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STUDY OF PROTRAY TECHNOLOGY IN MULTIPLICATION OF PLANT MATERIAL AND ITS EFFECT ON SEEDLING GROWTH AND ECONOMICS OF TURMERIC (*CURCUMA LONGA* L.) VARIETIES

Macherla Chandana[1]*, M. Padma[1], B. Neeraja Prabhakar[2], Veena Joshi[3], B. Mahender[4], P. Gouthami[5] and G. Sathish[6]

[1]Department of PSMA (Plantation, Spices, Medicinal and Aromatic crops) College of Horticulture, Rajendranagar, Sri Konda Laxman Telangana Horticultural University (SKLTGHU), Mulugu, Siddipet Dist., India

[2]Senior Professor (Hort.) & University Head PJTAU and Former Hon'ble Vice-Chancellor, Department of Horticulture, SKLTGHU, Mulugu, Siddipet Dist., India

[3]Department of Horticulture, College of Horticulture, Rajendranagar, SKLTGHU, Mulugu, Siddipet Dist., India

[4]Department of Plant Pathology, Turmeric Research Station, Kammarpally, Nizamabad, SKLTGHU, Mulugu, Siddipet Dist., India

[5]Department of Crop Physiology, College of Horticulture, Mojerla, SKLTGHU, Mulugu, Siddipet Dist.

[6]Department of Agricultural Statistics, PGIHS, SKLTGHU, Mulugu, Siddipet Dist.

*Corresponding author email: chandanamacherla1299@gmail.com

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ABSTRACT

The present investigation on "Study of protray technology in the multiplication of plant material and its effect on seedling growth and economics of turmeric (*Curcuma longa* L.) varieties" was conducted at College of Horticulture, Rajendranagar, SKLTGHU, Mulugu. The experiment was laid out in a Factorial Randomised Block Design (FRBD) with 3 replications and 12 treatments. The results conferred that among different sizes of planting material, S_3 - Vertical split of mother rhizome recorded minimum number of days for initiation of sprouting (8.66), number of days for 50 % sprouting (12.55), number of days for complete sprouting (20.10), maximum seedling vigour index (2825.33) and minimum number of days taken for final transplanting (30.10). The treatment S_2 – Two node cutting of the primary rhizome recorded a maximum percentage of sprouting (94.03 %). The treatment S_4 (Full mother rhizome) recorded maximum seedling height (43.54 cm), maximum number of leaves (2.16), and maximum chlorophyll content (29.31). Among the varieties, variety V_1**-**Salem has taken the shortest number of days for initiation of sprouting (8.16 days), for 50% sprouting (11.50 days), for complete sprouting (18.58 days), and for final transplanting (25.58 days). The maximum percentage of sprouting (98.12 %), seedling height (46.10 cm), number of leaves (2.86), seedling vigour index (3166.85) and chlorophyll content (31.42) were recorded in Salem variety (V_1). The interaction between the size of planting material and varieties significantly influenced growth and quality parameters. S_3V_1-Vertical split of mother rhizome of Salem variety has taken a minimum number of days for initiation of sprouting (5.33), for 50% sprouting (9.00 days), for complete sprouting (16.00 days), for final transplanting (24.00 days), whereas maximum seedling vigour index (3871.21) was recorded. The treatment S_2V_1- two-node cutting of the primary rhizome of the Salem variety recorded the maximum percentage of sprouting (99.40%). The treatment S_4V_1-Full mother rhizome of Salem variety has recorded maximum seedling height (71.19 cm), number of leaves (3.26) and chlorophyll content (33.74). In terms of B : C ratio, the highest benefit-to-cost ratio (1.63) was recorded in S_1V_1- Single node cutting of primary rhizome + Salem and S_2V_1- Two node cutting of primary rhizome + Salem followed by S_3V_1- Vertical split of mother rhizome + Salem (1.58) was due to the reduction of the quantity of planting material which reduced cost of cultivation and in turn increased benefit-cost ratio.

Keywords **:** Protray, sprouting percentage, seedling vigour index, chlorophyll content, growth, quality, Salem.

Introduction

Turmeric (*Curcuma longa* L.) is an important, sacred and ancient spice of India. It is a major rhizomatous spice produced and exported from India. Turmeric is an herbaceous perennial plant, native to Tropical Southeast Asia, belonging to the family Zingiberaceae, under the order Scitaminae. It is cultivated for its underground rhizomes which are used as a spice, condiment and dyestuff. It is used in the cosmetic and drug industry, particularly in the preparation of anticancerous medicines. Globally, India is the world's largest producer and exporter of turmeric and produces nearly 50 per cent of global turmeric production. India is also the largest consumer of turmeric in the world accounting for nearly 90% of total production. Major producing states in India are Telangana, Andhra Pradesh, Tamil Nadu, Orissa, West Bengal, Karnataka and Kerala. In India turmeric is estimated to occupy an area of 295000 hectares with a production of 1102000 MT (Horticultural Statistics Database: 2020-21). The area in Telangana under turmeric cultivation is 55443 hectares with a production of 307000 MT ha^{-1} and Productivity is 5.5 t ha^{-1}. It is also used in auspicious rituals and religious occasions. Turmeric inhibits the development of cataracts, breast cancer, colon cancer, and lymphoma (Devi and Sangamithra, 2011).

Curcumin is the pigment that lends the bright stunning yellow color to turmeric which is used as a dye. Turmeric is a cross-pollinated, triploid species (2n =3x = 63), which can be propagated vegetatively using its underground rhizomes. Since rhizome multiplication is slow and maintenance of planting material is expensive, a rapid low-cost multiplication method through protrays and pathogens-free transplants which produce the planting material more effectively than standard seed rhizome is the need of the hour. As seed material cost in the form of rhizome is very high, there is a need to reduce the cost of seed material by adopting alternative planting material by selecting optimum size rhizome or rhizome cuttings.

The turmeric is propagated by mother rhizomes (shoot base) and finger rhizomes. The finger rhizomes of the species are considered to be different in size because primary finger rhizomes developed from the shoot base have secondary and tertiary finger rhizomes which are different in size due to the differences in developing time. In addition, all the primary finger rhizomes are not developed at a time from a shoot base. Therefore, it is necessary to determine the optimum size of seed rhizomes for turmeric cultivation. Evaluating the effects of seed size on the growth and development of plants is very important for increasing yield in the plant species producing different sizes of seed.

In turmeric, planting material requirement is very high and it involves 40 per cent of its cost of the total cost of cultivation. Turmeric seed rhizomes are rarely available and typically difficult to obtain. Whole or split rhizomes with single buds are used for planting. As the cost of planting material is very high in turmeric, there is a need to reduce the cost of seed material by evolving alternative methods of sowing and the selection of rhizomes of optimum size or rhizome cuttings is inevitable.

Material and Methods

The present investigation was conducted at the College of Horticulture, Rajendranagar during 2018-19. The experiment was laid out in a Factorial randomized block design (FRBD) with 12 treatments and 3 replications. The treatments used in this experiment are as follows:

Crop	:	Turmeric (*Curcuma longa* L.)
Number of treatments	:	12
Replications	:	3
Design	:	Factorial RBD
Season	:	*Kharif*, 2019
Location	:	PG Student's Research farm, College of Horticulture, Rajendranagar, Hyderabad.

Treatment Details

Factor 1 : Size of plant material (S)

S_1 : Single node cutting of primary rhizome (5g)
S_2 : Two node cutting of primary rhizome (10g)
S_3 : Vertical split of mother rhizome
S_4 : Full mother rhizome

Factor 2 : Varieties (V)

V_1 : Salem (Long duration)
V_2 : Rajendra Sonia (Medium duration)
V_3 : ACC - 79 (Short duration)

Treatment combinations :

S_1V_1 : Single node cutting of primary rhizome (5g) + Salem
S_1V_2 : Single node cutting of primary rhizome (5g) + Rajendra Sonia
S_1V_3 : Single node cutting of primary rhizome (5g) + ACC - 79
S_2V_1 : Two node cuttings of primary rhizome (10g) + Salem
S_2V_2 : Two node cuttings of primary rhizome (10g) + Rajendra Sonia
S_2V_3 : Two node cuttings of primary rhizome (10g) + ACC - 79
S_3V_1 : Vertical split of mother rhizome + Salem
S_3V_2 : Vertical split of mother rhizome + Rajendra Sonia

S_3V_3 : Vertical split of mother rhizome + ACC - 79
S_4V_1 : Full mother rhizome + Salem
S_4V_2 : Full mother rhizome + Rajendra Sonia
S_4V_3 : Full mother rhizome + ACC - 79

Results and Discussion

The results of the present investigation regarding the study of protray technology in multiplication of plant material and its effect on seedling growth of turmeric (*Curcuma longa* L.) varieties have been discussed and interpreted in light of previous research work in India. The results of the experiment are summarized below and also presented here under.

1. Days taken for initiation of sprouting

Data recorded on days taken for initiation of sprouting as influenced by the size of planting material, varieties and their interactions are presented in Table 1.

The size of planting material recorded a significant effect on days taken for initiation of sprouting. The treatment S_3-Vertical split of mother rhizome has recorded a significantly minimum number of days for initiation of sprouting (8.66) followed by S_1 – Single node cutting of primary rhizome (10.33) which was on par with S_2–Two node cutting of primary rhizome (10.44). In comparison, the treatment S_4–Full mother rhizome recorded a significant maximum number of days for initiation of sprouting (11.66).

There was a significant difference among varieties on days taken for the initiation of sprouting. Variety V_1- Salem sprouting was initiated early (8.16) followed by V_2 – Rajendra Sonia (10.16). Whereas the Variety V_3- ACC-79 took more number of days for initiation of sprouting (12.49).

Interaction between the size of plant material and varieties reported a significant effect on days taken for initiation of sprouting. Among all the interactions S_3V_1-Vertical split of the mother rhizome in Salem reported a significant minimum number of days for initiation of sprouting (5.33) followed by S_1V_1 – Single node cutting of primary rhizome in Salem (9.00), S_2V_1 – Two node cutting of primary rhizome in Salem (9.00) which were at par. In comparison, S_4V_3 using Full mother rhizome in ACC-79 recorded a significantly maximum number of days for initiation of sprouting (14.66).

Larger tubers have a larger surface area to retain water, which contributes to sprouting faster compared to the smaller tuber. Variation in the number of tillers per plant due to rhizome size might be because the plants produced from the largest seed rhizome size might have emerged earlier and showed healthy vigorous and rapid growth using the initial reserve food materials than the smallest rhizome size in ginger. These results conform with the findings of Sengupta and Dasgupta (2011) in ginger. Similar results were reported by Yothasiri *et al*. (1997) in turmeric who also found significant results for days to first sprouting as affected by different seed rhizome sizes. Usually, bigger seed rhizomes (20-80 g) are planted to promote earlier seed sprouts, more vigorous growth and higher yield (Sengupta *et al.* 1986, Whiley 1990, Wang *et al*. 2003, Xizhen *et al*. 2005).

Germination of seeds depends on the ability of seeds to utilize reserve food material more efficiently. Higher seedling survival, growth and better field performance were observed in larger seeds than in smaller seeds. Grading of seed based on size is a common practice in most plant species to regulate seed germination and seedling growth. Large healthy seeds give healthy seedlings, an important criterion for transplant in the field as reported by Singh and Saxena, 2009 in Jatropha.

2. Days taken for 50% sprouting

Data recorded on days taken for 50% sprouting as influenced by the size of planting material, varieties and their interactions are presented in Table 2.

The size of planting material has shown a significant effect on days taken for 50% sprouting. The treatment S_3 - Vertical split of mother rhizome significantly took a minimum of days for 50% sprouting (12.55) followed by S_1 – Single node cutting of primary rhizome (13.22). Meanwhile, the treatment S_4 – Full mother rhizome recorded significantly more days for 50% sprouting (15.66).

There was a significant difference among varieties on days taken for 50 % of sprouting. Variety V_1- Salem germinated early with a minimum number of days for 50% sprouting (11.50) followed by V_2 – Rajendra Sonia (14.16). Whereas the Variety V_3- ACC-79 took a greater number of days for 50% sprouting (16.33).

Interaction between the size of plant material and varieties was found to be significant. Among the interactions, S_3V_1-Vertical split of mother rhizome in Salem reported a significant minimum number of days for 50% sprouting (9.00) followed by S_1V_1 – Single node cutting of primary rhizome in Salem (11.00). In comparison, S_4V_3 using Full mother rhizome in ACC-79 recorded a significantly maximum number of days for 50% sprouting (18.66).

The size of the seeds is an important factor in the germination and early stage of seedling's growth as reported by Girish *et al*., 2001. The size of seeds having different levels of food storage is an important factor that influences the germination and growth of the seedlings (Wood *et al.*, 1977).

Similarly, Simmone *et al.*, 2000 reported that the size of the seed has shown a strong influence on germination as well as growth and biomass increment of a plant. The results of the present study agree with these previous studies stating that the largest seed had the best germination while the smallest sized seed recorded the lowest germination percentage.

3. Days taken for complete sprouting

Data recorded on days taken for complete sprouting as influenced by the size of planting material, varieties and their interactions are presented in Table 3 and depicted in Fig 1.

The size of planting material recorded a significant effect on days taken for complete sprouting. The treatment S_3 - Vertical split of mother rhizome has recorded a significantly minimum number of days for complete sprouting (20.10) followed by S_1–Single node cutting of primary rhizome (21.16). Whereas the treatment S_4–Full mother rhizome significantly recorded a greater number of days for complete sprouting (22.55).

There was a significant difference among varieties on days taken for complete sprouting. Variety V_1- Salem reported a minimum number of days for complete sprouting (18.58) followed by V_2- Rajendra Sonia (22.12). Whereas the Variety V_3- ACC-79 reported a greater number of days for complete sprouting (23.49).

Interaction between the size of plant material and varieties had a significant effect on days taken for complete sprouting. Among the interactions, S_3V_1- Vertical split of mother rhizome + Salem reported a significant minimum number of days for complete sprouting (16.00) followed by S_1V_1–Single node cutting of primary rhizome + Salem (18.33). In contrast, S_4V_3–Full mother rhizome + ACC-79 reported a maximum number of days for complete sprouting (24.33).

Small seeds of each tree species took more time to germinate after sowing. It is also noted that larger seeds germinate better and earlier than small seeds. Uniyal *et al.*, 2007 reported that larger seeds of *Azadirachta indica* germinated earlier compared to small seeds. Cicek and Tilki, 2007 reported that large seeds germinate early and show better germination than small seeds.

4. Percentage of sprouting

Data recorded on the percentage of sprouting as influenced by the size of planting material, varieties and their interactions are presented in Table 4 and depicted in Fig 2.

The size of the planting material recorded a significant effect on the percentage of sprouting. The treatment S_2 – Two node cutting of primary rhizome recorded a significant maximum percentage of sprouting (94.03 %) followed by S_1 – Single node cutting of primary rhizome (91.50 %). In comparison, the treatment S_4 – Full mother rhizome recorded a significantly minimum percentage of sprouting (87.43 %).

There was a significant difference among varieties in the percentage of sprouting. Variety V_1 – Salem reported a significant maximum percentage of sprouting (98.12 %) followed by V_2 – Rajendra Sonia (93.64 %). Whereas Variety V_3 – ACC-79 reported a significant minimum percentage of sprouting (78.93 %).

Interaction between the size of plant material and varieties had a significant effect on the percentage of sprouting. Among the interactions S_2V_1- Two node cutting of primary rhizome + Salem recorded a significant maximum percentage of sprouting (99.40 %), S_1V_1 – Single node cutting of primary rhizome + Salem (99.10 %) which remained on par, followed by S_3V_1 – Vertical split of mother rhizome + Salem (97.07 %). In comparison, S_4V_3 – Full mother rhizome + ACC-79 reported a minimum percentage of sprouting (73.23 %).

Uniformity and speed of seedling emergence are important components of seed performance, thus directly affecting crop stand and establishment. Early and uniform emergence of vigorous seedlings is the desired key to ensure better crop performance with ensured uniformity in development, yield and quality of the harvested produce. A lower percentage of germination in the mother rhizome can be attributed to meagre germination observed in the slices of the mother rhizome obtained from the crown portion of the bulb. Reduced internodal distance with the presence of scaly leaves and a lower number of viable buds at the apex or crown portion of the mother rhizome may be the reason for lower germination as compared to the primary rhizome.

Higher germination percentages (92.0 and 92.8%) were reported in seedlings raised in portrays using primary rhizome (Harsha *et al.* 2018). The results of the current study are in concurrence with the reports of Abirami *et al.* (2010).

Hojjat (2011) reported that the germination parameters were significantly related by seed weight and large seeds germinated early and showed better germination than small seeds of lentil genotypes. The results observed about germination percentage are in concurrence with the findings of Roozrokh *et al.*, (2005) on chick pea, Salih and Salih (1981) on Faba Bean and Roshanak (2013) on soybean.

5. Seedling height (cm)

Data recorded on Seedling height as influenced by the size of planting material, varieties and their interactions are presented in Table 5. depicted in Fig. 3.

The size of the planting material recorded a significant effect on seedling height. The treatment S_4 –Full mother rhizome recorded significant maximum seedling height (43.54 cm) followed by S_3 – Vertical split of mother rhizome (32.62 cm). Whereas the treatment S_2 –Two node cutting of primary rhizome recorded significant minimum seedling height (28.75 cm).

There was a significant difference among varieties in seedling height. Variety V_1 - Salem reported maximum seedling height (46.10 cm) followed by V_2-Rajendra Sonia (32.88 cm). Whereas the Variety V_3 - ACC-79 recorded a minimum seedling height (23.07 cm).

Interaction between the size of plant material and varieties had a significant effect on seedling height. Among the interactions, S_4V_1-Full mother rhizome + Salem reported significant maximum seedling height (71.19 cm) followed by S_3V_1 – Vertical split of mother rhizome + Salem (40.57 cm). Whereas S_2V_3 – Two node cutting of primary rhizome + ACC-79 recorded significant minimum seedling height (21.09 cm).

Larger seed rhizomes contain larger amounts of food reserves that enhance seedling growth, which ultimately results in a taller plant. In tropical soda apple and spring, wheat reported larger seeds produced longer coleoptiles and had higher reserves, which improved seedling establishment as reported by Akanda *et al*. (1996) and Stougaard and Xue (2004). The variation in growth parameters of ginger due to different seed rhizome sizes could be attributed to more reserve food in bigger-sized rhizomes resulting in quick emergence and more vigorous growth of the plant leading to the production of the tallest plants than the lower-sized seed rhizome. The larger buds and larger amount of food reserves in the larger seed rhizomes were also reported by Sengupta and Dasgupta (2011), Mahender *et al*. (2015) and Asafa and Akanbi (2018) in ginger.

Mtambalika *et al*., 2014 also reported that significant difference in seedling height and root collar diameter among the different seed sizes with large seeds having higher seedling height. Seed size significantly affected the seedling's emergence, and seedling survival in Colacasia as reported by Cicek and Tilki, 2007.

Gonzalez (1993) stated that seed size affects plant vigour and stated that seeds with greater mass produced vigorous plants. Seeds in the large seed size had the highest values of seedling height, collar diameter and number of leaves. A similar result had earlier been reported by Boot (1996) who found that bigger seeds usually produce bigger seedlings with larger areas of green leaves capable of conducting greater photosynthesis. However, the different sizes of seeds did not significantly affect in biomass production. Plants arising from 50-60 g mother rhizomes were found healthier because larger rhizomes had larger buds and diameter. Among the different grades of rhizome used, the mother rhizome with 50-60 g recorded the highest plant height (121.33 cm), the reason being larger seed rhizomes contain larger amounts of food reserves that enhanced seedling growth, which ultimately resulted in taller plants (Padmadevi *et al*., 2012).

6. Number of leaves

Data recorded on a number of leaves as influenced by the size of planting material, varieties and their interactions are presented in Table 6 and depicted in Fig. 4.

The size of the planting material had a significant effect on a number of leaves. The treatment S_4 –Full mother rhizome recorded a significant maximum number of leaves (2.33) followed by S_3 – Vertical split of mother rhizome (2.16). Whereas the treatment S_2 – Two node cutting of primary rhizome reported a significantly minimum number of leaves (1.90).

There was a significant difference among varieties in the number of leaves. Variety V_1 - Salem recorded a significant maximum number of leaves (2.86) followed by V_2 – Rajendra Sonia (1.88). Whereas the Variety V_3 - ACC-79 reported a significantly minimum number of leaves (1.53).

Interaction between the size of plant material and varieties had a significant effect on number of leaves. Among the interactions, S_4V_1-Full mother rhizome + Salem reported a significant maximum number of leaves (3.26) followed by S_3V_1 – Vertical split of mother rhizome + Salem (2.93), S_1V_1 – Single node cutting of primary rhizome + Salem (2.66) and S_2V_1 – Two node cutting of primary rhizome + Salem (2.60) which were remained at par. In comparison, S_2V_3 – Two node cutting of primary rhizome + ACC-79 reported a significantly minimum number of leaves (1.46).

The number of leaves increased as the seed size increased because the plants from the larger seeds were longer and had a larger number of tillers. The shoot with a larger leaf number and larger leaf size received a higher solar energy for photosynthesis, which ultimately resulted in a larger shoot biomass. This result is in agreement with the report of Sarker *et al.* (2001) on rice plants.

Leaves are the site of photosynthetic activities of crops through which biomass is produced, partitioned among various parts of plants and stored for crop productivity. The higher the number of leaves, the higher the rate of photosynthesis with a resultant increase in carbohydrates, and protein and hence increase in food production. The number of leaves produced by a plant is directly proportional to the photosynthates produced and indicates that when photosynthesis becomes active in a young seedling, the power of the plant to synthesize new materials is dependent on the number of leaves exposed to direct sunlight (Asare *et al.*, 2011).

7. Seedling vigour index

Data recorded on seedling vigour index as influenced by the size of planting material, varieties and their interactions are presented in Tables 7. depicted in Fig. 5.

The size of the planting material significantly influenced the seedling vigour index. The treatment S_3 –Vertical split of mother rhizome recorded a significant maximum seedling vigour index (2825.33) followed by S_4 –Full mother rhizome (2560.14). Whereas the treatment S_1–Single node cutting of primary rhizome recorded significant minimum seedling vigour index (2216.79).

There was a significant difference among varieties on the seedling vigour index. Variety V_1 - Salem recorded a significant maximum seedling vigour index (3166.85) followed by V_2 – Rajendra Sonia (2300.67). Whereas the Variety V_3 - ACC-79 reported a significant minimum seedling vigour index (1995.45).

Interaction between the size of plant material and varieties was observed a significant effect on seedling vigour index. Among all the interactions S_3V_1- Vertical split of mother rhizome + Salem reported a significant maximum seedling vigour index (3871.21) followed by S_4V_1– Full mother rhizome + Salem (3129.99). Whereas S_1V_3 –Single node cutting of primary rhizome + ACC-79 reported a significant minimum seedling vigour index (1592.15).

Seeds with higher food reserves will efficiently mobilize reserves from storage tissues to the embryo axis and this capacity is reflected in seedling growth (Isely, 1957). The seed showing the higher seed vigour index is considered to be more vigorous (Harsha *et al.*, 2018).

In wheat, seed size is positively correlated with seed vigour, larger seeds tend to produce more vigorous seedlings (Ries and Everson, 1973). Germination rate and seedling vigour index values increased with the increase in seed size suggesting the selection of larger seeds for good stand establishment in rice (Roy *et al.*, 1996). The results about seedling vigour conform with the findings of Roozrokh *et al.*, (2005) on chickpeas, Salih and Salih (1981) on Faba Bean and Roshanak (2013) on soybean.

8. Days taken for final transplanting

Data recorded on days taken for final transplanting as influenced by the size of planting material, varieties and their interactions are presented in Table 8.

The size of the planting material recorded a significant effect on the days taken for final transplanting. The treatment S_3 –Vertical split of mother rhizome recorded a significant minimum number of days for final transplanting (30.10) followed by S_4 –Full mother rhizome (31.10). Whereas the treatment S_1 –Single node cutting of primary rhizome recorded a significant maximum number of days for final transplanting (34.88).

There was a significant difference among varieties on days taken for final transplanting. Variety V_1 - Salem reported a significant minimum number of days for final transplanting (25.58) followed by V_2 – Rajendra Sonia (31.91). Whereas the Variety V_3 - ACC-79 recorded a significant maximum number of days for final transplanting (40.41).

Interaction between the size of plant material and varieties was observed significant effect on days taken for final transplanting. Among the interactions, the S_3V_1-Vertical split of mother rhizome + Salem reported a significant minimum number of days for final transplanting (24.00) and S_4V_1 – Full mother rhizome + Salem (24.33) which remained on par, followed by S_2V_1 – Two node cutting of primary rhizome + Salem (26.66). Whereas S_1V_3 –Single node cutting of primary rhizome + ACC - 79 reported a significant maximum number of days for transplanting

(41.33) and S_2V_3 – Two node cutting of primary rhizome + ACC-79 (41.00) which were at par.

9. Chlorophyll content (SPAD meter reading)

Data recorded on chlorophyll content as influenced by the size of planting material, varieties and their interactions are presented in Table 9 and depicted in Fig 6.

The size of planting material recorded a significant effect on chlorophyll content. The treatment S_4 –Full mother rhizome recorded significant maximum chlorophyll content (29.31) followed by S_3 – Vertical split of mother rhizome (28.17). Whereas the treatment S_1 –Single node cutting of primary rhizome reported significantly minimum chlorophyll content (26.88).

There was a significant difference among varieties in chlorophyll content. Variety V_1 **-** Salem recorded a significant maximum chlorophyll content (31.42) followed by V_2 – Rajendra Sonia (28.10). Whereas the Variety V_3 - ACC - 79 reported significantly minimum chlorophyll content (24.46).

Interaction between the size of plant material and varieties had a significant effect on chlorophyll content. Among all the interactions S_4V_1- Full mother rhizome + Salem recorded significantly maximum chlorophyll content (33.74) followed by S_3V_1 – Vertical split of mother rhizome + Salem (31.51). Whereas S_1V_1 –Single node cutting of primary rhizome + Salem reported significantly minimum chlorophyll content (22.99).

The enhanced chlorophyll content in leaves due to bigger size rhizomes might result in vigorous and rapid growth using the increased reserve food material, which positively influenced the photosynthetic activity. Chlorophyll serves as an indicator of photosynthetic activity, growth, development, and production as well as biochemical aspects of plant species thus providing valuable information about the physiological status of plants (Shraddha *et al.*, 2019).

10. Benefit-cost ratio

Data recorded on the benefit-cost ratio of turmeric as influenced by the size of planting material, varieties and their interactions on turmeric is presented in Table 10

Significantly the highest benefit-to-cost ratio (1.63) was recorded in S1V1- Single node cutting of primary rhizome + Salem and S2V1- Two node cutting of primary rhizome + Salem followed by S3V1- Vertical split of mother rhizome + Salem (1.58). A significantly lesser benefit-to-cost ratio (1.00) was recorded in the treatment S4V3 - Vertical split of mother rhizome + ACC-79 variety.

The highest B: C ratio was recorded with S1V1- Single node cutting of primary rhizome + Salem and S2V1- Two node cutting of primary rhizome + Salem. The probable reason might be a reduction of the quantity of planting material which reduced the cost of cultivation and in turn increased benefit-cost ratio.

Table 1 : Effect of size of plant material and varieties in protrays on days taken for initiation of sprouting of Turmeric

Treatments	**Days taken for initiation of sprouting**			
Size of plant material (S)	**Varieties (V)**			
	V_1	**V_2**	**V_3**	**Mean**
S_1	9.00	10.00	12.00	10.33
S_2	9.00	10.00	12.33	10.44
S_3	5.33	9.66	11.00	8.66
S_4	9.33	11.00	14.66	11.66
Mean	8.16	10.16	12.49	

	S	V	S x V
S.Em±	0.56	0.48	0.97
C.D	1.68	1.44	2.91

Table 2 : Effect of size of planting material and varieties in protrays on days taken for 50% sprouting of Turmeric

Treatments	Days taken for 50% sprouting			
Size of plant material (S)	Varieties (V)			
	V_1	V_2	V_3	Mean
S_1	11.00	13.66	15.00	13.22
S_2	13.00	14.66	16.00	14.55
S_3	9.00	13.00	15.66	12.55
S_4	13.00	15.33	18.66	15.66
Mean	11.50	14.16	16.33	

	S	V	S x V
S.Em±	0.47	0.40	0.81
C.D	1.41	1.20	2.43

Table 3 : Effect of size of planting material and varieties in ignific on days taken for complete sprouting of Turmeric

Treatments	Days taken for complete sprouting			
Size of plant material (S)	Varieties (V)			
	V_1	V_2	V_3	Mean
S_1	18.33	21.83	23.33	21.16
S_2	19.33	22.33	23.66	21.77
S_3	16.00	21.66	22.66	20.10
S_4	20.66	22.66	24.33	22.55
Mean	18.58	22.12	23.49	

	S	V	S x V
S.Em±	0.69	0.60	1.20
C.D	2.04	1.77	3.56

Table 4 : Effect of size of planting material and varieties in portrays on percentage of sprouting

Treatments	Percentage of sprouting			
Size of plant material (S)	Varieties (V)			
	V_1	V_2	V_3	Mean
S_1	99.10	94.03	81.37	91.50
S_2	99.40	96.13	86.57	94.03
S_3	97.07	92.30	74.57	87.98
S_4	96.93	92.13	73.23	87.43
Mean	98.12	93.64	78.93	

	S	V	S x V
S.Em±	0.30	0.26	0.52
C.D	0.88	0.76	1.53

Table 5 : Effect of size of planting material and varieties in portrays on seedling height of Turmeric

Treatments	Seedling height (cm)			
Size of plant material (S)	Varieties (V)			
	V_1	V_2	V_3	Mean
S_1	37.58	32.89	23.10	31.19
S_2	35.08	30.10	21.09	28.75
S_3	40.57	34.15	23.14	32.62
S_4	71.19	34.41	24.98	43.54
Mean	46.10	32.88	23.07	

	S	V	S x V
S.Em±	0.23	0.20	0.40
C.D	0.68	0.59	1.18

Table 6 : Effect of size of planting material and varieties in protrays on number of leaves of Turmeric

Treatments	**Number of leaves**			
Size of plant material (S)	**Varieties (V)**			
	V_1	**V_2**	**V_3**	**Mean**
S_1	2.66	1.73	1.53	1.97
S_2	2.60	1.66	1.46	1.90
S_3	2.93	2.00	1.56	2.16
S_4	3.26	2.13	1.60	2.33
Mean	2.86	1.88	1.53	

	S	V	S x V
S.Em±	0.06	0.60	0.12
C.D	0.20	0.17	0.35

Table 7 : Effect of size of planting material and varieties in protrays on seedling vigour index of Turmeric

Treatments	**Seedling vigour index**			
Size of plant material (S)	**Varieties (V)**			
	V_1	**V_2**	**V_3**	**Mean**
S_1	2786.10	2272.13	1592.15	2216.79
S_2	2880.13	2279.13	1886.00	2348.42
S_3	3871.21	2332.30	2272.50	2825.33
S_4	3129.99	2319.13	2231.30	2560.14
Mean	3166.85	2300.67	1995.45	

	S	V	S x V
S.Em±	1.39	1.21	2.42
C.D	4.10	3.55	7.10

Table 8 : Effect of size of planting material and varieties in protrays on days taken for final transplanting of seedlings of Turmeric

Treatments	**Days taken for final transplanting of seedlings**			
Size of plant material (S)	**Varieties (V)**			
	V_1	**V_2**	**V_3**	**Mean**
S_1	27.33	36.00	41.33	34.88
S_2	26.66	35.66	41.00	34.44
S_3	24.00	27.66	38.66	30.10
S_4	24.33	28.33	40.66	31.10
Mean	25.58	31.91	40.41	

	S	V	S x V
S.Em±	0.86	0.74	1.49
C.D	2.53	2.19	4.38

Table 9 : Effect of size of planting material and varieties in protrays on chlorophyll content of Turmeric

Treatments	**Chlorophyll content (SPAD meter reading)**			
Size of plant material (S)	**Varieties (V)**			
	V_1	**V_2**	**V_3**	**Mean**
S_1	29.96	27.70	22.99	26.88
S_2	30.50	27.94	24.43	27.62
S_3	31.51	27.94	25.06	28.17
S_4	33.74	28.82	25.38	29.31
Mean	31.42	28.10	24.46	

	S	V	S x V
S.Em±	0.76	0.66	1.32
C.D	2.24	1.94	3.88

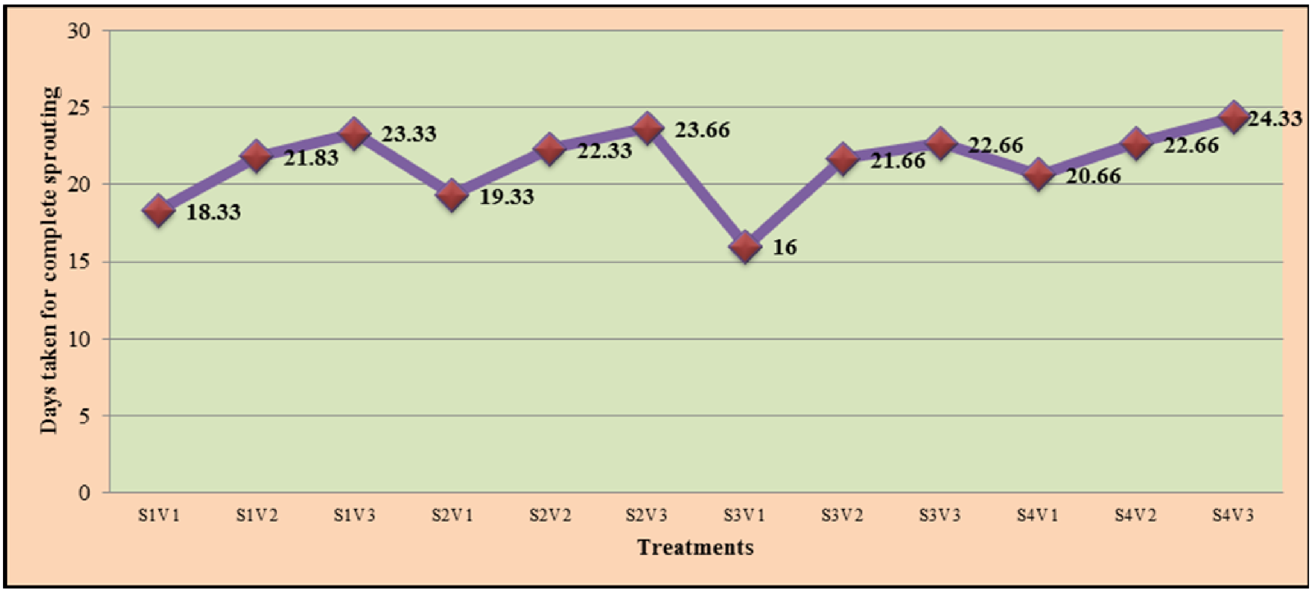

Fig. 1 : Effect of size of plant material and varieties in protrays on days taken for complete sprouting

Treatments :

S_1V_1 : Single node cutting of primary rhizome (5g) + Salem
S_1V_2 : Single node cutting of primary rhizome (5g) + Rajendra Sonia
S_1V_3 : Single node cutting of primary rhizome (5g) + ACC – 79
S_2V_1 : Two node cuttings of primary rhizome (10g) + Salem
S_2V_2 : Two node cuttings of primary rhizome (10g) + Rajendra Sonia
S_2V_3 : Two node cuttings of primary rhizome (10g) + ACC – 79
S_3V_1 : Vertical spl of mother rhizome + Salem
S_3V_2 : Vertical spl of mother rhizome + Rajendra Sonia
S_3V_3 : Vertical spl of mother rhizome + ACC - 79
S_4V_1 : Full mother rhizome + Salem
S_4V_2 : Full mother rhizome + Rajendra Sonia
S_4V_3 : Full mother rhizome + ACC - 79

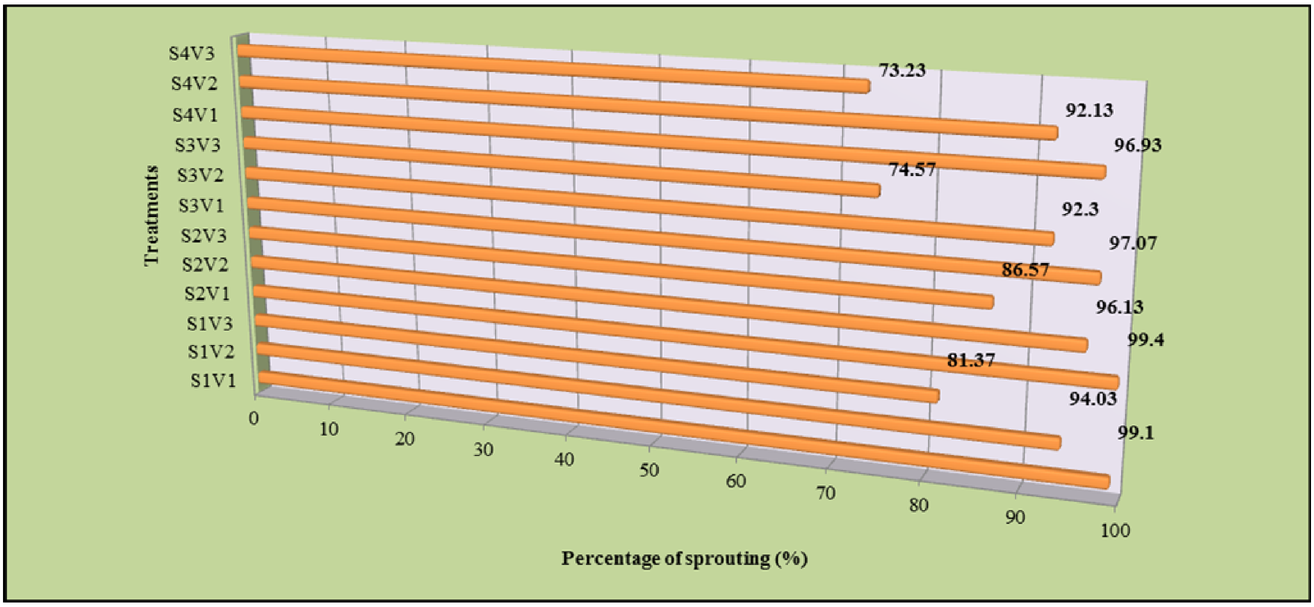

Fig. 2 : Effect of size of plant material and varieties in protrays on percentage of sprouting

Treatments:

S_1V_1 : Single node cutting of primary rhizome (5g) + Salem
S_1V_2 : Single node cutting of primary rhizome (5g) + Rajendra Sonia
S_1V_3 : Single node cutting of primary rhizome (5g) + ACC – 79
S_2V_1 : Two node cuttings of primary rhizome (10g) + Salem
S_2V_2 : Two node cuttings of primary rhizome (10g) + Rajendra Sonia
S_2V_3 : Two node cuttings of primary rhizome (10g) + ACC – 79
S_3V_1 : Vertical spl of mother rhizome + Salem
S_3V_2 : Vertical spl of mother rhizome + Rajendra Sonia
S_3V_3 : Vertical spl of mother rhizome + ACC - 79
S_4V_1 : Full mother rhizome + Salem
S_4V_2 : Full mother rhizome + Rajendra Sonia
S_4V_3 : Full mother rhizome + ACC - 79

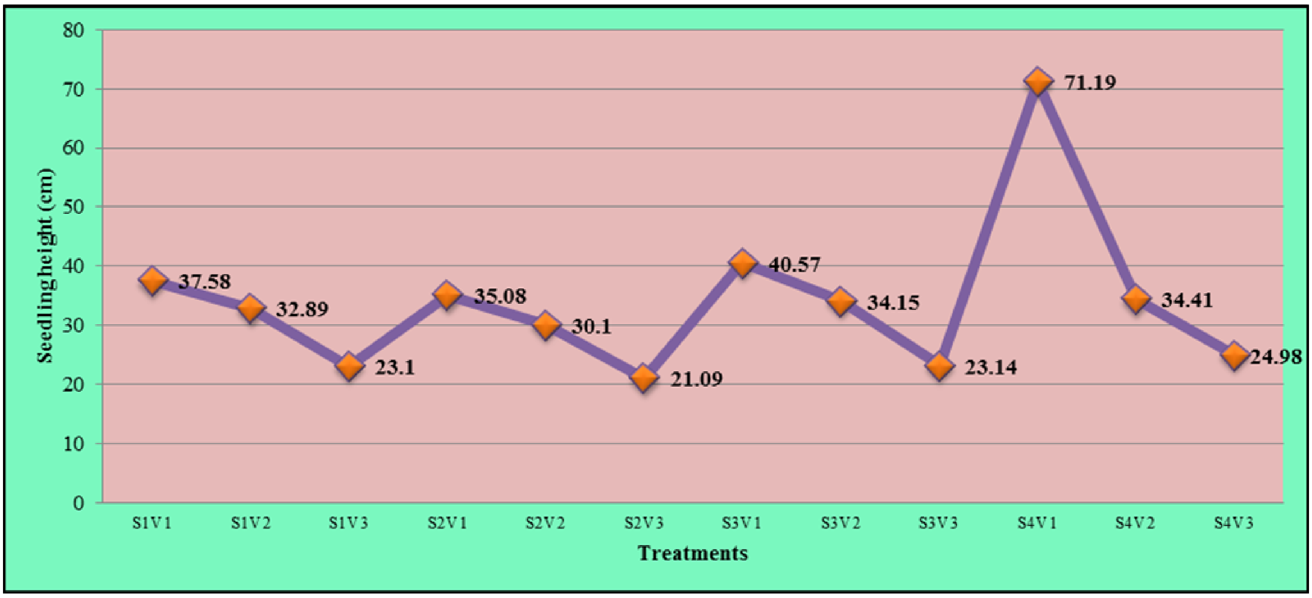

Fig. 3 : Effect of size of plant material and varieties in protrays on seedling height (cm)

Treatments :

S_1V_1 : Single node cutting of primary rhizome (5g) + Salem
S_1V_2 : Single node cutting of primary rhizome (5g) + Rajendra Sonia
S_1V_3 : Single node cutting of primary rhizome (5g) + ACC – 79
S_2V_1 : Two node cuttings of primary rhizome (10g) + Salem
wS_2V_2 : Two node cuttings of primary rhizome (10g) + Rajendra Sonia
S_2V_3 : Two node cuttings of primary rhizome (10g) + ACC – 79
S_3V_1 : Vertical spl of mother rhizome + Salem
S_3V_2 : Vertical spl of mother rhizome + Rajendra Sonia
S_3V_3 : Vertical spl of mother rhizome + ACC - 79
S_4V_1 : Full mother rhizome + Salem
S_4V_2 : Full mother rhizome + Rajendra Sonia
S_4V_3 : Full mother rhizome + ACC - 79

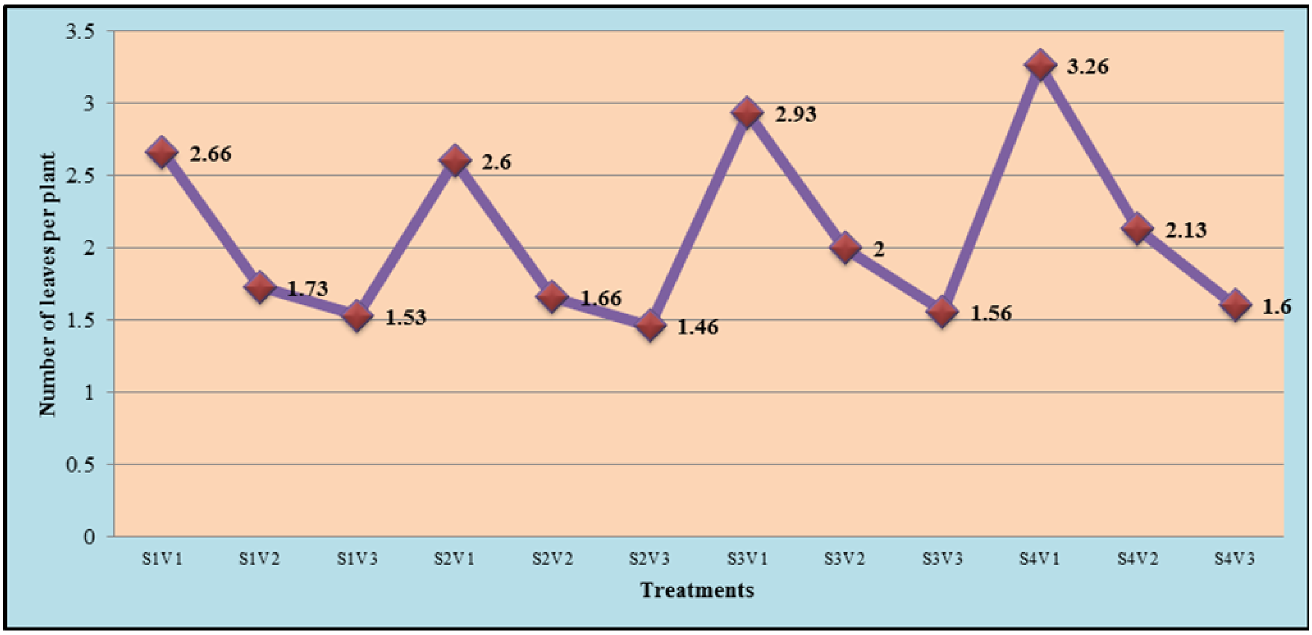

Fig. 4 : Effect of size of plant material and varieties in protrays on number of leaves per plant

Treatments:

S_1V_1 : Single node cutting of primary rhizome (5g) + Salem
S_1V_2 : Single node cutting of primary rhizome (5g) + Rajendra Sonia
S_1V_3 : Single node cutting of primary rhizome (5g) + ACC – 79
S_2V_1 : Two node cuttings of primary rhizome (10g) + Salem
S_2V_2 : Two node cuttings of primary rhizome (10g) + Rajendra Sonia
S_2V_3 : Two node cuttings of primary rhizome (10g) + ACC – 79
S_3V_1 : Vertical spl of mother rhizome + Salem
S_3V_2 : Vertical spl of mother rhizome + Rajendra Sonia
S_3V_3 : Vertical spl of mother rhizome + ACC - 79
S_4V_1 : Full mother rhizome + Salem
S_4V_2 : Full mother rhizome + Rajendra Sonia
S_4V_3 : Full mother rhizome + ACC - 79

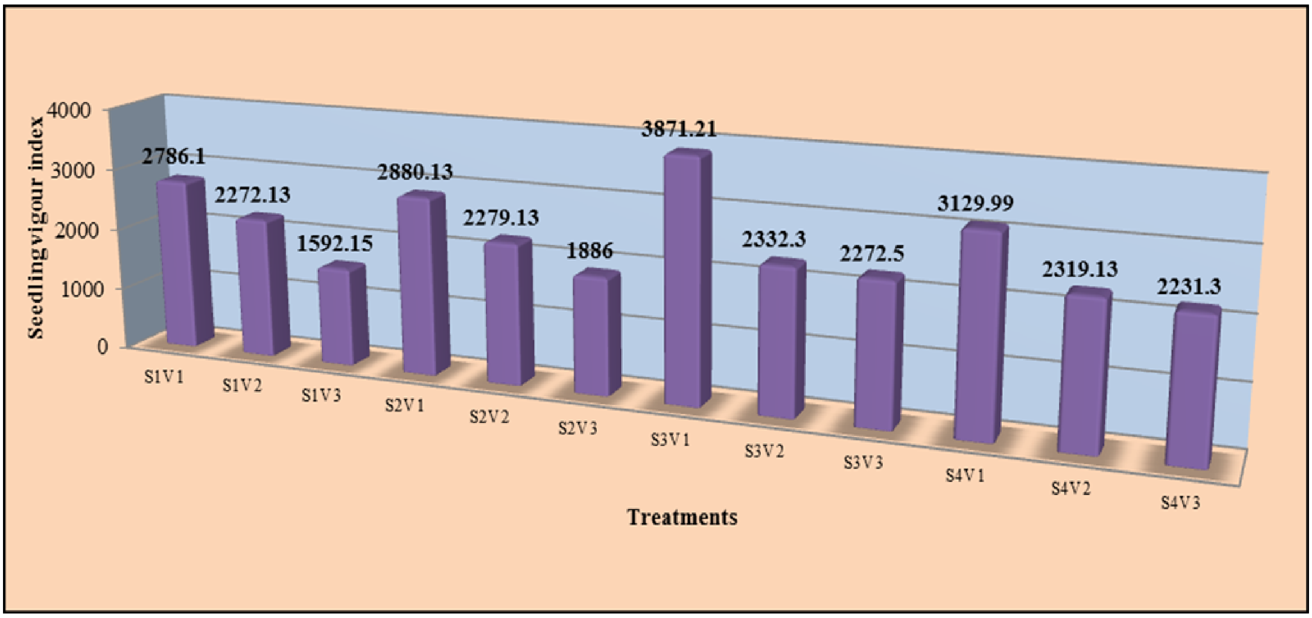

Fig. 5 : Effect of size of plant material and varieties in protrays on seedling vigour index

Treatments :

S_1V_1 : Single node cutting of primary rhizome (5g) + Salem
S_1V_2 : Single node cutting of primary rhizome (5g) + Rajendra Sonia
S_1V_3 : Single node cutting of primary rhizome (5g) + ACC – 79
S_2V_1 : Two node cuttings of primary rhizome (10g) + Salem
S_2V_2 : Two node cuttings of primary rhizome (10g) + Rajendra Sonia
S_2V_3 : Two node cuttings of primary rhizome (10g) + ACC – 79
S_3V_1 : Vertical spl of mother rhizome + Salem
S_3V_2 : Vertical spl of mother rhizome + Rajendra Sonia
S_3V_3 : Vertical spl of mother rhizome + ACC - 79
S_4V_1 : Full mother rhizome + Salem
S_4V_2 : Full mother rhizome + Rajendra Sonia
S_4V_3 : Full mother rhizome + ACC - 79

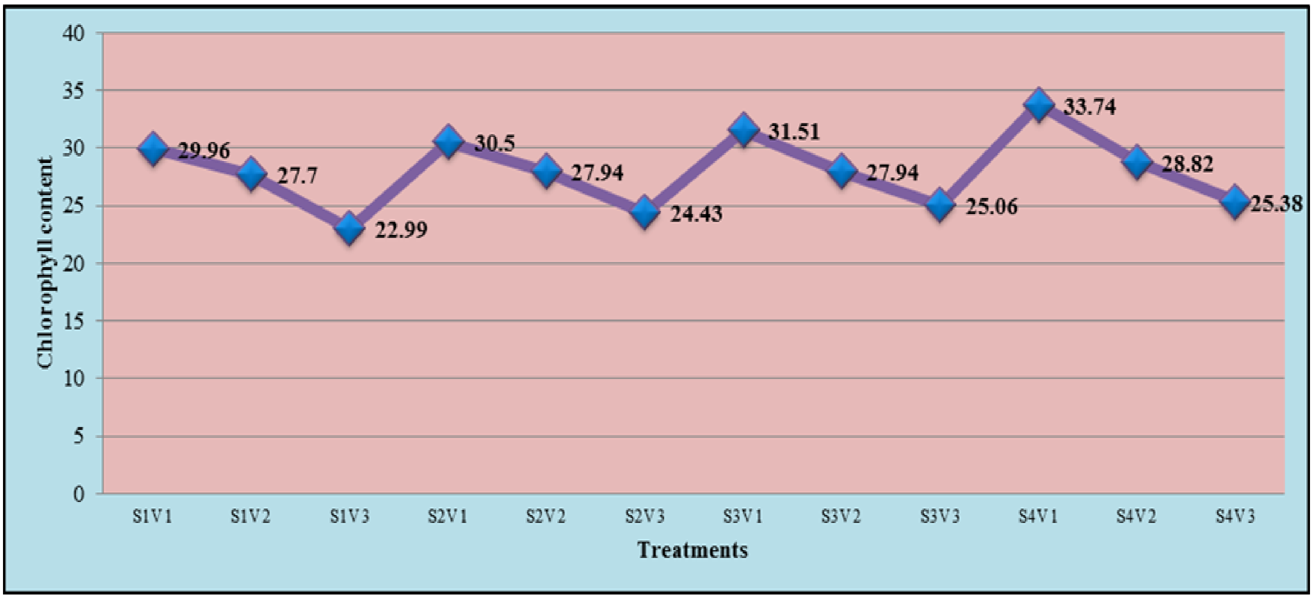

Fig. 6 : Effect of size of plant material and varieties in protrays on chlorophyll content

Treatments :

S_1V_1 : Single node cutting of primary rhizome (5g) + Salem
S_1V_2 : Single node cutting of primary rhizome (5g) + Rajendra Sonia
S_1V_3 : Single node cutting of primary rhizome (5g) + ACC – 79
S_2V_1 : Two node cuttings of primary rhizome (10g) + Salem
S_2V_2 : Two node cuttings of primary rhizome (10g) + Rajendra Sonia
S_2V_3 : Two node cuttings of primary rhizome (10g) + ACC – 79
S_3V_1 : Vertical spl of mother rhizome + Salem
S_3V_2 : Vertical spl of mother rhizome + Rajendra Sonia
S_3V_3 : Vertical spl of mother rhizome + ACC - 79
S_4V_1 : Full mother rhizome + Salem
S_4V_2 : Full mother rhizome + Rajendra Sonia
S_4V_3 : Full mother rhizome + ACC - 79

Table 10 : Benefit cost ratio of turmeric effected by size of planting material and varieties in protrays

Treat-ments	Plant population Per tray	Plant population Per hectare	Seedling price Rs.	Qty. of seed rhizome kg. ha^{-1}	Seed rhizome cost per kg	Amount (Rs.)	Fixed price* (Rs.)	Total cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B: C ratio
S1V1	49.55	86712.50	2	99.10	80	7928.00	58,080	66008.00	173425	107417.00	1.63
S1V2	47.02	82285.00	2	94.04	80	7523.20	58,080	65603.20	164570	98966.80	1.51
S1V3	40.69	71207.50	2	81.38	80	6510.40	58,080	64590.40	142415	77824.60	1.20
S2V1	49.70	86975.00	2	99.40	80	7952.00	58,080	66032.00	173950	107918.00	1.63
S2V2	48.07	84122.50	2	96.14	80	7691.20	58,080	65771.20	168245	102473.80	1.56
S2V3	43.29	75757.50	2	86.57	80	6925.60	58,080	65005.60	151515	86509.40	1.34
S3V1	48.54	84945.00	2	97.08	80	7766.40	58,080	65846.40	169890	104043.60	1.58
S3V2	46.15	80762.50	2	92.30	80	7384.00	58,080	65464.00	161525	96061.00	1.47
S3V3	37.29	65257.50	2	74.58	80	5966.40	58,080	64046.40	130515	66469.00	1.04
S4V1	48.47	84822.50	2	96.93	80	7754.40	58,080	65834.40	169645	103810.60	1.57
S4V2	46.06	80605.00	2	92.12	80	7369.60	58,080	65449.60	161210	95760.40	1.46
S4V3	36.62	64085.00	2	73.24	80	5859.20	58,080	63939.20	128170	64230.80	1.00

Factor 1: Size of plant material (S)
S1: Single node cutting of primary rhizome (5g)
S2: Two-node cutting of primary rhizome (10g).
S3: Vertical split of mother rhizome.
S4: Full mother rhizome

Factor 2 : Varieties (V)
V1 : Salem
V2 : Rajendra Sonia
V3 : ACC - 79

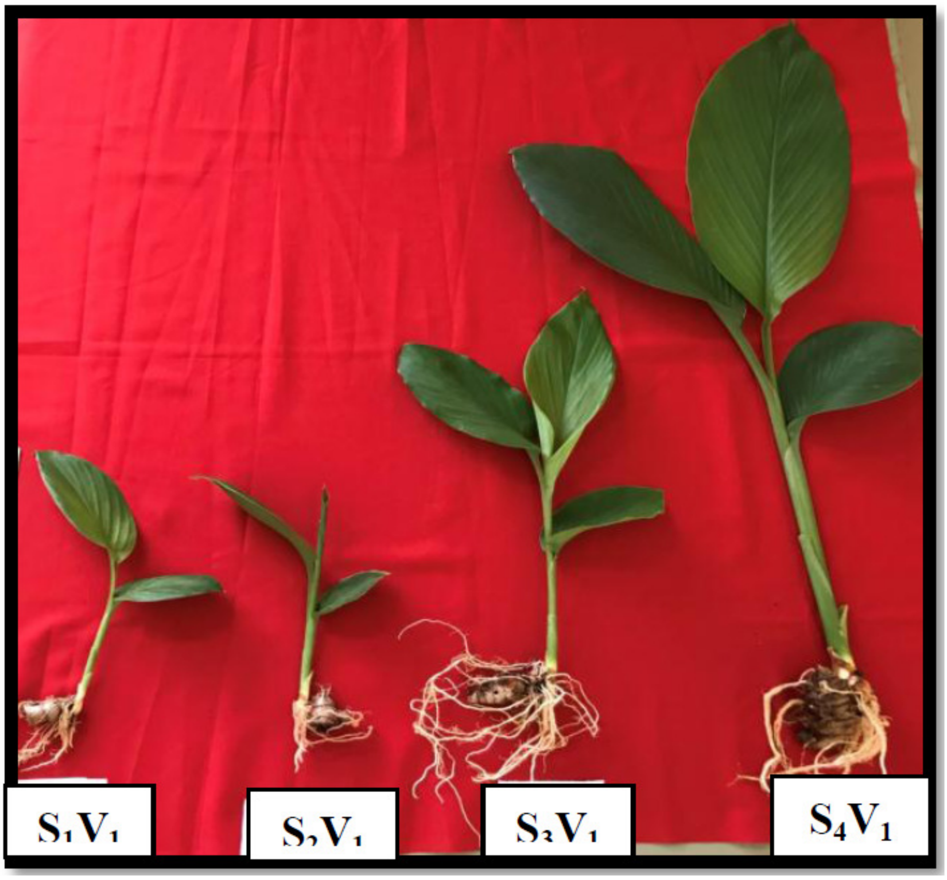

Plate 1 : Seedling vigour index – Salem

Plate 2 : Seedling vigour index – Rajendra Sonia

Plate 3 : Seedling vigour index – ACC 79

Plate 4 : SPAD meter reading – chlorophyll content

Plate 5 : Overall field view of the experiment

Conclusion

From the results obtained by the use of portrays in the multiplication of plant material of turmeric, it was indicated that the size of planting material and varieties influenced the germination, growth and quality parameters of turmeric. The vertical split of the mother rhizome of the Salem variety has shown the best results in terms of germination, growth and quality parameters followed by the vertical split of the mother rhizome of the Rajendra Sonia variety. In terms of benefit-cost (B: C) ratio, the treatment S_1V_1- Single node cutting of primary rhizome + Salem and S_2V_1- Two node cutting of primary rhizome + Salem has recorded maximum benefit-cost ratio (1.63) followed by S_3V_1- Vertical split of mother rhizome + Salem (1.58). This was due to the reduction of the quantity of planting material which reduced the cost of cultivation and in turn increased the benefit-cost ratio.

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