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Aeroponic system is boon for rainfed mulberry cultivation and enhance productivity

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Abstract
Investigation on the growth parameters of mulberry saplings (*Morus sp.*) grown under aeroponic system and nursery condition were assessed at 15, 30, 45 and 60 days after transplanting. The plants grown under aeroponic system were recorded maximum for longest root length, number of primary roots, root biomass, longest shoot length and number of shoots. Among treatments, T_3 (three buds per cutting) recorded maximum for all growth parameters studied followed by T_2 (two buds per cutting) and T_1 (one bud per cutting). The interaction effect between propagation systems and number of buds per cutting showed significant results. S_1T_3 (Three budded cuttings under aeroponic system) recorded maximum for growth parameters *viz.*, number of primary roots (46.80), longest root length (26.90cm), root biomass (1.17g), number of shoots (6.63), longest shoot length (24.55cm) whereas least was recorded by S_2T_1(One budded cuttings under nursery) i.e., 20.00, 14.60cm, 0.38 g, 1.06 and 15.47 cm respectively at 60 DAT. From these results it can be concluded that, the aeroponic system could be effectively used for the production of V-1 mulberry saplings.

Keywords: V-1 mulberry, aeroponics, nursery, number of buds per cutting, root parameters

Introduction
Mulberry is grown in different ecological conditions based on soil type, variety, pruning practices and amount of water. Therefore, when there is a deficit of moisture, the varieties which are grown under stress conditions are preferred. Now, an attempt has been made to establish mulberry under less stress condition i.e., aeroponic system. The word 'Aeroponics' is derived from two Greek words *viz.*, – aer (air) and ponos (Labour).
Aeroponics is the new plant growing technique of modern agriculture. "Aeroponics is the process of growing crops suspended in the air or in a mist without using soil. The roots of the crops are misted with nutrients at regular intervals and it is considered as a type of high-technology/precision farming".Aeroponic method of plant cultivation was defined by International Society for Soilless Culture as "a system where roots are continuously or discontinuously exposed to an environment saturated with fine drops (a mist) of nutrient solution" (Nugali *et al.*, 2005). Therefore, an investigation was undertaken to know the response of V-1 mulberry under both nursery conditions and aeroponic system.

Material and Methods
The experiment was conducted by growing V-1 mulberry saplings both in Aeroponic chamber and nursery condition during 2020-21 at Department of Sericulture, UAS, GKVK, Bengaluru-65 in collaboration with Innova Technology Solutions Mysore Private Limited. The experiment was laid out in factorial CRD with 3 treatments and 6 replications.

Treatment details

Systems of Propagation (S)	Treatments (T)	Treatment combinations
Aeroponic system (S_1)	One bud per cutting (T_1)	S_1T_1
	Two buds per cutting (T_2)	S_1T_2
	Three buds per cutting (T_3)	S_1T_3
Nursery system (S_2)	One bud per cutting (T_1)	S_2T_1
	Two buds per cutting (T_2)	S_2T_2
	Three buds per cutting (T_3)	S_2T_3

Layout of the experiment

Description of aeroponic chamber and nursery bed

The aeroponic prototype was specifically designed for mulberry crop. The three important parts of aeroponic structure are root chamber, nutrient solution tank and automated nutrient misting system. The prototype was designed for experimental purpose by Innova Technology Solutions Mysore Pvt. Ltd. The root chamber of 4×2×1.7 feet was made of aluminium. The top of the root chamber had space to accommodate 18 saplings with a spacing of 15 cm apart.

The nutrient tank was connected with motor to pump the nutrient solution to root chamber with a minimum pressure of 60 psi. To ensure fine misting of nutrient solution to root chamber 40-100µ size nozzles were used, so that roots do not get injured due to pressure and large size of mist. This maintained the higher relative humidity inside the chamber. The motor was connected with automated timer set so that the time and duration of misting could be managed with different schedule of time.

Nursery bed measuring 300cm × 120cm (L× B) with a spacing 20 cm between rows and 8 cm between cuttings was prepared. The care had been taken to transfer more number of cuttings than aeroponic chamber to study root parameters.

The cuttings were treated with 2000 ppm IBA solution and after 30 days of root development, the rooted cuttings with at least 18-20 roots were transferred from cocopeat to both aeroponic chambers and raised nursery bed.

Preparation of nutrient solution

The nutrient stock solution was prepared by dissolving each nutrient in one litre of deionized water separately. Later 100ml of each solution was taken and made up the volume to 10 litres of water and filled into nutrient tank. The protocol developed by Hoagland and Arnon (1938) [2] was modified for mulberry. Further, the dissolved nutrients were sprayed to the root zone directly by automizers at regular intervals.

Nutrients used: Urea – 30 g/L; Potassium dihydrogen orthophosphate – 15 g/L; Calcium nitrate – 75 g/L; SOP – 50 g/L; Magnesium sulphate – 35 g/L; Micronutrients – 4 g/L

Spray on time (sec)		Spray interval (min)	
6:30 AM to 6:30 PM	6:30 PM to 6:30 AM	6:30 AM to 6:30PM	6:30 PM to 6:30 AM
30 sec	30 sec	15 min	30 min

Concentration of different nutrients present in nutrient tank : $N(NO_3^-)$ – 107.43 ppm; $N(NH_4^+)$-240 ppm; K-230 ppm; P-30 ppm; Mg- 30 ppm; Ca-140.262 ppm; S-119.139 ppm; Fe – 0.669 ppm; Zn – 1.004 ppm; B-0.167 ppm; Cu- 0.335 ppm; Mo-0.033 ppm; Na- 5.571 ppm; Cl-15.32 ppm; Mn-0.335.

Results and Discussion

The observations of V-1 mulberry were recorded on growth parameters *viz.*, longest root length, number of primary roots, root biomass, longest shoot length and number of shoots on 15, 30, 45 and 60 DAT. The aeroponic system of cultivation and the number of buds on cutting had significant influence on growth parameters of V-1 mulberry variety.

Growth Parameters

Number of primary roots, longest root length (cm) and root biomass (g)

The number of primary roots, longest root length and root biomass influenced by systems of propagation and number of buds per cutting revealed significant results. Maximum of 41.50 (number of primary roots), 23.17cm (longest root length) and 0.89 g (root biomass) was recorded at 60 days of transplanting in aeroponic system. On contrary it was found minimum of 23.22 number of primary roots, 18.00 cm longest root length and 0.56 g root biomass recorded for nursery conditions. Further, number of buds per cutting *viz*., one bud, two buds and three buds per cutting also revealed significant results from 15, 30, 45 and 60 days after transplanting. T_3 recorded maximum for root parameters followed by T_2 and T_1. Among interaction effect S_1T_3 recorded maximum for number of primary roots (22.00, 24.10, 38.88 and 46.80), longest root length (10.89, 17.20, 19.31 and 26.90 cm) at 15, 30, 45 and 60 days respectively and root biomass (1.17g) at 60 DAT followed by S_2T_3, S_1T_2, S_2T_2, S_1T_1 and minimum of 17.50, 12.00, 14.60 and 20.00 number of primary roots, 10.10, 11.50, 13.60 and 14.60 cm longest root length at 15,30, 45 and 60 DAT and 0.38 g of root biomass at 60 DAT was recorded by one budded cuttings under nursery condition. (Table 1, Fig. 1, Fig. 2, Fig. 3 and Plate 1).

Lee (1997) [5] observed aeroponic culture as an effective method to be used for rooting of hardwood cutting which are difficult to root and successfully grown. This technology has already been successfully scaled up and shown to be economically viable, taking into account the number of trees grown in a limited area and found cost effective as well (Kay and Lee, 1995) [3].

These results are in parity with findings of Sharma *et al.* (2018) [10] who reported that, root length, number of roots per plant were found to be significantly higher in aeroponically rooted stem cuttings as compared to rooted in soil conditions in *Tamarix aphylla.* Further, it was confirmed by Qiansheng *et al.* (2018) [9] when lettuce cultivated under aeroponics system were recorded significantly enhanced root parameters with a significantly higher total root length compared to hydroponics and soilless culture. It was also inferred from El-Helaly and Darwish, (2019) [1] that, the lettuce cultivar fire red grown under aeroponic system was recorded longest root length compared to hydroponic and sandy substrate. They also revealed that, roots fresh and dry weight were found highest in aeroponic system after 4 and 6 weeks of transplanting. These results are further in agreement with Movahedi and Rostami (2020) [7]. According to them medicinal plants *viz.*, *Cichorium*, *Withania* and *Echinacea* grown under aeroponic confirmed longest root length after six months than in soil. Their results also showed that, the plants harvested after six months from aeroponic system has produced the highest root fresh and dry weight in comparison with soil system. As reflected in the present study, the mulberry saplings after 60 DAT to aeroponic system was recorded 26.90 cm and 21.40 cm in nursery in three budded cuttings. Further, Qiansheng *et al.* (2018) [9] also evaluated aeroponics, hydroponics and soilless culture for lettuce and recorded significantly enhanced root parameters with a significantly higher root biomass, root area and root volume compared to hydroponics and soilless culture and it was found that aeroponic system was found to be superior for high value true root crop cultivation compared to other two systems of culture. It was also confirmed by Tabatabaei (2008) [11] who studied the effects of four different cultivation systems (aeroponic, floating, growing media *viz.*, a perlite and vermiculite mix and soil systems) on *Valeriana officinalis* L.

var. common and found positive effect of aeroponics on root fresh weight (208.0 g), root dry weight (12.66 g), root volume (210.0ml) as also reported in the present study.

Present findings are also in close conformity with the results of Mehandru *et al.* (2014) [6] who inferred that, in all the species, *viz., Caralluma edulis*, *Leptadenia reticulata* and *Tylophora indica* – three threatened medicinal Asclepiads, the number of adventitious roots per cutting and the percentage of cuttings rooted aeroponically were significantly higher than the soil grown stem cuttings. The root biomass of *T. riparia* improved significantly in aeroponic-grown plants in comparison to greenhouse grown-plants. The study suggested that, the aeroponic system is found suitable for production of good quality and purity of root biomass of *M. whitei* and *T. riparia* which could be exploited for commercial cultivation and phytopharmaceutical industries. The present findings are also in accordance with Kumari *et al.* (2016) [4] who studied the changes in morphogenesis and bioactivity of *Tetradenia riparia*, *Mondia whitei* and *Cyanoptis speciosa* by an aeroponic system and found that, the fresh and dry weight of root was significantly higher in aeroponically grown plants.

Table 1: Number of primary roots, longest root length (cm) and root biomass (g) of V-1 as influenced by aeroponic system and nursery conditions at different days after transplanting

	Number of primary roots				**Longest root length (cm)**				**Root biomass (g)**
Particulars	**15 DAT**	**30 DAT**	**45 DAT**	**60 DAT**	**15 DAT**	**30 DAT**	**45 DAT**	**60 DAT**	**60 DAT**
	Systems of propagation								
S_1	19.67	22.07	36.13	41.5	10.38	16.09	18.17	23.17	0.89
S_2	19.5	16	18	23.22	10.77	12.67	14.83	18	0.56
F test	NS	*	*	*	*	*	*	*	*
S.Em±	0.12	0.12	0.17	0.2	0.06	0.09	0.1	0.13	0.01
CD@ 5%	0.34	0.34	0.5	0.59	0.18	0.25	0.29	0.36	0.03
	No. of buds (Treatments)								
T_1	17.75	15.85	25.1	29.4	9.9	13.14	15.25	16.42	0.43
T_2	19.5	19.2	25.95	30.45	10.74	14.7	16.35	21.2	0.82
T_3	21.5	22.05	30.14	37.23	11.07	15.3	17.91	24.15	0.92
F test	*	*	*	*	*	*	*	*	*
S.Em±	0.15	0.14	0.21	0.25	0.08	0.11	0.12	0.15	0.01
CD@ 5%	0.42	0.41	0.61	0.72	0.23	0.31	0.35	0.45	0.02
	Interaction (S x T)								
S_1T_1	18.01	19.7	35.6	38.8	9.7	14.77	16.9	18.23	0.48
S_1T_2	20	22.4	33.9	38.9	10.55	16.3	18.3	24.39	1.01
S_1T_3	22	24.1	38.88	46.8	10.89	17.2	19.31	26.9	1.17
S_2T_1	17.5	12	14.6	20	10.1	11.5	13.6	14.6	0.38
S_2T_2	19	16	18	22	10.6	12.2	14.4	18	0.63
S_2T_3	21	20	21.4	27.66	11.6	14.3	16.5	21.4	0.66
F test	*	*	*	*	*	*	*	*	*
S.Em±	0.21	0.2	0.3	0.35	0.11	0.15	0.17	0.22	0.01
CD@ 5%	0.59	0.58	0.86	1.02	0.32	0.44	0.5	0.63	0.02

Number of shoots and longest shoot length (cm)

Among the systems of propagation, the aeroponics system showed considerably highest number of shoots and longest shoot length (5.68 and 20.22 cm) compared to nursery condition (1.51 and 18.99 cm) at 60 DAT. Same trend was observed at 15, 30 and 45 DAT. Among treatments T_3 (three buds per cutting) showed maximum no. of shoots (4.44) and longest shoot length (23.90 cm) followed by T_2 and T_1 respectively at 60 DAT. Same trend was observed in 15, 30 and 45 DAT.

Among the interaction effect, a significantly higher number of shoots and longest shoot length was recorded in S_1T_3 (6.63 and 24.55cm) followed by S_1T_2, S_1T_1, S_2T_3, S_2T_2 and least no. of shoots was recorded in S_2T_1 (1.06 and 15.47cm) at 60 DAT. Similar trend was observed at 15, 30 and 45 DAT (Table 2, Fig. 3 and Plate 2).

As it was reflected in the experimental data, the lettuce grown under aeroponics were recorded significantly enhanced root and shoot ratio than in hydroponics and soilless culture (Qiansheng *et al.*, 2018) [9]. The present findings are in accordance with Martin-Laurent *et al.* (1997) [5] who studied a new approach to enhance growth and nodulation of *Acacia mangium* through aeroponic culture. They confirmed that, the plants grown through aeroponic system reached mature stage (54 days) which was considered as four times taller than those grown in sand. These plants had greater height than those grown in sand. Further, they also concluded that, the aeroponic system is clearly superior to the other systems for growth and development of *A. mangium.* Further, in support to the present investigation Kumari *et al*. (2016) [4] found that, shoot height of three-month-old aeroponic and greenhouse-grown *T.riparia*, *C. speciosa* and *M. whitei* were recorded and found higher in plants grown under aeroponic system compared to soil grown. It was also inferred by Mehandru *et al.* (2014) [6] that, the shoot growth measured in terms of shoot length was significantly found higher in cuttings rooted aeroponically as compared to the cuttings rooted under soil conditions, in all the species *viz.,Caralluma edulis*, *Leptadenia reticulata* and *Tylophora indica* – three threatened medicinal Asclepiads.

Table 2: Number of shoots, longest shoot length (cm) of V-1 as influenced by aeroponic system and nursery conditions at different days after transplanting

	No. of shoots	**Longest shoot length (cm)**

Particulars	15 DAT	30 DAT	45 DAT	60 DAT	15 DAT	30 DAT	45 DAT	60 DAT
	Systems of propagation							
S_1	1.29	1.29	1.29	5.68	9.74	14.1	16.95	20.22
S_2	1.09	1.09	1.09	1.51	9.06	13.42	16.47	18.99
F test	*	*	*	*	*	*	*	*
S.Em±	0.05	0.05	0.05	0.1	0.06	0.08	0.1	0.12
CD@ 5%	0.14	0.14	0.14	0.28	0.17	0.24	0.29	0.35
	No. of buds (Treatments)							
T_1	1	1	1	2.91	6.63	10.61	13.51	16.21
T_2	1.28	1.28	1.28	3.43	9.57	13.27	16.1	20.2
T_3	1.29	1.29	1.29	4.44	12	17.4	20.53	23.9
F test	*	*	*	*	*	*	*	*
S.Em±	0.06	0.06	0.06	0.12	0.07	0.1	0.13	0.15
CD@ 5%	0.17	0.17	0.17	0.34	0.2	0.3	0.36	0.43
	Interaction (S x T)							
S_1T_1	1	1	1	4.76	6.58	10.76	14.66	16.95
S_1T_2	1.33	1.33	1.33	5.64	10.14	13.94	15.4	19.15
S_1T_3	1.53	1.53	1.53	6.63	12.5	17.6	20.8	24.55
S_2T_1	1	1	1	1.06	6.68	10.45	12.35	15.47
S_2T_2	1.06	1.05	1.05	1.66	9	12.6	16.8	21.25
S_2T_3	1.22	1.22	1.22	2.25	11.5	17.2	20.25	23.25
F test	*	*	*	*	*	*	*	*
S.Em±	0.08	0.08	0.08	0.17	0.1	0.15	0.18	0.21
CD@ 5%	0.24	0.24	0.24	0.49	0.29	0.42	0.51	0.61

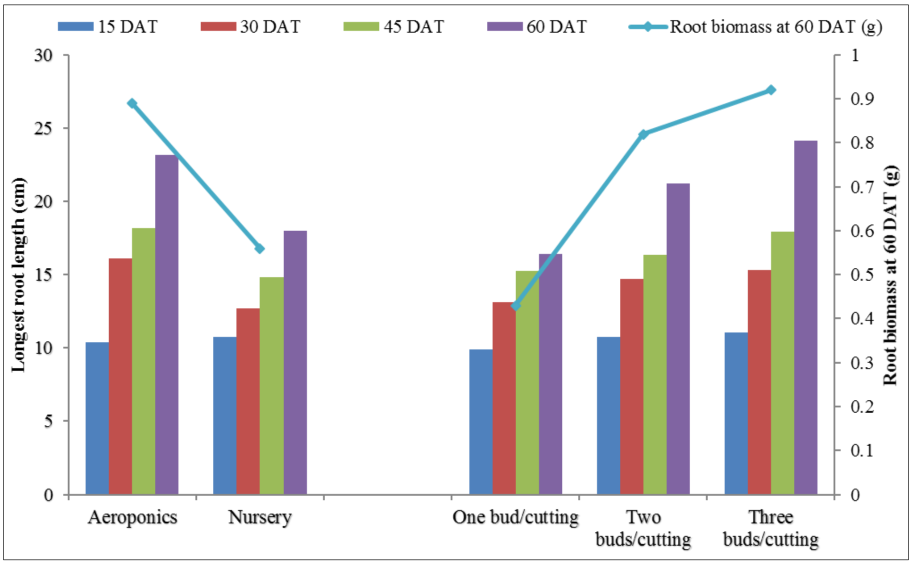

Fig 1: Longest root length (cm) and root biomass (g) of V-1 as influenced by systems of propagation and number of buds on cuttings at 15, 30, 45 and 60 days after transplanting

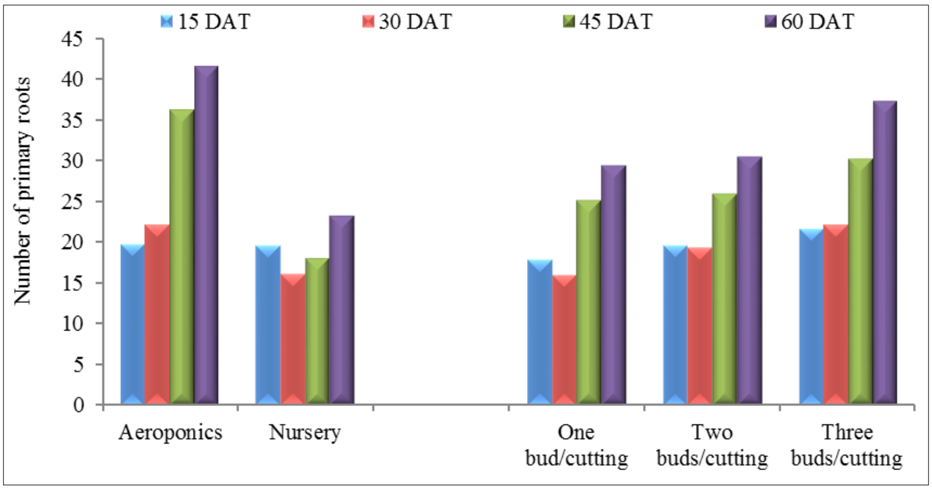

Fig 2: Number of primary roots of V-1 as influenced by systems of propagation and number of buds on cuttings at 15, 30, 45 and 60 days after transplanting

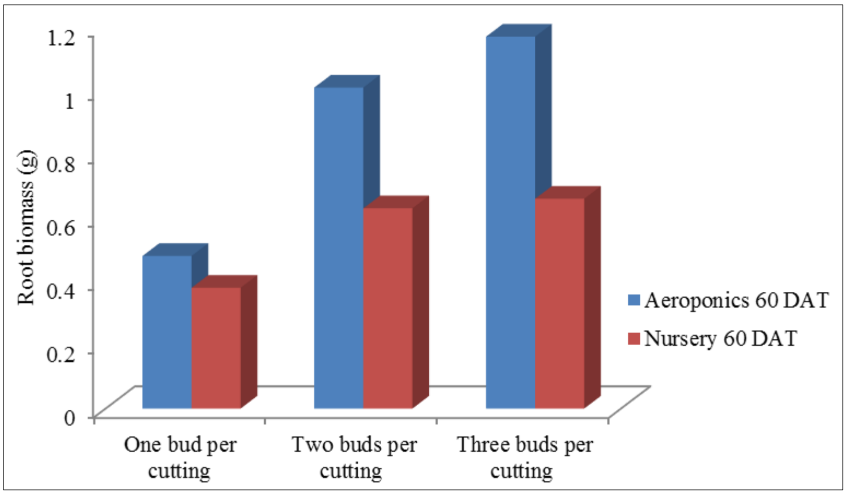

Fig 3: Interaction effect of systems of propagation and number of buds on cuttings on root biomass (g) of V-1 mulberry at 15, 30, 45 and 60 days after transplanting

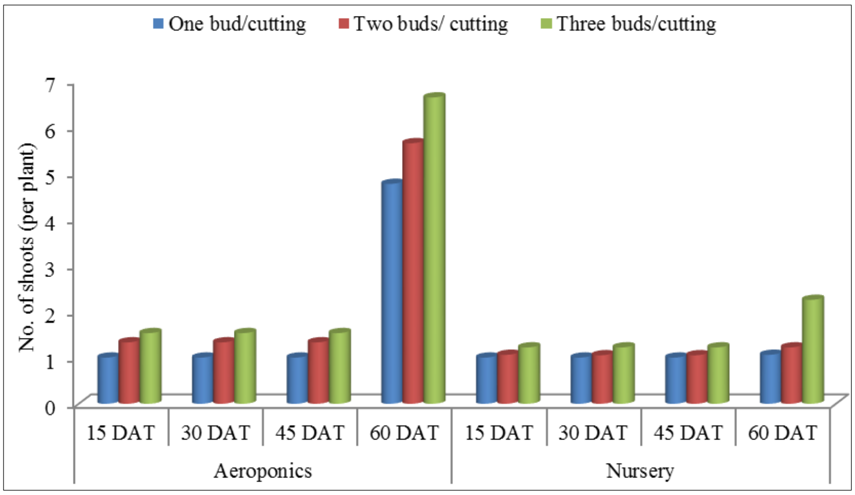

Fig 4: Interaction effect of systems of propagation and number of buds on cuttings on no. of shoots of V-1 mulberry at 15, 30, 45 and 60 days after transplanting

Plate 1: Establishment of mulberry rootzone (Three buds per cutting) under (a) nursery and (b) aeroponic at 60 DAT

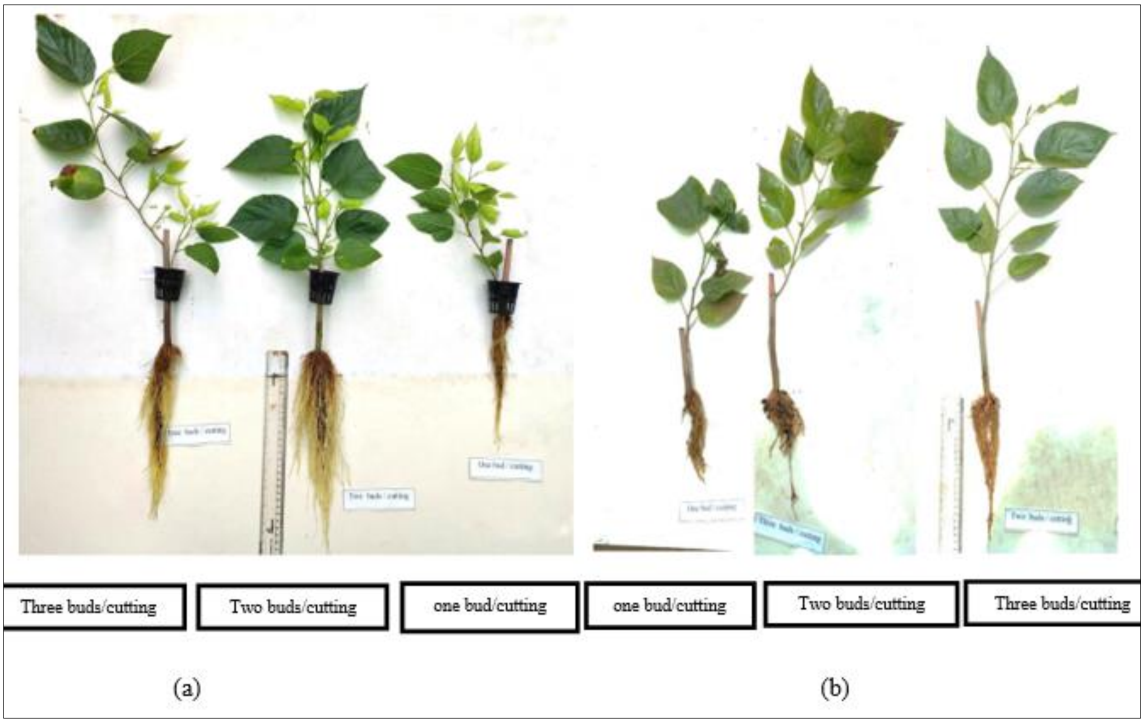

Plate 2: Mulberry saplings at 60 DAT in (a) Aeroponic chamber (b) Nursery

The results of the present investigation indicated that, the growth parameters of V-1 mulberry saplings are influenced by propagation systems (aeroponic system and nursery conditions), different number of buds (one, two and three) on cuttings and the interaction effect of both systems of propagation and varying number of buds on cuttings. It was confirmed that, aeroponic system found to be an effective method for multiplication of V-1 mulberry where there is deficit of soil moisture and poor soil fertility. The study also revealed that, the root and shoot parameters grown under aeroponic system have recorded higher values compared to nursery bed method. Therefore, aeroponics could be a future technology for mulberry where the varieties have poor rooting ability and poor soil health.

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