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Development of Aeroponics System for Amaranthus, a Green Leafy Vegetable

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ABSTRACT: Aeroponics is a soil less culture, so it's easy to harvest the crops. Plant growth is fast in aeroponics as compared to soil and the water could be saved on large amount as water is recycled in this. Vertical farming can be done with aeroponic system which will lead to save the space required to grow the crops as compared to regular soil farming. Looking into these advantages and to explore the possibility of growing the crop under aeroponics in Konkan region the study was undertaken. For developing the aeroponics system, selection of the components of aeroponic system likes nutrient tank, electrical pump, nozzles, lateral and timer was done. Tank having height of 120 cm, diameter 50 cm was selected for building aeroponic system. Other components like electrical pump, nozzles, laterals and timer were connected to each other. The arrangement was made to recalculate the nutrient in the tank through pump. The amaranthus plants were grown in plastic tray for 10 days and on the 11th day they were transplanted in the developed aeroponic setup. The amaranthus plants were grown for next 6 days after transplanting and their grown parameters were observed and noted daily. The Average plant height, root length and stem diameter was found to be 30.58, 8.31, 0.29 cm among all 8 plants on 6 days of transplanting.

KEY WORDS: Aeroponic System, Soil less culture, Amaranthus

I INTRODUCTION

In order to meet food demand and cater the needs of sufficient water for irrigation, new technologies are to be adopted. Many alternative methods are available nowadays which would make it easier for society to grow crops either for personal needs or for economic purposes. Aeroponics is the practice of growing the plants without the soil and its roots in the misty environment. This technique uses the mineral nutrients from the nutrient solution in the form of mist in a more efficient way than from soil. Aeroponic culture is similar to the Hydroponics system. The only difference is the supply of nutrients in Aeroponics and Hydroponics are methods which are plant cultivation techniques with no soil usage by providing an artificial environment for the cultivation. The nutrients to roots in aeroponics and hydroponics are provided by nutrient tanks in a controlled environment by making an artificial supporting structure.

Aeroponics is the process of growing plants in an air or mist environment without use of soil or an aggregate media. The word aeroponic is derived from the Latin word 'aero' (air) and 'ponic' means labour (work) [4]. This is an alternative method of soil-less culture in growth-controlled environments. The growing regimen is designed to provide a year-round continual harvest by offsetting planting times, so that a steady and reliable crop yield can be achieved while providing full-time year round employment in a safe environment with benefits.



An aeroponic system is medium-less in that the roots of the plant are free hanging inside an open root-zone atmosphere. The vegetation zone is separated by the supports used to hold the plants in the top of the unit. Nutrients are mixed in with water in a reservoir basin; this is then filtered and pumped into a pressurized holding tank that is intermittently misted onto the root system. The water droplet size must be big enough to carry the nutrients to the roots in sufficient quantity, but small enough to not immediately precipitate out of the root mass. Unused solution drips down into the base of the unit and is strained, filtered, and pumped back into the reservoir [3].

Nowadays, aeroponics is being applied successfully in South America and attempts are made to introduce this technology also in some African countries [5]. The utilization of aeroponic systems for potato seed production is very recent in Europe. Until 10 year ago, the use of these technologies was limited almost everywhere in the world and only some countries such as China or Korea were using them for the commercial production of potato quality seeds [7].

Techniques of growing plants without soil were first developed in 1920s by botanists who used primitive aeroponics to study plant root structure; aeroponics has long been used as a research tool in root physiology [1]. The technology was largely used as a research tool rather than an economically feasible method of crop production. It was W. Carter in 1942 who first researched air culture growing and described a method of growing plants in water vapor to facilitate examination of roots. The study of Carter (1942) [2] and Went (1957) [13] named the air-growing process in spray culture as "aeroponics".

Despite increasing interest in soil less culture methods in commercial horticultural production, little information is available for various crops. Aeroponic practice can be done on small, medium, large scale and this system provides more control over the environment required for plant growth. Quick growth and maximum production can be obtained with this system. Looking into these advantages and to explore the possibility of growing the crop under aeroponics in Konkan region the study is undertaken to develop aeroponics system and termination of growth parameters of amaranthus, a leafy vegetable.

II RELATED WORK

The primitive air plant growing system in laboratory was developed by Barker (1922). Carter (1942) studied the air-growing culture and cultivated the pineapple plant. It was concluded that air-growing culture is useful technique for plant roots studies. The air-growing culture reduced the mechanical injuries and interferences with significant growth compared with soil, sand, or even aerated water culture. Klotz (1944) studied discrete nature of interval/duration aeroponics allows the measurement of nutrient uptake over time under varying conditions. Interval/duration aeroponics involves the intermittent misting of the root zone on periodic intervals for a short duration rather than a constant fogging or misting. It was discovered that vapour mist grown plants facilitated his studies of the effects of nutrient concentration and disease in citrus and avocado roots.

Went (1957) studied aeroponics at the Earhart Laboratories in Pasadena, California. Tomato and coffee plants was grown in a water-tight container with fine nutrient mist propelled by atomization injector with pressure. Wu *et al.* (1997) claimed that the aeroponic system is highly accepted and recommended for plant cultivation in countries like Taiwan. Ritter *et al.* (2001) found that plants in the aeroponic system showed increased vegetative growth, delayed tuber formation and an extended vegetative cycle of about seven months after transplanting compared with total production in hydroponics, the tuber yield per plant in the aeroponic system was almost 70% higher and tuber number more than 2.5 fold higher. Christie and Nichols (2003) conducted the study at Massey University where aeroponics for both plant research and for crop production was used and developed systems for growing vegetable crops e.g. tomatoes, cucumbers, potatoes and herbs, and flower crops Lisianthus and Zantedeschia. It was stated that Aeroponic techniques have also been used as a research tool to examine gas levels in the root zone, crop nutrition and root growth.

He and Lee (1998) found that the growth of shoot, root and photosynthetic responses of three cultivars of Lettuce confined to different root zone temperatures and growth irradiances under tropical aerial conditions was better to the aeroponically grown crops compared to the control. Mirza *et al.* (1998) stated that in aeroponics system plant roots quickly nourished by the available nutrients and grows under controlled conditions. The controlled conditions include uniform nutrients concentration, EC and pH values, temperature, humidity, light intensity, atomization frequency, atomization spray time, atomization interval time, and oxygen availability. However, the plant grows speedily in the system due to the sterile environment and abundant oxygen availability in the growth chamber. Molitor *et al.* (1999) conducted the study in which Chrysanthemum stock plants were cultivated in aeroponics. Cutting number and quality



in response to the spraying interval and duration during day and night were tested. Further trials concerned the temperature of the circulating nutrient solution. It was claimed that the irradiation-based spraying interval should be limited to about 1.05 J/cm² during the summer season and 4.2 J/cm² during winter time. During the night a constant interval of about 30 minutes was sufficient. Spraying duration should last about 120 seconds in summer and 30 seconds during wintertime. The response of the plants to the nutrient solution temperature was quadratic and relatively small within the tested range of up to 40 °C. However, temperature of the nutrient solution should be held between 20 and 25 °C.

Otazú (2014) reported that in the aeroponics system, both air and nutrient solution temperature should be controlled for quick plant maturation. As temperatures rise, the chemical processes proceed at faster rates and deteriorate the enzyme activities. The optimum temperature range for all plants is 15–25°C. However, the temperature of growth chamber should be not higher than 30°C and less than 4°C. However, the aeroponic is not entirely implemented among local farmers, and very few farmers have adopted the system due to the lack of research and technical information available in the literature. Therefore, his study was planned to provide information about the development and maintenance tasks required for practicing the aeroponic system.

III METHODOLOGY

For developing the aeroponics system for present pilot study under polyhouse condition, selection of the components of aeroponic system likes nutrient tank, electrical pump, nozzles, laterals and timer was done. The plastic tank of 200 l capacity was selected for this study. For deciding the spacing between the plants which need to be kept on the lid of the nutrient tank, the dimensions of fully grown amaranths were taken. This nutrient tank was selected for storing the nutrient solution inside them as well as to provide the space to grow the plants roots inside the tank. Selection of pump was done after the selection of the nutrient tank by doing some formula based numeric calculations and on that basis pump of 180 Watt was selected (Table 1) which was available in the market for delivering the nutrient solution to the plants. After selecting the pump, selection of nozzles and laterals was done. The hollow cone nozzles (Fig. 1) available in market with 180° cone angle were selected and lab testing was done to test the performance and understand the pattern of discharge of all three nozzles. The HDPE lateral of 16 mm was selected for fitting these nozzles on it. These nozzles and lateral were used for delivering the nutrient solution to the plants. The lateral was placed at 22.8 cm from the top of tank in the upward faced manner. A timer for aeroponic system was selected for operating the system for 15 sec on and 4 min off (Table 2). In order to support the plant stem during its growth period, the net pots having depth 7.6 cm and diameter of 7.98 cm were selected. Total seven pots in circular manner and one at the centre were placed on the lid of tank. The sponge strips in form of coil were placed in the pots for supporting the plant stem. The sponge of thickness 2.2 cm were used for this purpose. Selection of DC battery of 12 V was done to supply current to timer for running it on continuously.

Table 1 Specification of Water Pump

kW / HP	0.18 / 0.25
Voltage	220 ± 6%
Speed	2780 rpm
Current	1.80 amp
Cap run	8 µF 440 V
Type	Minimaster- III
Size	20 x 20 mm
Duty	S1
Head	3 /19.5 M
Discharge	1950 / 700 lph



Table 2 Specification of Timer used for aeroponic system

Timing Range (Selectable)	0.1 ~ 99.9 s, 1 ~ 999 s, 1~ 999 min
Operating Voltage (VDC)	12
Signal Voltage	4 20VDC
Output Capacity	Can control the Load Within DC 30V 5A or AC 220V 5A
Static Current	20 mA
Working Current	50 mA
Operating Temperature (°C)	- 40 to 85

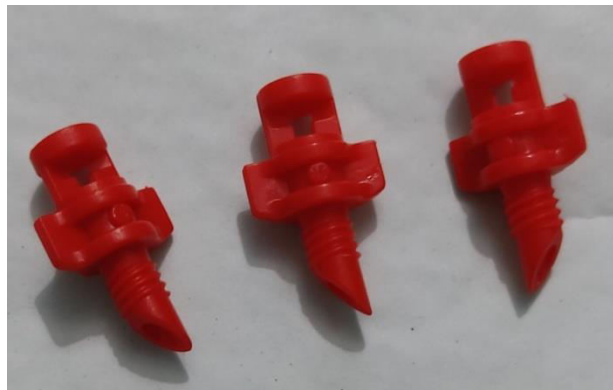


Fig. 1 Hollow cone nozzles used for study

The growth parameters of amaranthus used for vegetable purpose obtained from market were studied. The root length is an important parameter in aeroponics. Based on this parameter the total height of tank and distance of lateral from top of tank was decided. The maximum root length was found to be 13 cm. Maximum height of amaranthus vegetable was measured to be 59 cm while minimum was obtained as 37.8 cm. The maximum and minimum spread diameter was obtained as 20.1 and 10.4 cm respectively while the stem diameter were found to be 6.06 mm as maximum and 2.12 mm as minimum. It was considered as 20 cm considering maximum growth of plants under aeroponic technique. The spread of 20 cm is considered for the growth of plants. This gave plant to plant distance of 20 cm in the developed structure. The maximum root diameter of 6 mm is considered as the hole of 6 mm diameter was drilled in the plastic growing bowl of the growing plants. The developed aeroponic system for the study is shown in Fig.2. The plants grown under developed system is shown in Fig 3. The amaranthus plants earlier grown in the plastic tray in the media of coco peat and vermicompost of age 10 days were transplanted into aeroponic system.



. Fig 2. Developed aeroponic system for study



Fig 3. The developed aeroponic system and plants

IV EXPERIMENTAL RESULTS

1. Laboratory tests of aeroponic setup

The developed setup was tested in laboratory for its nozzle discharges and discharge pattern and nozzle cone angle.

1.1 Discharge through nozzles

The discharges obtained in each nozzle was measured at pressure 2 kg/cm². The observations are as given in Table 3.

Table 3 Discharge of nozzles

Sr. No.	Nozzle 1 (ml/min)	Nozzle 2 (ml/min)	Nozzle 3 (ml/min)
1	1640	1626	1600
2	1620	1620	1610
3	1606	1614	1614
Average	1622	1620	1608

It was observed that the nozzles have given the discharge in the range of 1608 ml/min to 1622 ml/min.

1.2 Nozzle pattern of discharge

All the three nozzles along with lateral when fitted above the patternator and they were tested for their spray pattern and nozzle cone angle. The graph of liquid collected in different tubes of patternator and discharge of nozzle using three nozzles is also plotted. It is shown in Figure 4. The total swath of three nozzles spray was obtained 2.24 m.

Table 4. Volume of water collected in different tubes of patternator

Cone angle: 136.66°

Pressure: 2.0 kg/cm²

Tube No.	Volume of liquid (Average) (ml)	Tube No.	Volume of liquid (Average) (ml)
1	2.66	20	51.66
2	4.33	21	43.66
3	5.00	22	50.00
4	8.66	23	89.66
5	9.66	24	49.66
6	14.66	25	43.66
7	20.00	26	42.00



8	24.33	27	31.66
9	26.00	28	34.66
10	28.66	29	27.00
11	33.33	30	32.66
12	38.33	31	34.33
13	40.66	32	29.00
14	42.66	33	22.33
15	48.00	34	10.66
16	39.66	35	5.33
17	41.66	36	4.66
18	33.33	37	2
19	37.66		

The graph (Fig.4) shows that spray pattern followed by the nozzles.

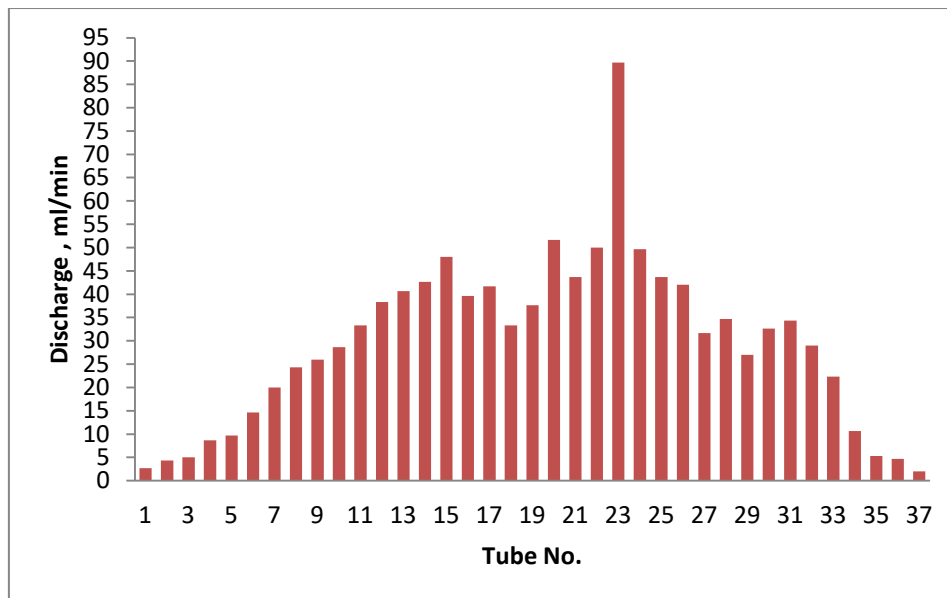


Fig.4. Pattern of Spray through three nozzles

1.3 Droplet size analysis

Based on the counts it can be observed that (Table 4) 33.05% droplets are in the range of 0 to 100 micron, followed by 27.20% of 101 to 200 micron size and 18.69% by 201 to 300 micron size. It means that droplets produced by nozzles are very fine in size. Maximum (more than 60%) droplets are having diameter in the range of 0 to 200 microns were generated with the developed system. The VMD (Volume mean diameter) of the droplets of the nozzles was found to be 209.20 microns.



Table 4. Observations on droplet size analysis

Range of droplet, micron	Number	Mean diameter, micron	Volume of Droplets	% Count of Actual Diameter
0-100	695	50	65416.7	33.05
101-200	572	150.5	1783971.4	27.20
201-300	393	250.5	8226244.0	18.69
301-400	191	350.5	22534216.6	9.08
401-500	88	450.5	47847889.2	4.18
501-600	60	550.5	87307261.8	2.85
601-700	39	650.5	144052334.4	1.85
701-800	18	750.5	221223106.9	0.86
801-900	32	850.5	321959579.5	1.52
901-1000	8	950.5	449401752.1	0.38
over 1000	7	1050.5	606689624.7	0.33

1.4. Plant growth under aeroponic condition

The maximum plant height, root length and stem diameter for plant 1 was found to be 26.53, 5.96 and 0.25 cm respectively. Similarly, growth parameters of plant 2 such as plant height, root length and stem diameter maximum was found to be 32.43, 8.97 and 0.3 cm respectively. Growth parameters of plant 3 such as plant height, root length and stem diameter maximum was found to be 35.77, 11.52 and 0.31 cm respectively. Growth parameters of plant 4 such as plant height, root length and stem diameter maximum was found to be 33.73, 8.70 and 0.38 cm respectively. Growth parameters of plant 5 such as plant height, root length and stem diameter maximum was found to be 33.02, 10.97 and 0.31cm respectively. It was observed that growth parameters of plant 6 such as plant height, root length and stem diameter maximum to be 30.21, 6.46 and 0.31 cm respectively. The growth parameters of plant 7 such as plant height, root length and stem diameter maximum was found to be 29.02, 8.97 and 0.26 cm respectively. Similarly the growth parameters of plant 8 such as plant height, root length and stem diameter maximum was found to be 24.02, 4.96 and 0.25 cm respectively. Table 5 shows that the average percent increase in plant height was found to be 2.16%, also the average percent increase in plant root length was found to be 5.31% and the average percent increase in plant stem diameter was found to be 9.82%. It was found that the plant growth in terms of height, root length and stem diameter was satisfactory on 6th day of transplanting during 15 days of study.

Table 5 Average percent increase in plant growth parameters

Parameter	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Average (%)
Plant height, %	2.03	2.17	2.20	2.20	2.23	2.06	2.20	2.21	2.16
Root Length, %	5.38	5.41	5.02	5.44	5.02	5.40	5.40	5.41	5.31
Stem Diameter, %	9.69	9.89	10	9.88	9.89	9.71	9.74	9.82	9.82



V. CONCLUSION

Based on pilot study conducted, it can be concluded that the amaranthus plants can be grown successfully under developed aeroponic system.

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