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Influence of Aeroponic System on Quality Parameters of V-1 Mulberry

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ABSTRACT: Due to increasing problems in soil-based crop production, such as the loss of arable land, soil degradation, soil-borne pathogens and the impacts of climate change, soilless culture systems are currently one of the fastest-growing sectors. Growing plants in a limited rooting volume, root restriction, is a powerful technique to improve the utilization efficiency of agricultural resources such as space, water, and nutrition. Looking into these advantages and to explore the possibility of growing the V-1 mulberry saplings under aeroponics the study was undertaken. Propagating hard wood cuttings using aeroponics can indeed be challenging, as there are not many studies available on this topic. However, with careful experimentation and observation, we developed an aeroponic system for mulberry cuttings propagation. The quality parameters of mulberry saplings (*Morus* sp.) grown under aeroponic system and nursery condition were assessed at 60 days after transplanting. The plants grown under aeroponic system were recorded maximum for protein percentage and leaf nutrient contents (N, P, K, Ca, Mg, S). Total chlorophyll content in mulberry leaf and carbohydrate percentage were found maximum under nursery conditions. However, the percent leaf moisture and moisture retention capacity after 6 hours were found on par under both the systems. Among treatments, three buds per cutting recorded maximum for all the quality parameters followed by two buds per cutting and one bud per cutting. Among interaction, three budded cuttings under aeroponic system recorded maximum leaf quality parameters nutrient contents (N, P, K, Ca, Mg, S) (2.18, 0.49, 3.48, 0.45, 0.37 and 0.27%) and protein percentage (13.65%) whereas least was recorded by one budded cuttings under nursery at 60 DAT. However, three budded cuttings under nursery recorded maximum carbohydrate content (18.03%). There was no significant difference with respect to total chlorophyll content, leaf moisture percentage and moisture retention capacity after 6 hours.

Keywords: Aeroponics, Nursery, V-1 Mulberry, Quality parameters.

INTRODUCTION

Aeroponic system is a way for future through which water, land and nutrients could be utilized effectively. This in turn help in utilization of nutrients in a required quantity by plants. By adopting this method, 98 percent of water and 60 percent of fertilizers utilization could be minimized and therefore plants are potentially healthier and nutritious. This could be commercially exploited for chawki rearing where silkworm requires more healthy and nutritious leaves for their further development.

Aeroponics is the science of plant cultivation without soil or a substrate culture, where plant grows in the air with the assistance of an artificial support and no soil or substrate is required to support the plant (Osvald *et al*., 2001). In addition, the use of fertilizers and water in these systems is more efficient due to their reuse since they are in closed system (Nir, 1982).

In aeroponic system, nutrients are directly delivered to the plant roots, which results in a faster growth of crops. Fruits and vegetables obtained from an aeroponics-based greenhouse are healthy, nutritious, pure, rich, fresh and tasteful. Uniform growth among all crops was also observed (Mithunesh *et al.,* 2015).

Several studies confirmed that, aeroponics is a modern-day agricultural activity which is practiced in an enclosed growth chamber under entire controlled conditions, as it could eliminate the external environmental factors as compared with traditional agriculture activity. Hence, it is no longer dependent on large-scale land use, and it could be set up in any place, a building that has lifted global climate without considering the current climate such as rainy season and winter (Lakhiar *et al.,* 2018b).

In aeroponics system, the nutrient reservoir is designated for the purpose to store the nutrient solution in a separate chamber outside or within the growth chamber. The atomization nozzles were connected to the deliver line through pressure pump to supply the solution to the growth chamber. The drain line is provided in the growth chamber to recycle excess solution. Although, in inside reservoir, the atomization nozzles directly get the nutrient supply from the bottom of the growth chamber where it drips back down after misting on the root system (Lakhiar *et al.,* 2018a).

Some of the previous studies conducted by different authors regarding the quality parameters of plants grown under aeroponics system have been reviewed. Tan *et al.* (2002) reported that, the lettuce grown at 20°C root zone temperature under aeroponics accumulated higher nitrogen and phosphorus contents in leaves. Also more accumulation of nitrate, potassium, calcium, copper, iron, magnesium, manganese and zinc in both shoot and root of lettuce were found under aeroponics. Tabatabaei (2008) studied the effects of four different cultivation systems (aeroponic, floating, growing media *viz.,* a perlite and vermiculite mix and soil systems) on the growth and essential oil content and composition of valerian (*Valeriana officinalis* L. var. common) and reported that the chlorophyll index (40.1) was found higher in aeroponically grown plants than in soil system (37.0).

Kamies *et al.* (2010) found that, the relative water content (RWC) of hydrated leaves of *Xerophyta viscosa* from both aeroponically and soil grown plants were similar and was maintained for 4 and 7 days. The RWC of roots at full hydration was found higher in aeroponically grown plants than those of plants grown in soil.

Bohme and Pinker (2014) found that, the vitamin C content was highest in all herbs cultivated in aeroponics. A comparison of the product yield, total phenolics, total flavonoids, and antioxidant properties was done in different leafy vegetables/herbs (basil, chard, parsley, and red kale) and fruit crops (bell pepper, cherry tomatoes, cucumber, and squash) grown in aeroponic growing systems and in the field. An average increase of about 19%, 8%, 65%, 21%, 53%, 35%, 7%, and 50% in the yield was recorded for basil, chard, red kale, parsley, bell pepper, cherry tomatoes, cucumber, and squash, respectively, when grown in aeroponic systems, compared to that grown in the soil. In general, the study showed that the plants grown in the aeroponic system had a higher yield and comparable phenolics, flavonoids, and antioxidant properties as compared to those grown in the soil (Chandra *et al.,* 2014).

Ali (2015) reported that the total nutrients uptake was found to be higher in aeroponics system over those of hydroponic systems. Further, the average nitrate content of 155.52 and 113.73 mg/ plant and the average water use efficiency of 4.75 and 2.93 kg/m^3 were recorded for aeroponics and hydroponic system, respectively. Salachas *et al.* (2015) investigated the effect of the available root zone volume on yield and quality characteristics of aeroponically cultivated sweet basil (*Ocimum basilicum* L.) plants. Their results showed that basil plants grown aeroponically were of superior nutritional quality characteristics. Li *et al*. (2018) reported that the nutrients uptake of lettuce under both aeroponic and hydroponic were higher than that in substrate cultivated. An experiment to evaluate the greenhouse effect of different culture systems *viz.,* hydroponic, aeroponic and sandy substrate on lettuce cultivar fire red revealed that, the sandy substrate recorded the lowest N, P and K % compared with aeroponic and hydroponic systems (El-Helaly and Darwish 2019).

Akachukwu *et al.* (2020) investigated the chlorophyll, proximate and mineral compositions of four elite yam varieties grown under aeroponic and field systems. They reported that the Leaf moisture, crude fibre content of aeroponics grown yam seedlings were significantly higher than those of the field system. Calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and phosphorus (P) content of the field samples were not significantly different from that of aeroponics system. The differences in chlorophyll content in this study may be due to differences in exposure to sunlight. This could enhance yam mineral concentration thereby improving nutrition.

Morus alba L. grown under aeroponic system revealed 18 fold increase in prenylated flavonoids *viz*., moracenin A and B, kuwanon C, wittorumin F and morusin from roots of mulberry having anti-ageing properties of skin (collagenase inhibitory effect of prenylated compounds) (Chajra *et al.*, 2020).

Iikiz *et al.* (2020) cultivated onion in aeroponic system and studied optimization of nutrient spray time on roots of fresh onion. They confirmed that the aeroponic system is convenient for growing fresh leafy onion (*Allium cepa* L.). Khater *et al.* (2021) showed that the uptake of nitrogen, phosphorus, potassium, calcium and magnesium by the basil plants were higher in aeroponic system compared those of hydroponic system and peatmoss slabs at the vegetative and flowering stages. Tunio *et al*. (2023) found that the relative water content, nutrient use efficiency, total phenolic and total flavonoid contents were higher in aeropoically grown lettuce compared to hydroponics and conventional system of growing.

According to the aforementioned, this study was intended to compare the quality parameters *viz.,* leaf moisture content (%), moisture retention capacity (% after 6 hours), chlorophyll content (mg/g), carbohydrates (%), protein (%) and leaf nutrient contents (N, P, K, Ca, Mg, S %) of V-1 mulberry saplings with different number of buds (one, two and three) in two cultivation systems (aeroponics and nursery systems).

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 Table 1.

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.

Table 1: 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

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 2000ppm 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) was modified for mulberry. Further, the dissolved nutrients were sprayed to the root zone directly by automizers at regular intervals (Table 2).

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.

Table 2:

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^+)-240ppm; K-230ppm; P-30ppm; Mg- 30ppm; Ca-140.262 ppm; S-119.139 ppm; Fe – 0.669ppm; Zn – 1.004ppm; B-0.167ppm; Cu- 0.335 ppm; Mo-0.033ppm; Na- 5.571ppm; Cl-15.32ppm; Mn-0.335. The observations were made at an interval of 15, 30, 45 and 60 days after transplanting.

RESULTS AND DISCUSSION

Leaf moisture content (%), moisture retention capacity (% after 6 hours), chlorophyll content (mg/g), carbohydrates (%) and protein (%) of V-1 as influenced by aeroponic system and nursery conditions at 60 days after transplanting.

The data on leaf moisture percentage, moisture retention capacity (after 6 hours) percentage, chlorophyll content, carbohydrates and protein content of V-1 mulberry as influenced by systems of propagation (aeroponics and nursery conditions), varying number of buds per cutting and the interaction effect of systems of propagation and treatments are furnished in the Table 3 and Fig. 1.

Table 3: Leaf moisture content (%), moisture retention capacity (% after 6 hours), chlorophyll content (mg/g), protein (%) and carbohydrates (%) of V-1 as influenced by aeroponic system and nursery conditions at 60 days after transplanting.

Particulars	Leaf moisture (%)	Moisture retention capacity (% after 6 hours)	Total Chlorophyll content (mg/g)	Carbohydrates (%)	Protein (%)
Systems of propagation					
S_1	69.53	84.59	1.72	11.69	13.07
S_2	68.82	86.88	1.98	16.49	11.91
F test	**NS**	**NS**	*	*	*
S.Em±	0.42	0.96	0.08	0.08	0.07
CD@ 5%	1.21	2.77	0.24	0.25	0.21
No. of buds (Treatments)					
T_1	67.83	83.28	1.74	11.78	11.3
T_2	69	85.07	1.74	13.44	12.95
T_3	70.7	88.86	2.06	17.05	13.22
F test	*	*	*	*	*
S.Em±	0.5141	1.1767	0.1004	0.1067	0.0917
CD@ 5%	1.4847	3.3985	0.2898	0.3082	0.2649
Interaction (S × T)					
S_1T_1	68.75	79.98	1.49	8.62	12.62
S_1T_2	69.63	85.07	1.78	10.37	12.93
S_1T_3	70.21	88.72	1.88	16.08	13.65
S_2T_1	66.91	86.58	1.99	14.95	9.98
S_2T_2	68.37	85.07	1.7	16.5	12.25
S_2T_3	71.19	89	2.24	18.03	13.51
F test	**NS**	**NS**	**NS**	*	*
S.Em±	0.727	1.6641	0.1419	0.1509	0.1297
CD@ 5%	2.0997	4.8062	0.4099	0.4358	0.3746

NS- Non significant; * - Significant at 5%

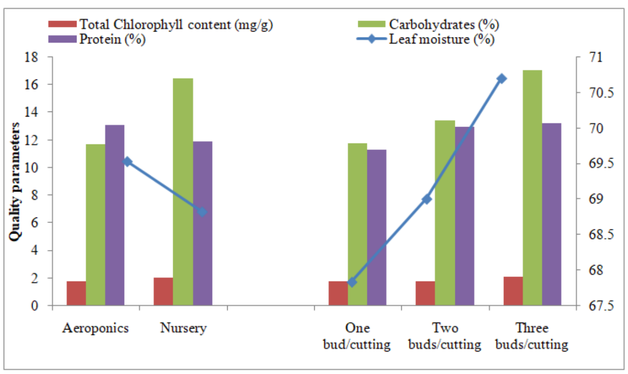

Fig. 1. Quality parameters of V-1 as influenced by systems of propagation and number of buds on cuttings at 60 days after transplanting.

The data reveals that there was no significance with respect to leaf moisture (%) and moisture retention capacity (% after 6 hours) and they were found on par under both the systems of propagation. However, protein % was seen maximum (13.07 %) under aeroponic system, whereas, total chlorophyll content (mg/g) and carbohydrates (%) were found maximum under nursery conditions (1.98 mg/g and 16.49%). Among treatments three budded cuttings (T_3) recorded maximum for all the above-mentioned parameters followed by two budded cuttings (T_2) and one budded cuttings (T_1).

The interaction effect of different treatments and systems of propagation showed no significance with respect to leaf moisture %, moisture retention capacity % after 6 hours and total chlorophyll content. However, the highest leaf moisture %, moisture retention capacity % after 6 hours and total chlorophyll content was found highest in S_2T_3 three budded cuttings under nursery condition (71.19%, 89.00 % and 2.24mg/g) and least was recorded by S_1T_1 i.e., one budded cuttings under aeroponics. Whereas, there was a significant difference with respect to carbohydrate and protein content of V-1 mulberry. Carbohydrate content was found maximum in three budded cuttings under nursery i.e., S_2T_3 (18.03%) and protein content was found maximum in three budded cuttings under aeroponics system *i.e.,* S_1T_3 (13.65%)

The present findings are in accordance with Kamies *et al.* (2010) who found that, the relative water content (RWC) of hydrated leaves of *Xerophyta viscosa* from both aeroponically and soil grown plants were similar and was maintained for 4 and 7 days. Also they found that the RWC of roots at full hydration was found higher in aeroponically grown plants than those of plants grown in soil.

Further, it was confirmed by Akachukwu *et al.* (2020) who reported that the leaf moisture content of aeroponically grown yam seedlings was significantly higher than those of the field system.

Tunio *et al.* (2023) found that the relative water content of lettuce was found to be highest in aeroponically grown plants compared to hydroponics and conventional system.

Tabatabaei (2008) studied the effects of four different cultivation systems (aeroponic, floating, growing media *viz.,* a perlite and vermiculite mix and soil systems) on the growth and essential oil content and composition of valerian *(Valeriana officinalis* L. var. common) and reported that the chlorophyll index (40.1) was found higher in aeroponically grown plants than in soil system (37.0).

Further it was inferred by Akachukwu *et al.* (2020) who investigated the chlorophyll, proximate and mineral compositions of four elite yam varieties grown under aeroponic and field systems. One node vines of yam varieties (TDa 98/01176, TDr 95/18544, TDr 95/19177 and TDr 95/19158) used in the experiment were recorded higher content of the chlorophyll a, b and total chlorophylls in aeroponic system compared to that of field grown varieties of TDr 95/18544, TDr 95/19177 and TDr 95/19158 However, the chlorophyll 'a' concentration was found higher than that of chlorophyll 'b' in all the field and aeroponic grown varieties except for aeroponics grown TDr 95/19177. The differences in chlorophyll content in the study may be due to differences in exposure to sunlight. This could enhance yam mineral concentration thereby improving nutrition.

As it was confirmed from the present study that three budded cuttings T_3 showed maximum moisture retention capacity (88.72%) and chlorophyll content (1.88mg/g) followed by two budded (85.07% and 1.78mg/g) and one budded (79.98% and 1.49mg/g) cuttings. Leaf moisture percent is significantly influenced by the number of buds per cutting in nursery condition where T_3 being maximum (71.19%) followed by T_2 (68.37%) and T_1 (66.91%).

However, Akachukwu *et al.* (2020) who reported that, a crude protein content for field samples (10.88-15.22%) were higher than that of aeroponics (9.58-14.14%) of four elite yam varieties. This review is not aligned with our findings where the experimental data on protein percent revealed maximum of 13.65 % (aeroponic system) and 13.51% (nursery condition) recorded for T_3 (three buds per cutting) followed by T_2 (12.93% and 12.25%) and T_1(12.62% and 9.98%) under aeroponic system and nursery condition respectively.

Leaf nutrient contents: N, P, K, Ca, Mg and S (%) of V-1 as influenced by aeroponic system and nursery conditions at 60 days after transplanting

The data on Leaf nutrient contents: N, P, K, Ca, Mg and S (%) of V-1 mulberry as influenced by varying number of buds per cutting, systems of propagation (aeroponic system and nursery condition) and their interaction effect are furnished in the Table 4 and Fig. 2.

Table 4: Leaf nutrient contents: N, P, K, Ca, Mg and S (%) of V-1 as influenced by aeroponic system and nursery conditions at 60 days after transplanting.

Particulars	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
Systems of propagation						
S_1	2.09	0.48	3.41	0.39	0.32	0.25
S_2	1.9	0.44	2.82	0.37	0.3	0.19
F test	*	*	*	*	*	*
S.Em±	0.0125	0.0029	0.0189	0.0023	0.002	0.0022
CD@ 5%	0.0362	0.0084	0.0545	0.0068	0.0058	0.0063
No. of buds (Treatments)						
T_1	1.81	0.45	3.11	0.32	0.26	0.18
T_2	2.07	0.45	3.06	0.37	0.31	0.23
T_3	2.11	0.48	3.18	0.45	0.36	0.25
F test	*	*	*	*	*	*
S.Em±	0.0153	0.0036	0.0231	0.0029	0.0025	0.0027
CD@ 5%	0.0443	0.0103	0.0667	0.0083	0.0071	0.0077
Interaction (S × T)						
S_1T_1	2.02	0.48	3.44	0.34	0.29	0.22
S_1T_2	2.07	0.46	3.32	0.37	0.28	0.26
S_1T_3	2.18	0.49	3.48	0.45	0.37	0.27
S_2T_1	1.6	0.43	2.78	0.29	0.22	0.13
S_2T_2	1.96	0.45	2.8	0.37	0.33	0.22
S_2T_3	2.15	0.46	2.88	0.45	0.34	0.2
F test	*	*	**NS**	*	*	*
S.Em±	0.0217	0.005	0.0327	0.0041	0.0035	0.0038
CD@ 5%	0.0626	0.0145	0.0944	0.0117	0.0101	0.0108

NS- Non significant * - Significant at 5%

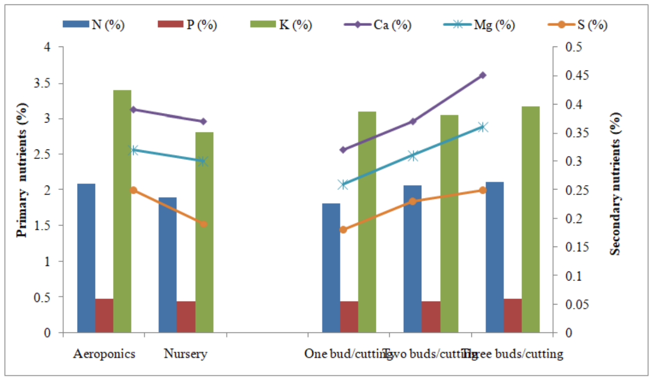

Fig. 2. Leaf nutrient contents (N, P, K, Ca, Mg, S %) of V-1 as influenced by systems of propagation and number of buds on cuttings at 60 days after transplanting.

All the primary (N, P and K) and secondary (Ca, Mg and S) nutrient contents of V-1 mulberry were significantly influenced by systems of propagation. All the plant nutrient contents (N. P, K, Ca, Mg and S) were found maximum under aeroponics system (2.09, 0.48, 3.41, 0.39, 0.32 and 0.25%) followed by nursery condition (1.90, 0.44, 2.82, 0.37, 0.30 and 0.19%) respectively.

The varying number of buds per cutting also influenced the leaf nutrient contents under both the systems. It was found that T_3 recorded maximum for all the nutrients *viz.,* N=2.11%, P=0.48%, K=3.18%, Ca=0.45%, Mg=0.36% and S=0.25% followed by T_2 and T_1. The interaction effect between systems of propagation and number of buds per cutting was found significant for all the leaf nutrient content except for potassium where it was found non-significant.

The varying number of buds per cutting also influenced the leaf nutrient contents under both the systems. It was found that S_1T_3 *i.e.,* three budded saplings under aeroponic system recorded maximum for all the nutrients *viz.,* N, P, K, Ca, Mg and S% (2.18, 0.49, 3.48, 0.45, 0.37 and 0.27% respectively) and minimum was observed in S_2T_1 *i.e.,* one budded cuttings under nursery condition (1.60, 0.43, 2.78, 0.29, 0.22 and 0.13% respectively).

These results are in parity with findings of Ali (2015) who found that the total nutrients uptake was higher in aeroponics system over those of hydroponic systems in lettuce. The average nitrogen, phosphorus, potassium, calcium and magnesium uptakes were 3.29, 1.25, 2.46, 0.43 and 0.44 % and 2.13, 0.82, 1.81, 0.32 and 0.40 % for aeroponics and hydroponic system, respectively. Tan *et al.* (2002) reported that, the lettuce grown at 20°C root zone temperature under aeroponics accumulated higher nitrogen and phosphorus contents in leaves. Also more accumulation of nitrate, potassium, calcium, copper, iron, magnesium, manganese and zinc in both shoot and root of lettuce were found under aeroponics.

In support to the present investigation, the results of the experiment conducted by Zhao *et al.* (2010) on aeroponically grown tomato with effect of root zone CO_2 concentrations confirmed that the ambient RZ CO_2 maximized the capability of nutrient uptake compared to RZ CO_2 treatments.

These results are also in line with Li *et al*. (2018) who reported that the nutrients uptake of lettuce under both aeroponic and hydroponic were higher than that in substrate cultivated. Further, Akachukwu *et al.* (2020) confirmed that, the nitrogen (N) content of variety TDa 98/01176 was significantly higher for the field sample of four elite yam varieties compared to that of aeroponic system which is contradictory with our findings. They also found no significant difference in Nitrogen composition for the other varieties. Calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and phosphorus (P) content of the field samples were not significantly different from that of aeroponics system as reflected from our study.

Khater *et al.* (2021) showed that the uptake of nitrogen, phosphorus, potassium, calcium and magnesium by the basil plants were higher in aeroponic system compared those of hydroponic system and peatmoss slabs at the vegetative and flowering stages. Tunio *et al.* (2023) found that the nutrient use efficiency, total phenolic and total flavonoid contents were higher in aeropoically grown lettuce compared to hydroponics and conventional system of growing.

CONCLUSIONS

The results of the present investigation indicated that, the quality 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. Based on this, it can be inferred that mulberry leaves grown aeroponically have higher quality parameters which are relevant to the growth and development of silkworms. The results also suggests that the use of aeroponically grow mulberry leaves for chawki rearing could lead to enhanced growth and development of silkworms. However, it is important to note that the exact effects of aeroponically grown leaves on silkworm growth and development may require further research and validation.

FUTURE SCOPE

Aeroponics could be a future technology for mulberry where the varieties have poor rooting ability. The mulberry leaf quality was influenced by nutrient status and also the absorption pattern which is going to be a new line of thought for standardization and package for aeroponic system. Further experiments could be carried out to exploit this technology for rearing of chawki. These results open a wide opportunity for further conducting of research in aeroponics.

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Conflict of interest. None.

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