant, anti-parasitic, anti-fungal, anti-carcinogenic and anti-inflammatory properties (Baatout et al., 2004; Fan et al., 2013; Ilyas et al., 2018; Majeed et al., 2021). Nutritional analysis of turmeric shows that 100 g of

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turmeric contains 390 kcal, total fat (10 g), saturated fat (3 g), cholesterol (0 mg), calcium (0.2 g), sodium (10 mg), phosphorous (0.26 g), iron (47.5 mg), potassium (2500 mg), thiamine (0.9 mg), riboflavin (0.19 mg), ascorbic acid (50 mg), niacin (4.8 mg), total carbohydrates (69.9 g), sugars (3 g), dietary fibre (21 g) and protein (8 g) (Balakrishnan, 2007). Turmeric is basically an emulsifying agent which means it is a strong medicine as a cholesterol regulatory agent (Feng et al., 2010).

Normally turmeric is propagated through a small portion of rhizomes known as seed rhizome which gives the economic yield (Ravindran et al., 2005). So, it is obvious that the selection of right size planting material (length, weight, and number of growing buds per seed) is an important factor for turmeric cultivation. Although the standard size of turmeric rhizome for planting is 20-30 g as per the scientific package of practices yet many researchers reported that planting larger turmeric seed rhizomes resulted in higher yield compared to smaller seed rhizomes (Hossain and Ishimine, 2005). Further, Aswathy and Jessykutty (2017) also reported that a turmeric rhizome bit of approximate weight i.e., 7 g with 3 nodes recorded the highest sprouting percentage with good morphological characteristics.

To achieve the maximum yield of turmeric standard rhizome size is required. In Pakistan, there is a lack of knowledge about turmeric production technology. Therefore, a study was planned to determine the effect of rhizome sizes on growth and yield of turmeric.

MATERIALS AND METHODS

Experimental site

The experiment was executed at Vegetable research Area, Institute of Horticultural Sciences (IHS), University of Agriculture, Faisalabad. Planting material was taken from the Vegetable area, IHS and RCBD designed was used for the experiment. And soil analysis was done before the experiment (Table 1). Ridges were made 60 cm apart and rhizomes were planted at 20 cm plant to plant distance on 25 April 2019. Each plot had 80.04 ft^2 area with three replications of each treatment. The 200 g DAP and 200 g SOP was applied during field preparation along with 15 kg Farmyard Manure in each replication. After four months, 100 g urea was also applied in replication. A light irrigation was done after sowing and later throughout the season according to crop requirement. Insects, diseases, and weeds were controlled by adopting standard plant protection measures. Six treatments were as follows: T_1: mother rhizome 15-25 g, T_2: mother rhizome 25-35 g, T_3: mother rhizome 35-45 g, T_4: finger rhizome <10 g, T_5: finger rhizome 15-25 g and T_6: finger rhizome 25-35 g. The experiment had three replications, each with 10 plants, and five plants were selected randomly for data collection. Harvesting was done manually by digging out rhizome from the soil on 17 January 2020.

Table 1: Physio-chemical characteristics of soil of experimental site.

Soil Properties	Soil Depth (0-15 inches)
Organic matter	0.88 %
pH	8.1
EC	0.67 dS m^{-1}
Nitrogen	0.044 %
Available phosphorous	4.2 mg kg^{-1}
Exchangeable potassium	300 mg kg^{-1}
Available zinc	0.52 mg kg^{-1}
Available iron	2.82 mg kg^{-1}
Available boron	0.11 mg kg^{-1}
Available manganese	1.22 mg kg^{-1}
Saturation	36 %
Sand	45 %
Silt	27.5 %
Clay	27.5 %
Textural class	Loam

The data of different morphological (seedling emergence percentage (%), plant height (cm), stem diameter (cm), number of tillers per plant, number of leaves per plant, leaf area (cm^2) and yield paraments (number of primary rhizomes per plant, number of secondary rhizomes per plant, total number of rhizomes, yield per plant (g/plant), rhizome length (mm), and rhizome diameter (mm) were measured by using standard procedures.

Curcumin content

High-performance liquid chromatography technique was used to quantify the curcumin content in turmeric. The sample was prepared from turmeric powder and analysed by following the protocol of Lim et al. (2011) through HPLC (Shimadzu, USA) containing shim-pack CLC-ODS C18 column (25 cm × 4.6 mm, 5µm particle size) with a manual sampler. The mobile phase comprises HPLC grade methanol (100%) at a low rate of 1 ml/ minute. The sample amount of 20 µl and column temperature at 40 °C was kept during the whole analysis. from methanol stock solution. The eluent was analysed at 254 nm using a UV- visible detector. The quantification of curcumin was achieved by comparing the retention time of peaks in samples to those of curcumin standards.

Statistical analysis

The experiment was laid out according to the Randomized Complete Block Design (RCBD) with three replications. Collected data was evaluated using Analysis of variance technique in Statistix 8.1 software. Treatment means were compared by using LSD test at 5% significance level (Steel et al., 1997).

RESULTS AND DISCUSSION

Seedling emergence percentage

Statistical analysis showed that seed type and seed size did not improve the seedling emergence percentage. And non-significant difference was noted for seedling emergence percentage among all the treatments (Table 2). Our results were strongly supported by the findings of the Hossain et al. (2005). They also reported non-significant difference for the seedling emergence among four different mother rhizome sizes (5 g, 10 g, 15 g, 20 g). Non-significant difference for seedling emergence

Table 2: Effect of different rhizome sizes on growth parameters of *Curcuma longa.*

Treatment	Seedling emergence percentage (%)	Plant height (cm)	Number of tillers per plant	Number of leaves per plant	Leaf area (cm^2)	Stem diameter (mm)
T1	85.18 ab	59.90 c	6.00 c	11.79 bc	62.04 bc	13.40 bc
T2	92.59 a	72.31 b	8.30 b	13.26 b	63.93 b	14.69 b
T3	88.88 a	82.57 a	10.31 a	16.04 a	73.21 a	17.39 a
T4	70.36 b	29.41 f	2.67 f	7.90 f	32.85 f	10.28 d
T5	77.77 ab	44.4 e	3.24 e	8.20 ef	46.10 e	12.51 c
T6	88.88 a	51.73 d	4.52 d	10.45 c	53.99 d	14.11 bc
Significance (0.05)	NS	*	*	*	*	*

*Significant, NS= non-significant, $T_{1=}$ mother rhizome 15-25 g, $T_{2=}$ mother rhizome 25-35 g, $T_{3=}$ mother rhizome 35-45 g, $T_{4\,=}$ finger rhizome <10 g, $T_{5=}$ finger rhizome 15-25 g and $T_{6=}$ finger rhizome 25-35 g.

might be due to the planting of rhizomes at the same time and depth.

Plant height

Plant height was significantly influenced by the rhizome types and sizes. Significant increase in plant height was observed from highest to lowest rhizome seed size. Highest plant height (82.57 cm) was noted in the mother rhizome treatment T_1 (mother rhizome 35-45 g) followed by treatment T_2 and T_3 while the lowest plant height (29.41 cm) was observed in the treatment T_4 (finger rhizome <10 g) (Table 2). The reason was that the mother rhizome showed vigorous and rapid growth by using initial reserves of food material which was higher in mother rhizomes and mother rhizome also contained more buds as compared to finger rhizomes. These findings are in agreement with the results of Ravi et al. (2016) and Shuhaimi et al. (2016). Hossain et al. (2005) reported that a maximum plant height of 73.7 cm was recorded from 40 g mother rhizome which was similar to our findings where T_3 (35-45 g mother rhizome) observed a maximum height of 82.570 cm.

Number of tillers per plant

Rhizome type and size had significant effect on the number of tillers. Maximum number of tillers per plant (10.31) were noted in the treatment T_1 (mother rhizome 35-45 g) while minimum numbers of tillers (2.67) in the treatment T_4 (finger rhizome <10 g) (Table 2). Variation among the treatments for the number of tillers might be due to the vigorous and rapid growth by using initial reserves of food material which was higher in mother rhizomes and mother rhizome also contained more buds as compared to finger rhizomes. Our results were strongly supported by the finding of Reddy et al. (2016) that number of tillers that arise from same size was significantly different due to planting material (mother and finger rhizomes). Because mother rhizomes contained a greater number of buds from which new soft stem was raised while the finger rhizomes contain low, or no buds showed lower number of tillers per plant. The mother rhizome showed vigorous and rapid growth by using initial reserves of food material which was higher in mother rhizome.

Number of leaves per plant

The maximum number of leaves was observed with the highest rhizome seed size. The mother rhizome grows faster with large number of leaves as compared to the finger rhizome which shows slow growth. The treatment T_3 with larger size of mother rhizome (35-45 g) recorded highest number of leaves (16.04) as compared to T_2 and T_1 mother rhizome while treatment T_4 (finger rhizome <10 g) recorded minimum number of leaves (7.90) (Table 2). The larger size of the rhizome held more stored food that sprouts early and grows fast and vigorously, which might be the reason for the highest number of leaves (Monnaf et al., 2010). Ravi et al. (2016) also concluded that largest rhizome 25 g produced maximum number of leaves 13.37 as compared to less rhizome sizes 10 and 5 g rhizome.

Leaf area

Statistical analysis showed that leaf area is significantly influenced by the rhizome type and rhizome sizes. Maximum leaf area (73.21 cm^2) was noted in the treatment T_3 (mother rhizome 35-45 g) followed by T_2 which was at par with treatment T_1. While minimum leaf area (32.85 cm^2) was obtained in the treatment T_4 (finger rhizome <10 g) (Table 2). As the turmeric plant increased in height and the leaf area because leaf length (cm) and width (cm) significantly increased with the increase in rhizome seed (Singh et al., 2016). Our results coincide with Ihenaecho et al. (2016) findings that largest rhizome size produced maximum leaf area.

Stem diameter

The stem diameter was significantly increased with the increase in rhizome seed size. The stem diameter grows irrespective of the seed size and attains its maximum girth. The stem of finger rhizomes was thinner and unhealthy as compared to stems of mother rhizomes seed size. Statistical analysis showed that maximum stem diameter (17.39 mm) in treatment T_3 (mother rhizome 35-45 g) while the minimum stem diameter was noted in the treatment T_4 (finger rhizome <10 g) (Table 2). The large mother rhizomes seed contained many small buds that stored adequate energy for the turmeric plant to grow rapid and vigorous. Mother rhizome seeds had a greater stem diameter than finger rhizome seeds because vigorous plants got more solar energy for photosynthesis which increased the stored food stores and ultimately rhizome diameter (Monnaf et al., 2010). Our findings were similar with the results of Angami et al. (2017) who observed maximum stem diameter in mother rhizomes having the size of 50-60 g.

Number of primary rhizomes

Number of primary rhizomes influenced with the size of the

Table 3: Effect of different rhizome sizes on yield and quality parameters of *Curcuma longa.*

Treatment	Number of primary rhizomes per plant	Number of secondary rhizomes per plant	Total number of rhizomes per plant	Yield per plant (g)	Rhizome Length (mm)	Rhizome diameter (mm)	Curcumin contents (%)
T_1	6.24 c	15.08 c	23.54 c	156.97 c	16.45 c	17.96 bc	5.90 c
T_2	8.94 b	18.48 b	26.22 b	233.18 b	21.29 b	18.57 b	7.18 b
T_3	11.70 a	21.45 a	28.01 a	345.06 a	25.93 a	22.53 a	8.11 a
T_4	3.53 ef	5.98 f	8.12 f	34.18 f	7.77 f	9.17 f	1.96 f
T_5	3.16 e	9.54 e	10.63 e	88.24 e	10.13 e	12.51 de	3.03 e
T_6	5.45 d	12.56 d	19.44 d	129.12 d	12.22 d	13.52 d	4.95 d
Significance (0.05)	*	*	*	*	*	*	*

*Significant, NS= non-significant, $T_{1=}$ mother rhizome 15-25 g, $T_{2=}$ mother rhizome 25-35 g, $T_{3=}$ mother rhizome 35-45 g, $T_{4=}$ finger rhizome <10 g, $T_{5=}$ finger rhizome 15-25 g and $T_{6=}$ finger rhizome 25-35 g.

rhizome. Treatment T_3 (mother rhizome 35-45 g) produced highest number of primary rhizomes (11.7) followed by T_2 and T_3. While lowest number of primary rhizomes (3.53) were obtained in T_4 (finger rhizome <10 g) (Table 3). Higher number of buds on the mother rhizome produced more primary rhizomes. The large size seed provides better supply of energy for plant growth therefore the mother rhizome stored more food for growing plant as compared to the finger rhizome and resulted the large number of primary rhizomes. The large amount of photosynthetic product was reported in mother rhizome as compared to the finger rhizome (Kumar and Gill, 2011). Waman et al. (2018) reported that rhizome size of 5-10 g showed minimum number of primary rhizome (3.39) which was in complete accordance with our findings that less than 10 g finger rhizome seed size reported 3.533 number of primary rhizomes.

Number of secondary rhizomes

The secondary rhizomes produced from primary rhizomes which directly arise from mother rhizome of seed. Treatment T_3 (mother rhizome 35-45 g) recorded maximum number of secondary rhizomes (21.45) followed by T_2 and T_1 while T_4 treatment (finger rhizome <10 g) recorded minimum number of secondary rhizomes (5.98) (Table 3). This finding agrees with Kumar and Gill (2011), who found that the mother rhizome produced highest secondary rhizomes than finger rhizome seeds. Our results were in parallel with the finding of the Waman et al. (2018).

Total number of rhizomes

As the number of primary and secondary rhizomes increased with the increase in rhizome seed size therefore the total number of rhizomes was also increased with seed size. Treatment T_3 (mother rhizome 35-45 g) recorded maximum total number of rhizomes (28.01) followed by T_2 and T_1 while treatment T_6 (finger rhizome <10 g) produced minimum total number of rhizomes (8.12) (Table 3). Ihenaecho et al. (2016) also found that mother rhizome seed produced maximum number as rhizomes when compared to the finger rhizomes. Ravi et al. (2016) reported that number of rhizomes increased significantly with the increase in rhizome seed size such as 40 g rhizome size showed highest number of rhizomes 22.95. These findings are similar to these results which shows that 35-45 g mother produced 28.01 rhizomes.

Yield per plant

Yield per plant was significant among the treatments of rhizome type and sizes. Treatment T_3 (mother rhizome 35-45 g) produced maximum yield (345.06 g/plant) whereas minimum yield was noted in treatment T_4 (finger rhizome <10 g) (Table 3). The larger seed shows the faster growth of plant with a higher weight of rhizomes. Because rhizome sizes were determined by the sink-source relationship and mother rhizomes found a stronger sink which stored more energy as compared to finger (Temteme et al., 2017). Angami et al. (2017) found the same results that the larger seed size of mother rhizome produced highest fresh weight of rhizomes per plant such as 50-60 g rhizome size recorded 24.58 t/ha rhizome yield.

Rhizome length

Maximum rhizome length (25.93 mm) was noted in the treatment T_3 (mother rhizome 35-45 g) while, minimum rhizome length (7.77 mm) was obtained in T_4 (finger rhizome <10 g) (Table 3). The large size rhizome seed grows faster and increase the length and diameter of rhizome while the rhizome length and dimeter decreased with the reduction in rhizome size. Mahender et al. (2015) obtained similar results that 40 g rhizome size resulted maximum rhizome length of 15.82 mm as compared to 20 g and 30 g rhizome size. Our results coincided with the findings of Deb et al. (2013).

Rhizome diameter

Maximum rhizome diameter (22.53 mm) was noted in the treatment T_3 (mother rhizome 35-45 g) followed by T_2 and T_1 while, minimum rhizome length (9.17 mm) was obtained in T_4 (finger rhizome <10 g) (Table 3). The large size rhizome seed grows faster and increase the length and diameter of rhizome while the rhizome length and dimeter decreased with the reduction in rhizome size (Angami et al., 2017). Sengupta and Basudeb (2011), Mahender et al. (2015), Ravi et al. (2016) and Deb et al. (2013) also reported the similar results.

Curcumin content

The rhizome seed size has a significant effect on curcumin content of the turmeric. Treatment T_3 (mother rhizome 35-45 g) produced the maximum curcumin contents (8.11%) while minimum curcumin contents (1.96 %) were noted the treatment

T_4 (finger rhizome <10 g) (Table 3). Angami et al. (2017) reported that increased in rhizome seed size will increase the curcumin content percentage while the small rhizome size cause reduction in curcumin contents. They found that 50-60 g rhizome size resulted highest curcumin content 6.20 % which coincide with our findings. The larger rhizome seed size has larger food reserves which enhances the growth of turmeric and resulted the more photosynthates, essential for the higher secondary metabolites (Pujari et al., 2015; Ravi et al., 2016).

CONCLUSION

It is concluded that increasing the rhizome seed size enhanced the growth, yield, and curcumin contents of the turmeric plant. It was concluded that mother rhizome having the size of 35-45 g as seed material produced better quantitative and qualitative growth characteristics of the turmeric plant under the climatic conditions of Faisalabad.

Author contribution statement

Zarsha Afzal: Conducted the experiment, collected data. **Muhmmad Bilal Shaukat:** Manuscript writing, assisted in methodology, and reviewing. **Yasir Majeed & Amina Kousar:** Conceptualized idea and assisted in manuscript writing. **Hassan Munir & Iqra Kanwal:** Assisted in writing, editing, and reviewing.

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