



Drought screening in cocoa (*Theobroma cacao* L.) based on root and shoot parameters

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Abstract

Cocoa (*Theobroma cacao* L.) belongs to the family Malvaceae originated from Amazon forests and highly sensitive to drought or water deficit condition. This study was conducted with 35 cocoa single plant selections collected from Thondanuthur and Vedapatti regions of Coimbatore districts and the screening was done in Coconut nursery, Department of Spices and Plantation crops, Horticultural College and Research Institute, Tamilnadu Agricultural University, Coimbatore. The seedling of 3 months old were used for the screening with two different moisture conditions viz., 100 percent field capacity and 50 percent field capacity. After imposition of treatments, observations on root and shoot parameters were taken after 45 days. Among the 35 plus trees, under 50% FC Tc (Vedapatti) 48 recorded more number of roots, maximum fresh weight, maximum whole plant fresh weight and highest root volume. Tc (Vedapatti) 2 recorded increased fresh root weight and dry root weight under stress condition. Tc (Vedapatti) 86 recorded high dry shoot weight and whole plant dry weight under 50% FC when compared to control. Baby santhini (2017) also reported the same in case of root characters evaluated under different stress condition in cocoa. Similarly, the seedling of plus trees, Tc (Vedapatti) 2, Tc (Vedapatti) 48 and Tc (Vedapatti) 86 was also recorded less difference in root recorded under different irrigation regime (50 and 100 per cent respectively). Hence, these plus trees can be further evaluated in the field condition to screen for drought tolerance.

Keywords: cocoa, drought, field capacity, root and shoot parameters

1. Introduction

Cocoa, one of the world's most important perennial crop, is almost exclusively used for chocolate manufacturing. Growth and development of cacao are highly dependent on temperature, which mainly affects the vegetative growth, flowering and fruit development. Cocoa is highly sensitive to changes in climate from hours of sunshine to rainfall and irrigation, soil condition and particularly to temperature due to effects on evapotranspiration (Janani, 2014) [6]. Due to the recent impact of global warming, rain in the cocoa growing areas are either irregular or low often causing water stress which affects not only the yield but also its contributory factors such as canopy architecture, photosynthesis and partitioning of assimilates etc. Therefore, it is of paramount importance to identify clones which can withstand moisture stress conditions in the field and to evolve management strategies for conserving soil water in order to mitigate adverse effect of drought (Adewale, 2013) [1].

Cocoa is highly susceptible to drought and the cropping pattern is related to rainfall distribution. It is mainly cultivated as intercrop under coconut and arecanut plantations because of diversified climatic conditions in Tamil Nadu. When compared to other plantation crops, cocoa is less efficient in controlling of water loss and does not tolerate periods of long water stress (Raja Harun and Hardwick, 1988) [7]. Cocoa seedling mortality is high during dry season. Even when there is a short period of drought, pod filling and bean size are adversely affected. Due to the severe

changes in climate nowadays, need to produce a clone suitable for drought in cocoa is mandatory. Hence, this study was conducted to identify a clone suitable to drought condition in cocoa based on their root and shoot parameters.

2. Materials and Methods

Thirty five high yielding plus trees were selected for this study based on previous yield analysis. Three month old seedlings from the identified 35 plus trees were subjected to two different irrigation regimes (100% field capacity and 50% field capacity). The treatment was fixed based on the following calculation. Each empty pot was weighed accurately and weight was noted as 'A'. The pots were filled with soil: sand: vermicompost mixture in the ratio of 1:1:1. The pots were weighed along with the soil and noted as 'B'.

Above data was used to calculate the soil dry weight (C) as $C=B-A$. The pots were flooded with water and allowed overnight to drain excess water and attain field capacity. Pot weight was taken after saturation and denoted as 'D'. The amount of water required to maintain 100 per cent field capacity (E) was obtained by subtracting the dry soil weight from the saturated soil weight i.e. $E= D-B$. Further, pots were weighed once in two days and water was supplied to maintain the weight of pot at field capacity up to initiation of new flush. The water supply was withheld when new flushing initiation was observed in plant and it was watered only

when pot weighed below 50 per cent of field capacity as per the treatment (Shivakumar, 2013)^[9].

100 per cent field capacity for control and 50 per cent field capacity for treatment were maintained by weighing and watering each plant at regular interval. The experiment was laid out in completely factorial randomized block design with three replications. After 45 days of drought imposition the root and shoot parameters were measured.

Plants exposed to different irrigation regimes were uprooted after 45 days and cleaned then root length was measured and expressed in centimeter. Similarly, fresh shoot weight and fresh root weight was also taken and expressed in gram. Root volume was estimated after immersion of roots in a known water volume and observing its displacement and expressed in cm³. Girth of root was measured using thread and scale. Five roots were randomly selected for observation and the average was calculated and expressed in centimeter. Number of roots were counted and expressed in numbers. Whole plant fresh weight was calculated by adding of fresh root weight and fresh shoot weight and expressed in gram. The root and shoot samples were dried in oven for a week and dry weight of root and shoot was taken and expressed in gram. Whole plant dry weight was calculated by adding dry root weight and dry shoot weight and expressed in gram.

3. Results and Discussion

Root length

Significant variation was observed among the 35 plus trees, irrigation schedule and their interaction for root length. The highest mean activity was found in Tc (Vedapatti) 29 (40.4cm) and lowest mean length was recorded in Tc (Vedapatti) 110 (11.00cm). For different irrigation regime, the root length was recorded as 25.2cm against control 26.6cm.

The interaction between irrigation schedule and plus trees, highest root length was found in Tc (Vedapatti) 29 (42.00cm) and low value was found in Tc (Vedapatti) 86 (12.8cm) for the control plants. For the treated plants, the lowest root length was recorded about 40.00cm in Tc (Vedapatti) 29 against the highest root length of 9.3cm in Tc (Vedapatti) 110.

Fresh shoot weight

Significant variation for fresh shoot weight in plus trees, irrigation schedule and their interaction was recorded. In plus trees, the highest mean weight was recorded in Tc (Vedapatti) 86 (25.34g) and the lowest was observed in Tc (Vedapatti) 63 (2.22g). For different irrigation schedule, the increased fresh shoot weight of 6.3g was recorded in case of treated plants against 5.6g for the plants kept under 100 per cent field capacity.

Among interaction between genotypes and irrigation regime, the highest fresh shoot weight 23.09g was recorded in Tc (Vedapatti) 86 and lowest was recorded about 2.13g in Tc (Vedapatti) 1 for the plants treated with 100 per cent field capacity. At 50 per cent field capacity, the highest fresh shoot weight was recorded in Tc (Vedapatti) 48 (26.50g) and lowest was recorded in Tc (Vedapatti) 63 (2.09g)

Fresh root weight

Significant variation for fresh root weight was observed for the selected 35 plus trees, irrigation schedule and their interactions. Among the 35 plus trees, Tc (Vedapatti) 2 recorded highest mean

weight (16.43g) and lowest mean weight was recorded by Tc (Vedapatti) 15 (2.26g). For different irrigation regime, the fresh root weight was recorded as 4.5g against control (4.1g).

For the interaction between the plus trees and irrigation schedule, highest fresh root weight was recorded in Tc (Vedapatti) 2 (12.63g) and lowest was recorded in Tc (Vedapatti) 55 (2.08g) in 100 per cent field capacity. For the drought condition, the highest value was recorded in Tc (Vedapatti) 2 (17.38g) and the lowest was recorded in Tc (Vedapatti) 15 (2.15g).

Root volume

Root volume showed significant difference between plus trees, irrigation regime and their interactions. Plus tree Tc (Vedapatti) 91 and Tc (Vedapatti) 76 recorded highest mean root volume (32.50cm³) and Tc (Vedapatti) 85 recorded lowest mean root volume (15.50cm³). For different irrigation regime, 50 per cent field capacity recorded 23.9cm³ of root volume against 24.1cm³ at 100 per cent field capacity.

Interaction between irrigation schedule and plus trees, highest root volume was found in Tc (Vedapatti) 34 (34.00cm³) and low value was found in Tc (Vedapatti) 85 (16.00cm³) for the control plants. For treated plants, the highest root volume was recorded about 34.00cm³ in Tc (Vedapatti) 48 and Tc (Vedapatti) 111 while the lowest root volume of 15cm³ in Tc (Vedapatti) 85.

Root girth

Significant variation was observed for root girth among 35 plus trees, irrigation schedule and their interactions. Among all, Tc (Vedapatti) 2 recorded highest root girth (2.46cm) and lowest value was recorded by Tc (Vedapatti) 110 (1.32cm). For different irrigation regime, the root girth was remains unchanged for both treatment as well as control (1.9cm).

The interaction between the plus trees and irrigation schedule, highest root girth was recorded in Tc (Vedapatti) 2 and Tc (Vedapatti) 33 (2.32cm), and lowest was recorded in Tc (Vedapatti) 67 (1.52cm) in 100 per cent field capacity. For the drought condition, the highest value was recorded in Tc (Vedapatti) 2 (2.50cm) and the lowest was recorded in Tc (Vedapatti) 67 (1.57cm).

Dry shoot weight

Dry shoot weight was significantly varied among 35 plus trees, drought treatment and their interactions. The highest mean dry shoot weight was recorded in the plus tree, Tc (Vedapatti) 86 (10.58g), the lowest weight was found in Tc (Vedapatti) 76 (0.79g). For different irrigation regime, treated plants recorded increased dry root weight 2.8g against 2.7g in control.

Variation was observed between interaction of plus trees and drought condition. For 100 per cent field capacity the highest dry shoot weight was recorded as 12.98g in Tc (Vedapatti) 48, lowest weight was recorded in Tc (Vedapatti) 66 (1.00g). For the treated plants, high dry shoot weight was observed in Tc (Vedapatti) 86 (12.13g) and low dry shoot weight was recorded in Tc (Vedapatti) 110 (0.31g)

Dry root weight

Observation on dry root weight showed significant variation for irrigation schedule, plus trees and their interaction. The highest mean dry root weight (5.36g) was recorded in Tc (Vedapatti) 2 and the lowest value (0.45g) was recorded in Tc (Vedapatti) 66.

For different irrigation regime, the increased dry root weight of 1.5g recorded in 50 per cent field capacity against 1.4g in 100 per cent field capacity.

Among the interaction effects between plus trees and irrigation regime, 100 per cent field capacity recorded highest and lowest dry root weight in Tc (Vedapatti) 86 (4.73g) and Tc (Vedapatti) 85 (0.16g) respectively. At 50 per cent field capacity, lowest value in Tc (Vedapatti) 110 and highest value in Tc (Vedapatti) 2 recorded 0.28g and 5.71g respectively.

Number of roots

Observation on number of roots varied among the plus trees, irrigation regime and their interactions. Among 35 plus trees, the highest mean was recorded in Tc (Vedapatti) 48 (47.00), lowest was recorded in Tc (Vedapatti) 63. For different irrigation regime, the number of roots at 50 per cent filed capacity is 29.1 against 24.4 in 100 per cent field capacity.

The interaction effect showed that, the highest and lowest number of roots (57 and 7) recorded by Tc (Vedapatti) 99 and Tc (Vedapatti) 63 respectively for the plants treated with 100 per cent field capacity. At the same time, Tc (Vedapatti) 48 and Tc (Vedapatti) 37 recorded highest and lowest number of roots (51 and 12 respectively) for drought imposed plants.

Whole plant fresh weight

Significant variation was observed between drought application, plus trees and their interaction for whole plant fresh weight. Highest mean whole plant fresh weight for plus trees was recorded about 34.61g in Tc (Thondamuthur) 86 and lowest was recorded in Tc (Vedapatti) 68 (4.88g). For different irrigation regimes, whole plant fresh weight was 10.7g in drought imposed plants against 9.6g in control.

Interaction between plus trees and treatment showed variation for whole plant fresh weight. It was observed that, Tc (Vedapatti) 86 (32.70g) and Tc (Vedapatti) 68 (4.46g) recorded highest and lowest whole plant fresh weight respectively for 100 per cent field capacity. Under 50 per cent filed capacity, the weight was recorded about 36.80g (highest) and 4.32g (lowest) in Tc (Vedapatti) 48 and Tc (Vedapatti) 15 respectively.

Whole plant dry weight

There is a significant variation for whole plant dry weight in plus Trees, irrigation schedule and their interaction. In plus trees, the highest mean was recorded in Tc (Vedapatti) 86 (14.95g) and the lowest was observed in Tc (Vedapatti) 15 (1.73g). For different irrigation schedule, the whole plant fresh weight was recorded as 4.2g in case of treated plants against 4.1g in control.

The interaction on plus trees and irrigation regime also showed variation. The highest whole plant fresh weight 16.17g was recorded in Tc (Vedapatti) 48 and lowest was recorded about 1.32g in Tc (Vedapatti) 85 for the plants treated with 100 per cent field capacity. Plants treated with 50 per cent filed capacity, the highest whole plant fresh weight was recorded in Tc (Vedapatti) 86 (16.15g) and lowest was recorded in Tc (Vedapatti) 110 (0.59g).

4. Discussion

During drought condition, plants tend to reduce their activity and try to end their life cycle (Balasimha, 1985) ^[4]. In this study, under drought condition roots showed stunted growth. The experiment conducted with young cocoa plants showed depressive effect of water deficit stress on biomass, leaf emergence, girth, height and mortality of cocoa. The root and aerial biomass of cocoa decreased according to the degree of severity of stress. These results confirmed the sensitivity of cocoa to the slight variation of soil moisture. (Alban *et al.*, 2016) ^[2]; (Elian Apshara *et al.*, 2013) ^[2]. In this study, under drought condition Tc (Vedapatti) 48 recorded more number of roots, maximum fresh weight, maximum whole plant fresh weight and highest root volume. Tc (Vedapatti) 2 recorded increased fresh root weight and dry root weight under stress condition. Tc (Vedapatti) 86 recorded high dry shoot weight and whole plant dry weight under 50% FC when compared to control. Baby santhini (2017) ^[3] also reported the same in case of root characters evaluated under different strees condition in cocoa. Among the 35 plus trees evaluated for water stress, Tc (Vedapatti) 2, Tc (Vedapatti) 48 and Tc (Vedapatti) 86 showed less difference in root parameters recorded under different irrigation regime (50 and 100 per cent respectively). Hence, these plus trees can be further evaluated in the field condition to screen for drought tolerance.

Table 1: Effect of different irrigation regime on root length (cm) on the seedlings of screened plus trees

S. No	Plus trees	Root length (cm)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	28.0	18.0	20.0
2	Tc (Vedapatti) 2	33.2	38.0	37.0
3	Tc (Vedapatti) 9	25.5	23.5	23.9
4	Tc (Vedapatti) 15	27.9	27.0	27.2
5	Tc (Vedapatti) 18	31.0	30.5	30.6
6	Tc (Vedapatti) 29	42.0	40.0	40.4
7	Tc (Vedapatti) 31	21.2	24.5	23.8
8	Tc (Vedapatti) 33	18.5	21.1	20.6
9	Tc (Vedapatti) 37	33.5	16.4	19.8
10	Tc (Vedapatti) 40	31.0	29.5	29.8
11	Tc (Vedapatti) 41	24.3	26.4	26.0
12	Tc (Vedapatti) 42	21.0	22.6	22.3
13	Tc (Vedapatti) 45	28.0	29.0	28.8
14	Tc (Vedapatti) 48	21.8	27.0	26.0
15	Tc (Vedapatti) 55	27.1	29.3	28.9

16	Tc (Vedapatti) 61	27.6	31.6	30.8
17	Tc (Vedapatti) 63	18.2	10.8	12.3
18	Tc (Vedapatti) 64	23.2	26.5	25.8
19	Tc (Vedapatti) 66	28.5	37.0	35.3
20	Tc (Vedapatti) 67	28.0	22.5	23.6
21	Tc (Vedapatti) 68	31.0	16.9	19.7
22	Tc (Vedapatti) 72	23.6	22.1	22.4
23	Tc (Vedapatti) 75	26.7	33.5	32.1
24	Tc (Vedapatti) 76	23.5	29.6	28.4
25	Tc (Vedapatti) 78	30.0	23.1	24.5
26	Tc (Vedapatti) 85	29.0	30.0	29.8
27	Tc (Vedapatti) 86	12.8	14.2	13.9
28	Tc (Vedapatti) 88	27.0	17.0	19.0
29	Tc (Vedapatti) 90	33.0	30.3	30.8
30	Tc (Vedapatti) 91	36.5	30.5	31.7
31	Tc (Vedapatti) 94	28.7	15.9	18.5
32	Tc (Vedapatti) 99	24.5	29.5	28.5
33	Tc (Vedapatti) 110	17.7	9.3	11.0
34	Tc (Vedapatti) 111	12.9	24.0	21.8
35	Tc (Thondamuthur) 121	33.0	26.6	27.9
Mean		26.6	25.2	25.5
		P	I	P×I
SE(d)		0.392	0.101	0.555
CD (P=0.05)		0.776	0.200	1.097
NS – Non significant, * - Significant, ** - Highly Significant				

Table 2: Effect of different irrigation regime on shoot weight (g) on the seedlings of screened plus trees

S. No	Plus trees	Fresh shoot weight (g)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	2.13	3.65	3.35
2	Tc (Vedapatti) 2	5.67	7.82	7.39
3	Tc (Vedapatti) 9	2.41	4.55	4.12
4	Tc (Vedapatti) 15	3.53	2.17	2.44
5	Tc (Vedapatti) 18	2.37	2.70	2.63
6	Tc (Vedapatti) 29	9.15	4.60	5.51
7	Tc (Vedapatti) 31	3.11	2.78	2.85
8	Tc (Vedapatti) 33	10.73	16.70	15.51
9	Tc (Vedapatti) 37	3.15	2.32	2.49
10	Tc (Vedapatti) 40	3.79	2.85	3.04
11	Tc (Vedapatti) 41	6.86	19.60	17.05
12	Tc (Vedapatti) 42	3.80	4.97	4.74
13	Tc (Vedapatti) 45	4.70	5.75	5.54
14	Tc (Vedapatti) 48	18.54	26.50	24.91
15	Tc (Vedapatti) 55	2.63	4.25	3.93
16	Tc (Vedapatti) 61	8.95	2.86	4.08
17	Tc (Vedapatti) 63	2.76	2.09	2.22
18	Tc (Vedapatti) 64	5.01	5.32	5.26
19	Tc (Vedapatti) 66	2.95	2.65	2.71
20	Tc (Vedapatti) 67	7.37	3.18	4.02
21	Tc (Vedapatti) 68	2.04	2.45	2.37
22	Tc (Vedapatti) 72	3.52	4.41	4.23
23	Tc (Vedapatti) 75	5.91	5.17	5.32
24	Tc (Vedapatti) 76	2.49	2.89	2.81
25	Tc (Vedapatti) 78	2.95	3.27	3.21
26	Tc (Vedapatti) 85	3.19	3.92	3.77
27	Tc (Vedapatti) 86	23.09	25.90	25.34
28	Tc (Vedapatti) 88	2.79	2.19	2.31
29	Tc (Vedapatti) 90	2.79	2.53	2.58
30	Tc (Vedapatti) 91	4.58	3.28	3.54
31	Tc (Vedapatti) 94	8.07	2.01	3.22
32	Tc (Vedapatti) 99	4.31	7.51	6.87
33	Tc (Vedapatti) 110	2.32	7.63	6.57

34	Tc (Vedapatti) 111	7.87	10.90	10.29
35	Tc (Thondamuthur) 121	10.05	8.15	8.53
Mean		5.6	6.3	5.9
		P	I	P×I
SE (d)		0.134	0.035	0.190
CD (P=0.05)		0.265	0.068	0.375
NS – Non significant, * - Significant, ** - Highly Significant				

Table 3: Effect of different irrigation regime on root weight (g) on the seedlings of screened plus trees

S. No	Plus trees	Fresh root weight (g)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	3.08	2.49	2.61
2	Tc (Vedapatti) 2	12.63	17.38	16.43
3	Tc (Vedapatti) 9	2.65	5.13	4.63
4	Tc (Vedapatti) 15	2.72	2.15	2.26
5	Tc (Vedapatti) 18	2.19	2.51	2.45
6	Tc (Vedapatti) 29	3.67	2.64	2.85
7	Tc (Vedapatti) 31	3.61	6.73	6.11
8	Tc (Vedapatti) 33	2.32	3.18	3.01
9	Tc (Vedapatti) 37	3.15	3.35	3.31
10	Tc (Vedapatti) 40	2.95	2.78	2.81
11	Tc (Vedapatti) 41	4.17	4.27	4.25
12	Tc (Vedapatti) 42	2.32	2.54	2.50
13	Tc (Vedapatti) 45	4.43	5.35	5.17
14	Tc (Vedapatti) 48	6.85	10.30	9.61
15	Tc (Vedapatti) 55	2.08	2.48	2.40
16	Tc (Vedapatti) 61	3.99	4.86	4.69
17	Tc (Vedapatti) 63	3.25	3.18	3.19
18	Tc (Vedapatti) 64	2.73	3.27	3.16
19	Tc (Vedapatti) 66	2.72	2.88	2.85
20	Tc (Vedapatti) 67	5.11	2.25	2.82
21	Tc (Vedapatti) 68	2.42	2.85	2.76
22	Tc (Vedapatti) 72	4.31	2.53	2.89
23	Tc (Vedapatti) 75	4.69	3.83	4.00
24	Tc (Vedapatti) 76	2.73	2.74	2.74
25	Tc (Vedapatti) 78	2.59	3.09	2.99
26	Tc (Vedapatti) 85	2.34	3.62	3.36
27	Tc (Vedapatti) 86	9.61	10.61	10.41
28	Tc (Vedapatti) 88	2.36	2.57	2.53
29	Tc (Vedapatti) 90	2.54	2.41	2.44
30	Tc (Vedapatti) 91	5.95	2.32	3.05
31	Tc (Vedapatti) 94	4.53	3.65	3.83
32	Tc (Vedapatti) 99	4.56	3.05	3.35
33	Tc (Vedapatti) 110	5.31	2.16	2.79
34	Tc (Vedapatti) 111	6.38	12.76	11.48
35	Tc (Thondamuthur) 121	4.84	8.38	7.67
Mean		4.1	4.5	4.3
		P	I	P×I
SE (d)		0.073	0.019	0.103
CD (P=0.05)		0.144	0.037	0.204
NS – Non significant, * - Significant, ** - Highly Significant				

Table 4: Effect of different irrigation regime on root volume (cm³) on the seedlings of screened plus trees

S. No	Plus trees	Root volume (cm ³)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	23.00	21.00	22.00
2	Tc (Vedapatti) 2	18.00	28.00	23.00
3	Tc (Vedapatti) 9	18.00	20.00	19.00
4	Tc (Vedapatti) 15	21.00	17.00	19.00
5	Tc (Vedapatti) 18	23.00	25.00	24.00

6	Tc (Vedapatti) 29	21.00	19.00	20.00
7	Tc (Vedapatti) 31	19.00	20.00	19.50
8	Tc (Vedapatti) 33	21.00	25.00	23.00
9	Tc (Vedapatti) 37	32.00	27.00	29.50
10	Tc (Vedapatti) 40	28.00	23.00	25.50
11	Tc (Vedapatti) 41	29.00	27.00	28.00
12	Tc (Vedapatti) 42	25.00	22.00	23.50
13	Tc (Vedapatti) 45	19.00	21.00	20.00
14	Tc (Vedapatti) 48	27.00	34.00	30.50
15	Tc (Vedapatti) 55	27.00	24.00	25.50
16	Tc (Vedapatti) 61	21.00	19.00	20.00
17	Tc (Vedapatti) 63	17.00	21.00	19.00
18	Tc (Vedapatti) 64	25.00	21.00	23.00
19	Tc (Vedapatti) 66	23.00	25.00	24.00
20	Tc (Vedapatti) 67	27.00	23.00	25.00
21	Tc (Vedapatti) 68	19.00	21.00	20.00
22	Tc (Vedapatti) 72	21.00	19.00	20.00
23	Tc (Vedapatti) 75	26.00	22.00	24.00
24	Tc (Vedapatti) 76	34.00	31.00	32.50
25	Tc (Vedapatti) 78	25.00	20.00	22.50
26	Tc (Vedapatti) 85	16.00	15.00	15.50
27	Tc (Vedapatti) 86	25.00	32.00	28.50
28	Tc (Vedapatti) 88	26.00	21.00	23.50
29	Tc (Vedapatti) 90	24.00	19.00	21.50
30	Tc (Vedapatti) 91	32.00	33.00	32.50
31	Tc (Vedapatti) 94	31.00	32.00	31.50
32	Tc (Vedapatti) 99	29.00	27.00	28.00
33	Tc (Vedapatti) 110	27.00	28.00	27.50
34	Tc (Vedapatti) 111	26.00	34.00	30.00
35	Tc (Thondamuthur) 121	20.00	22.00	21.00
Mean		24.1	23.9	24.0
		P	I	P×I
SE (d)		0.365	0.094	0.516
CD (P=0.05)		0.721	0.186	1.020
NS – Non significant, * - Significant, ** - Highly Significant				

Table 5: Effect of different irrigation regime on root girth (cm) on the seedlings of screened plus trees

S. No	Plus trees	Root girth (cm)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	1.87	1.72	1.75
2	Tc (Vedapatti) 2	2.32	2.50	2.46
3	Tc (Vedapatti) 9	1.79	1.96	1.93
4	Tc (Vedapatti) 15	2.04	1.63	1.71
5	Tc (Vedapatti) 18	1.67	1.81	1.78
6	Tc (Vedapatti) 29	2.13	2.15	2.15
7	Tc (Vedapatti) 31	2.01	1.68	1.75
8	Tc (Vedapatti) 33	2.32	2.21	2.23
9	Tc (Vedapatti) 37	1.96	1.62	1.69
10	Tc (Vedapatti) 40	1.97	2.07	2.05
11	Tc (Vedapatti) 41	2.21	2.15	2.16
12	Tc (Vedapatti) 42	2.09	1.84	1.89
13	Tc (Vedapatti) 45	1.86	1.96	1.94
14	Tc (Vedapatti) 48	2.19	2.23	2.22
15	Tc (Vedapatti) 55	1.79	2.13	2.06
16	Tc (Vedapatti) 61	2.13	1.84	1.90
17	Tc (Vedapatti) 63	1.68	1.76	1.74
18	Tc (Vedapatti) 64	2.03	1.78	1.83
19	Tc (Vedapatti) 66	1.79	1.75	1.76
20	Tc (Vedapatti) 67	1.52	1.57	1.56
21	Tc (Vedapatti) 68	1.89	1.58	1.64
22	Tc (Vedapatti) 72	1.82	2.09	2.04
23	Tc (Vedapatti) 75	2.01	2.16	2.13

24	Tc (Vedapatti) 76	1.57	1.58	1.58
25	Tc (Vedapatti) 78	1.53	1.78	1.73
26	Tc (Vedapatti) 85	1.69	1.81	1.79
27	Tc (Vedapatti) 86	2.22	2.41	2.37
28	Tc (Vedapatti) 88	1.71	1.85	1.82
29	Tc (Vedapatti) 90	1.61	1.75	1.72
30	Tc (Vedapatti) 91	2.01	1.83	1.87
31	Tc (Vedapatti) 94	2.07	1.72	1.79
32	Tc (Vedapatti) 99	2.05	1.67	1.75
33	Tc (Vedapatti) 110	1.66	1.24	1.32
34	Tc (Vedapatti) 111	2.16	2.27	2.25
35	Tc (Thondamuthur) 121	1.98	1.95	1.96
Mean		1.9	1.9	1.9
		P	I	P×I
SE (d)		0.032	0.008	0.045
CD (P=0.05)		0.063	0.016	0.088
NS – Non significant, * - Significant, ** - Highly Significant				

Table 6: Effect of different irrigation regime on dry shoot weight (g) on the seedlings of screened plus trees

S. No	Plus trees	Dry shoot weight (g)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	1.75	1.87	1.81
2	Tc (Vedapatti) 2	3.87	9.06	6.46
3	Tc (Vedapatti) 9	1.30	1.90	1.60
4	Tc (Vedapatti) 15	1.30	1.04	1.17
5	Tc (Vedapatti) 18	1.62	1.31	1.47
6	Tc (Vedapatti) 29	2.71	1.54	2.13
7	Tc (Vedapatti) 31	1.55	1.59	1.57
8	Tc (Vedapatti) 33	4.92	3.83	4.38
9	Tc (Vedapatti) 37	1.74	1.58	1.66
10	Tc (Vedapatti) 40	1.36	1.67	1.52
11	Tc (Vedapatti) 41	3.98	11.13	7.56
12	Tc (Vedapatti) 42	1.57	1.96	1.77
13	Tc (Vedapatti) 45	1.99	2.69	2.34
14	Tc (Vedapatti) 48	12.98	6.20	9.59
15	Tc (Vedapatti) 55	1.30	1.82	1.56
16	Tc (Vedapatti) 61	3.67	1.82	2.74
17	Tc (Vedapatti) 63	1.61	1.55	1.58
18	Tc (Vedapatti) 64	1.79	1.96	1.87
19	Tc (Vedapatti) 66	1.00	1.85	1.42
20	Tc (Vedapatti) 67	3.07	1.86	2.46
21	Tc (Vedapatti) 68	1.16	1.59	1.38
22	Tc (Vedapatti) 72	1.39	1.53	1.46
23	Tc (Vedapatti) 75	2.29	3.38	2.83
24	Tc (Vedapatti) 76	1.10	0.49	0.79
25	Tc (Vedapatti) 78	1.39	1.48	1.44
26	Tc (Vedapatti) 85	1.16	1.40	1.28
27	Tc (Vedapatti) 86	9.02	12.13	10.58
28	Tc (Vedapatti) 88	1.58	1.53	1.56
29	Tc (Vedapatti) 90	1.08	1.94	1.51
30	Tc (Vedapatti) 91	1.84	1.95	1.90
31	Tc (Vedapatti) 94	5.78	2.56	4.17
32	Tc (Vedapatti) 99	1.95	2.46	2.21
33	Tc (Vedapatti) 110	1.50	0.31	0.90
34	Tc (Vedapatti) 111	4.07	2.93	3.50
35	Tc (Thondamuthur) 121	3.09	2.40	2.75
Mean		2.7	2.8	2.7
		P	I	P×I
SE (d)		0.058	0.015	0.082
CD (P=0.05)		0.114	0.029	0.161
NS – Non significant, * - Significant, ** - Highly Significant				

Table 7: Effect of different irrigation regime on dry root weight (g) on the seedlings of screened plus trees

S. No	Plus trees	Dry root weight (g)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	0.76	1.86	1.64
2	Tc (Vedapatti) 2	3.98	5.71	5.36
3	Tc (Vedapatti) 9	0.48	1.63	1.40
4	Tc (Vedapatti) 15	0.65	0.46	0.50
5	Tc (Vedapatti) 18	0.72	0.48	0.53
6	Tc (Vedapatti) 29	0.87	0.49	0.57
7	Tc (Vedapatti) 31	0.33	0.50	0.47
8	Tc (Vedapatti) 33	1.50	2.09	1.97
9	Tc (Vedapatti) 37	0.86	1.41	1.30
10	Tc (Vedapatti) 40	1.61	1.43	1.47
11	Tc (Vedapatti) 41	0.71	2.73	2.33
12	Tc (Vedapatti) 42	0.42	0.50	0.48
13	Tc (Vedapatti) 45	1.16	1.13	1.13
14	Tc (Vedapatti) 48	3.19	3.02	3.05
15	Tc (Vedapatti) 55	0.46	1.53	1.32
16	Tc (Vedapatti) 61	0.98	1.04	1.03
17	Tc (Vedapatti) 63	1.71	1.16	1.27
18	Tc (Vedapatti) 64	1.97	0.73	0.98
19	Tc (Vedapatti) 66	0.55	0.42	0.45
20	Tc (Vedapatti) 67	0.38	1.22	1.05
21	Tc (Vedapatti) 68	0.46	1.92	1.63
22	Tc (Vedapatti) 72	0.38	0.50	0.48
23	Tc (Vedapatti) 75	0.74	1.07	1.00
24	Tc (Vedapatti) 76	1.91	1.08	1.25
25	Tc (Vedapatti) 78	1.62	0.67	0.86
26	Tc (Vedapatti) 85	0.16	1.34	1.10
27	Tc (Vedapatti) 86	4.73	4.02	4.16
28	Tc (Vedapatti) 88	0.54	0.65	0.62
29	Tc (Vedapatti) 90	1.78	0.57	0.81
30	Tc (Vedapatti) 91	1.84	1.28	1.39
31	Tc (Vedapatti) 94	2.95	1.76	2.00
32	Tc (Vedapatti) 99	1.95	1.05	1.23
33	Tc (Vedapatti) 110	1.50	0.28	0.53
34	Tc (Vedapatti) 111	2.70	4.09	3.81
35	Tc (Thondamuthur) 121	3.09	1.30	1.66
Mean		1.4	1.5	1.4
		P	I	P×I
SE (d)		0.026	0.007	0.037
CD (P=0.05)		0.051	0.013	0.072
NS – Non significant, * - Significant, ** - Highly Significant				

Table 8: Effect of different irrigation regime on number of roots on the seedlings of screened plus trees

S. No	Plus trees	Number of roots		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	31.00	26.00	28.50
2	Tc (Vedapatti) 2	23.00	31.00	27.00
3	Tc (Vedapatti) 9	13.00	25.00	19.00
4	Tc (Vedapatti) 15	35.00	25.00	30.00
5	Tc (Vedapatti) 18	16.00	18.00	17.00
6	Tc (Vedapatti) 29	50.00	24.00	37.00
7	Tc (Vedapatti) 31	20.00	50.00	35.00
8	Tc (Vedapatti) 33	30.00	28.00	29.00
9	Tc (Vedapatti) 37	18.00	12.00	15.00
10	Tc (Vedapatti) 40	13.00	31.00	22.00
11	Tc (Vedapatti) 41	16.00	32.00	24.00
12	Tc (Vedapatti) 42	21.00	41.00	31.00
13	Tc (Vedapatti) 45	20.00	30.00	25.00

14	Tc (Vedapatti) 48	43.00	51.00	47.00
15	Tc (Vedapatti) 55	22.00	31.00	26.50
16	Tc (Vedapatti) 61	18.00	28.00	23.00
17	Tc (Vedapatti) 63	7.00	18.00	12.50
18	Tc (Vedapatti) 64	10.00	47.00	28.50
19	Tc (Vedapatti) 66	14.00	30.00	22.00
20	Tc (Vedapatti) 67	38.00	27.00	32.50
21	Tc (Vedapatti) 68	34.00	20.00	27.00
22	Tc (Vedapatti) 72	45.00	40.00	42.50
23	Tc (Vedapatti) 75	17.00	38.00	27.50
24	Tc (Vedapatti) 76	42.00	33.00	37.50
25	Tc (Vedapatti) 78	12.00	50.00	31.00
26	Tc (Vedapatti) 85	15.00	20.00	17.50
27	Tc (Vedapatti) 86	18.00	15.00	16.50
28	Tc (Vedapatti) 88	18.00	25.00	21.50
29	Tc (Vedapatti) 90	31.00	29.00	30.00
30	Tc (Vedapatti) 91	20.00	40.00	30.00
31	Tc (Vedapatti) 94	15.00	18.00	16.50
32	Tc (Vedapatti) 99	57.00	22.00	39.50
33	Tc (Vedapatti) 110	33.00	23.00	28.00
34	Tc (Vedapatti) 111	22.00	15.00	18.50
35	Tc (Thondamuthur) 121	18.00	27.00	22.50
Mean		24.4	29.1	26.79
		P	I	P×I
SE (d)		0.409	0.106	0.579
CD (P=0.05)		0.809	0.209	1.144
NS – Non significant, * - Significant, ** - Highly Significant				

Table 9: Effect of different irrigation regime on whole plant fresh weight (g) on the seedlings of screened plus trees

S. No	Plus trees	Whole plant fresh weight (g)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	5.21	6.14	5.68
2	Tc (Vedapatti) 2	18.30	25.20	21.75
3	Tc (Vedapatti) 9	5.06	9.68	7.37
4	Tc (Vedapatti) 15	6.25	4.32	5.29
5	Tc (Vedapatti) 18	4.56	5.21	4.89
6	Tc (Vedapatti) 29	12.82	7.24	10.03
7	Tc (Vedapatti) 31	6.72	9.51	8.12
8	Tc (Vedapatti) 33	13.05	19.88	16.47
9	Tc (Vedapatti) 37	6.30	5.67	5.99
10	Tc (Vedapatti) 40	6.74	5.63	6.19
11	Tc (Vedapatti) 41	11.03	23.87	17.45
12	Tc (Vedapatti) 42	6.12	7.51	6.82
13	Tc (Vedapatti) 45	9.13	11.10	10.12
14	Tc (Vedapatti) 48	25.39	36.80	31.10
15	Tc (Vedapatti) 55	4.71	6.73	5.72
16	Tc (Vedapatti) 61	12.94	7.72	10.33
17	Tc (Vedapatti) 63	6.01	5.27	5.64
18	Tc (Vedapatti) 64	7.74	8.59	8.17
19	Tc (Vedapatti) 66	5.67	5.53	5.60
20	Tc (Vedapatti) 67	12.48	5.43	8.96
21	Tc (Vedapatti) 68	4.46	5.30	4.88
22	Tc (Vedapatti) 72	7.83	6.94	7.39
23	Tc (Vedapatti) 75	10.60	9.00	9.80
24	Tc (Vedapatti) 76	5.22	5.63	5.43
25	Tc (Vedapatti) 78	5.54	6.36	5.95
26	Tc (Vedapatti) 85	5.53	7.54	6.54
27	Tc (Vedapatti) 86	32.70	36.51	34.61
28	Tc (Vedapatti) 88	5.15	4.76	4.96
29	Tc (Vedapatti) 90	5.33	4.94	5.14
30	Tc (Vedapatti) 91	10.53	5.60	8.07
31	Tc (Vedapatti) 94	12.60	5.66	9.13

32	Tc (Vedapatti) 99	8.87	10.56	9.72
33	Tc (Vedapatti) 110	7.63	9.79	8.71
34	Tc (Vedapatti) 111	14.25	23.66	18.96
35	Tc (Thondamuthur) 121	14.89	16.53	15.71
Mean		9.6	10.7	10.2
		P	I	P×I
SE (d)		0.161	0.042	0.228
CD (P=0.05)		0.319	0.082	0.451
NS – Non significant, * - Significant, ** - Highly Significant				

Table 10: Effect of different irrigation regime on whole plant dry weight (g) on the seedlings of screened plus trees

S. No	Plus trees	Whole plant dry weight (g)		Mean
		Irrigation regime		
		100% FC	50% FC	
1	Tc (Vedapatti) 1	2.51	3.73	3.12
2	Tc (Vedapatti) 2	7.85	14.77	11.31
3	Tc (Vedapatti) 9	1.78	3.53	2.66
4	Tc (Vedapatti) 15	1.95	1.51	1.73
5	Tc (Vedapatti) 18	2.34	1.79	2.06
6	Tc (Vedapatti) 29	3.58	2.03	2.81
7	Tc (Vedapatti) 31	1.88	2.09	1.98
8	Tc (Vedapatti) 33	6.42	5.92	6.17
9	Tc (Vedapatti) 37	2.61	2.99	2.80
10	Tc (Vedapatti) 40	2.97	3.10	3.04
11	Tc (Vedapatti) 41	4.69	13.86	9.28
12	Tc (Vedapatti) 42	1.99	2.46	2.22
13	Tc (Vedapatti) 45	3.15	3.82	3.48
14	Tc (Vedapatti) 48	16.17	9.22	12.70
15	Tc (Vedapatti) 55	1.76	3.35	2.55
16	Tc (Vedapatti) 61	4.65	2.86	3.76
17	Tc (Vedapatti) 63	3.32	2.71	3.01
18	Tc (Vedapatti) 64	3.76	2.69	3.23
19	Tc (Vedapatti) 66	1.55	2.27	1.91
20	Tc (Vedapatti) 67	3.45	3.08	3.26
21	Tc (Vedapatti) 68	1.62	3.51	2.57
22	Tc (Vedapatti) 72	1.77	2.03	1.90
23	Tc (Vedapatti) 75	3.03	4.45	3.74
24	Tc (Vedapatti) 76	3.01	1.57	2.29
25	Tc (Vedapatti) 78	3.01	2.15	2.58
26	Tc (Vedapatti) 85	1.32	2.74	2.03
27	Tc (Vedapatti) 86	13.75	16.15	14.95
28	Tc (Vedapatti) 88	2.12	2.18	2.15
29	Tc (Vedapatti) 90	2.86	2.51	2.69
30	Tc (Vedapatti) 91	3.68	3.23	3.46
31	Tc (Vedapatti) 94	8.73	4.32	6.53
32	Tc (Vedapatti) 99	3.90	3.51	3.70
33	Tc (Vedapatti) 110	3.00	0.59	1.80
34	Tc (Vedapatti) 111	6.77	7.02	6.90
35	Tc (Thondamuthur) 121	6.17	3.70	4.94
Mean		4.1	4.2	4.2
		P	I	P×I
SE (d)		0.086	0.022	0.121
CD (P=0.05)		0.169	0.044	0.239
NS – Non significant, * - Significant, ** - Highly Significant				

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