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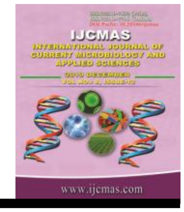

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Standardization of pH of the Solution under Soil-less Agriculture System for Tomato (*Solanum lycopersicum* L.)

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Aeroponics is one of the advanced techniques to cultivate plants without soil with minimal water and nutrient consumption. It is an eco-friendly approach widely used for commercial cultivation of vegetables to obtain the supreme quality and yield. In this context to harvest potentiality of the technology an experiment was designed to standardize the pH of the solution for tomato. The experiment was carried out under Completely Randomized Design (CRD) with three replications during the year 2017-18 at UAS, GKVK Bengaluru. If optimum pH doesn't prevail in the medium, though the nutrients are present in sufficient amount they will not be available to plants. Thus based on the earlier experimental results Hoagland's nutrient solution was prepared with five different levels of pH ranging from 4.5 to 7.0 and studied till 30 DAT. Higher total seedling length was noticed in pH 6-6.4 (118.4 cm) at 30 DAT followed by 5.5-5.9 pH range (115.9 cm) and lower was recorded in 4.5-4.9 pH range (39.6 cm). Thus tomato performed better in Hoagland's nutrient solution at pH ranging from 5.5-6.5.

Introduction

A great challenge will be faced all over the world concerning the feeding population from 6 to 9 billion by 2050 (Ditta *et al.*, 2015). About 40% of the population depends on agriculture in the developing countries like India; hence the agriculture can be considered a backbone in these countries (Ramady *et al.*, 2018). Conventional farming techniques used today involves irrigation of soil with large amounts of water and fertilizer, spraying of pesticides, and churning of the soil that releases large amounts of greenhouse gasses such as methane. In addition, farmers are at the mercy of weather conditions, droughts, and floods that may cause extensive damage to their crops. Increasingly greenhouse farming and urban agriculture are being looked at as more efficient and cost-effective way to grow produce. Advanced technology like soil-less agriculture would be near future; these are the technology which could bring the vertical growth in agriculture. In addition, the growing season can be extended throughout the year. Aeroponics is the process of cultivating plants in an air or mist environment without use of soil or an aggregate media. This system consists of enclosing the roots in a dark chamber and supplying a nutrient solution using mist device (Lakhiar *et al*., 2018). This is an alternative method of soil-less culture in growth-controlled environments. In the early 1940s, the technology was largely used as a research tool rather than an economically feasible method of crop production. Carter (1942) was the first researcher to studied air culture growing and described a method of growing plants in water mist to facilitate examination of roots. Fifteen years after this study, Went (1957) named the air-growing process in spray culture as "aeroponics".

Tomato (*Solanum lycopersicum* L.) a solanaceous self-pollinated vegetable crop. It occupies the largest area among the vegetable crops in the world after potato. An intensive breeding programme has since produced the wide range of tomato cultivars available throughout the world today. The total global area under tomato is 46.16 lakh ha and the global production is to the tune of 1279.93 lakh tonnes and India contribute 7.3 % share of world production and it occupies 789 thousand ha (Anon. 2018). But the productivity of India (17 t ha^{-1}) is least when compared to other countries *viz.,* USA (66 t ha^{-1}), Brazil (56 t ha^{-1}) and China (24 t ha^{-1}). Thus, there is a need for development of better performing system which could produce high quality and better yield throughout the year with the little interventions of environment effect during seed production where is not required, free from soil borne pest, diseases and weeds and with minimal water use (65-70 % less), nutrient (30-50 %), zero herbicides. Among factors affecting soil-less agriculture production the nutrient solution is considered to be one of the most important determining factors of crop yield and quality. If optimum pH doesn't prevail in the medium, though the nutrients are present in sufficient amount they will not be available to plants. Thus an attempt was made to standardization of pH through this experiment.

Materials and Methods

The present investigation was carried out during 2017-19, at National Seed Project, University of Agricultural Sciences in collaboration with BASF Nunhems Pvt Ltd. Aeroponics enclosures of 450 mm X 650 mm X 450 mm PVC boxes, integrated with motors along with the two misters and one timer per box to control the spray rate and an aluminium L angle frame (22 mm X 40 mm) fabricated above the box for staking purpose (Fig. 1 and Fig. 2). The experiment in aeroponics contains six chambers with the individual timer and motor. Six plants were accommodated per chamber, nutrient solution was sprayed to root zone at an interval of 30:180 sec and 30:360 on and off cycle in morning and night respectively.

Seeds were sown on coco-pith in portrays and necessary seedling protections were taken and watered regularly for twenty-eight days and then transferred to the aeroponics chamber with different pH in the solution. The selected Hoagland's nutrient solution was tested for tomato in aeroponics with 5 different levels of pH and tomato plants were monitored for about 30 days to identify the optimum pH based on the seedling performance. The pH of nutrient solution was measured using pH meter (potentiometric method) for every 6 days intervals (Jackson, 1958) and pH was adjusted when fresh nutrient solutions were added to the system.

The experimental data was statistically analysed by adopting Completely Randomized Design (CRD) as per Sundararaj *et al* (1972) adopting "Fisher Analysis of Variance Technique" with the Critical difference (CD) values were computed at 5 % level wherever F test was significant.

Results and Discussion

Hoagland's nutrient solution had prepared with five different levels of pH ranging from 4.5 to 7.0 and studied till 30 DAT to identify the best pH range for tomato hybrid seed production. Number of leaves per plant varied significantly on 10 DAT, it was found higher for all the three levels >5.5 pH (10) and lower was found for below 5.5 pH (9) and until 25 DAT all the 4 levels of pH was having on par results but lower was recorded in pH 4.5-5.0. There was an increasing trend for plant growth parameters as the pH increased till 6.4. Shoot length showed the significant difference from 5 days after transplanting and higher shoot length was recorded for 6-6.4 pH (14.4, 22.9, 26.5, 34.6, 38.2 and 58.5 cm) it was on par with 5.5-5.9 pH (14.3, 20.0, 26.5, 33.1, 37.6 and 57.6 cm) and lower was recorded for 4.5-4.9 pH (9.6, 11.0, 11.6, 13.1, 13.5 and 14.8 cm) at 5, 10, 15, 20, 25 and 30 DAT, respectively. Similarly, higher root length at 30 DAT was also noticed in 6-6.4 pH (58.7 cm) it was on par with 5.5-5.9 pH (57.6 cm). The plant growth rate was significantly higher with 6-6.4 pH (1.16, 5.7, 1.3, 2.9, 1.8 and 5.6) it was on par at 5.5-5.9 pH (0.9, 4.4, 1.8, 2.7, 1.8 and 5.4) and lower was noticed in 4.5-5 pH (0.48, 0.4 0.1, 0.8, 0.5 and 1.3) at 5, 10, 15, 20, 25 and 30 DAT respectively. Plant spread was higher at 5.5-5.9 pH range (40.4 cm) found on par with 6.0-6.4 pH (39.4 cm) and lower was recorded in 4.0-4.5 pH (16.2 cm) at 30 DAT.

The rhizosphere pH plays a key role in deciding nutrient availability and in turn plant growth and productivity. Manipulating pH would be more feasible in soil-less culture compared to soil medium (Silber and Bar-Tal 2008). But the fact is availability of nutrients varies based on the pH of the nutrient solution. If optimum pH doesn't prevail in the medium, though the nutrients are present in sufficient amount they will not be available to plants. Gericke (2007) indicated favourable pH range of 5 to 6.5 for soil-less nutrient solution in tomato production. According to Singh (2013), plants can grow in soil-less within a pH range of 5.8 to 6.8. He also reported that the ideal pH range for tomato in hydroponics is between 5.5 and 6.5. This is also stated by Wan *et al.* (1994) Hojhabrian (2014) and Dysko *et al.* (2015) in tomato (Table 1–3 and Fig. 3 and 4).

Table.1 Different levels of pH tested for tomato

Sl.No	pH Range
1	4.5-4.9
2	5-5.4
3	5.5-5.9
4	6-6.4
5	6.5-7

Table.2 Seedling growth parameters (up to 15 DAT) as influenced by different pH for aeroponic system in tomato

pH Range	Number of leaves per plant	Shoot length (cm)	Root length (cm)	Total seedling length(cm)	Plant growth rate	Plant spread
			ADT			
4.5-4.9	3.67	12.32	8.20	20.52	-	8.00
5.0-5.4	4.00	11.50	8.05	19.55	-	7.70
5.5-5.9	3.67	11.92	7.75	19.67	-	7.95
6.0-6.4	4.00	11.55	7.70	19.25	-	7.85
6.4-7.0	4.00	12.23	8.13	20.37	-	7.90
S.Em.±	**0.21**	**0.22**	**0.21**	**0.33**	**-**	**0.27**
CD@1%	**NS**	**NS**	**NS**	**NS**	**-**	**NS**
CV (%)	**9.44**	**3.25**	**4.48**	**2.85**	**-**	**5.83**
			5 DAT			
4.5-4.9	5.67	13.70	9.55	23.25	0.48	10.65
5-5.4	5.33	14.25	9.90	24.15	0.92	12.27
5.5-5.9	6.00	14.42	10.95	25.37	0.90	13.70
6-6.4	5.33	14.80	11.05	25.85	1.16	14.07
6.4-7	5.67	14.70	11.37	26.07	0.94	13.93
S.Em.±	**0.30**	**0.11**	**0.26**	**0.32**	**0.01**	**0.32**
CD@1%	**NS**	**0.49**	**1.15**	**1.41**	**0.04**	**1.42**
CV (%)	**9.22**	**1.31**	**4.19**	**2.19**	**1.76**	**4.24**
			10 DAT			
4.5-4.9	9.33	14.20	11.00	25.20	0.39	12.53
5-5.4	9.67	14.70	14.20	28.90	0.95	18.80
5.5-5.9	10.00	20.03	27.47	47.50	4.43	19.00
6-6.4	10.00	22.85	31.60	54.45	5.72	19.37
6.4-7	9.67	22.05	31.58	53.63	5.51	19.23
S.Em.±	**0.58**	**0.31**	**0.29**	**0.49**	**0.10**	0.26
CD@1%	**2.59**	**1.40**	**1.32**	**2.19**	**0.45**	1.15
CV (%)	**10.27**	**2.89**	**2.20**	**2.02**	**5.10**	2.50
			15 DAT			
4.5-4.9	10.33	14.83	11.60	26.43	0.12	14.10
5-5.4	9.67	18.07	15.37	33.43	0.45	22.20
5.5-5.9	11.67	26.53	39.17	65.70	1.82	25.07
6-6.4	11.67	26.07	41.15	67.22	1.28	24.77
6.4-7	12.00	25.07	39.57	64.63	1.10	25.17
S.Em.±	**0.30**	**0.51**	**0.68**	**0.79**	**0.09**	**0.54**
CD@1%	**1.34**	**2.28**	**3.06**	**3.53**	**0.40**	**2.44**
CV (%)	**4.67**	**3.98**	**4.03**	**2.65**	**16.15**	**4.23**

Table.3 Seedling growth parameters (between 20, 25 and 30 DAT) as influenced by different pH for aeroponic system in tomato

pH Range	Number of leaves per plant	Shoot length (cm)	Root length (cm)	Total seedling Length (cm)	Plant growth rate	Plant Spread
			20 DAT			
4.5-4.9	12.33	17.45	13.10	30.55	0.82	15.33
5-5.4	14.33	23.97	23.00	46.97	2.64	27.17
5.5-5.9	16.00	33.10	46.00	79.10	2.67	29.03
6-6.4	16.00	34.57	46.97	81.53	2.86	29.60
6.4-7	15.33	32.37	44.03	76.40	2.35	29.00
S.Em.±	**0.26**	**0.71**	**0.68**	**1.11**	**0.19**	**0.66**
CD @1%	**1.16**	**3.19**	**3.05**	**4.97**	**0.85**	**2.95**
CV (%)	**3.02**	**4.36**	**3.41**	**3.05**	**14.49**	**4.38**
			25 DAT			
4.5-4.9	14.67	19.73	13.47	33.20	0.53	16.77
5-5.4	17.67	28.27	32.53	60.80	2.77	30.90
5.5-5.9	18.67	37.60	51.30	88.90	1.75	33.80
6-6.4	18.67	38.17	52.20	90.37	1.77	34.00
6.4-7	18.00	35.90	49.97	85.87	1.86	32.43
S.Em.±	**0.47**	**0.77**	**0.69**	**0.93**	**0.15**	**0.67**
CD(@1%)	**2.11**	**3.44**	**3.09**	**4.16**	**0.69**	**3.00**
CV (%)	**4.66**	**4.17**	**2.99**	**2.24**	**15.40**	**3.92**
			30 DAT			
4.5-4.9	14.00	24.73	14.83	39.57	16.20	16.20
5-5.4	17.67	35.37	34.33	69.70	35.87	35.87
5.5-5.9	19.00	57.63	58.23	115.87	40.40	40.40
6-6.4	20.00	58.47	59.97	118.43	39.93	39.93
6.4-7	18.33	55.30	54.93	110.23	39.73	41.07
S.Em.±	**0.61**	**1.49**	**1.30**	**2.43**	**0.54**	**0.59**
CD (@1%)	**2.75**	**6.70**	**5.84**	**10.89**	**2.42**	**2.63**
CV (%)	**5.98**	**5.59**	**5.07**	**4.64**	**2.72**	**2.93**

DAT: Days after transplanting

Fig.1

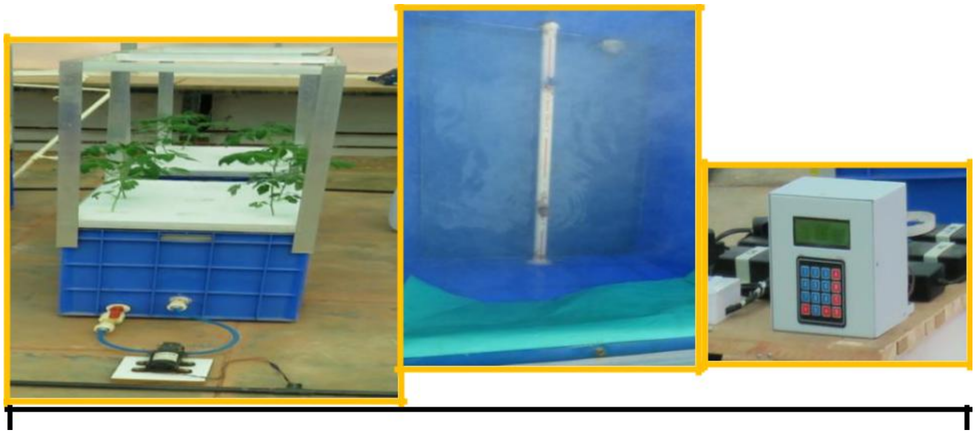

Fig.2 Experimental layout for nutrient standardization in aeroponics for tomato

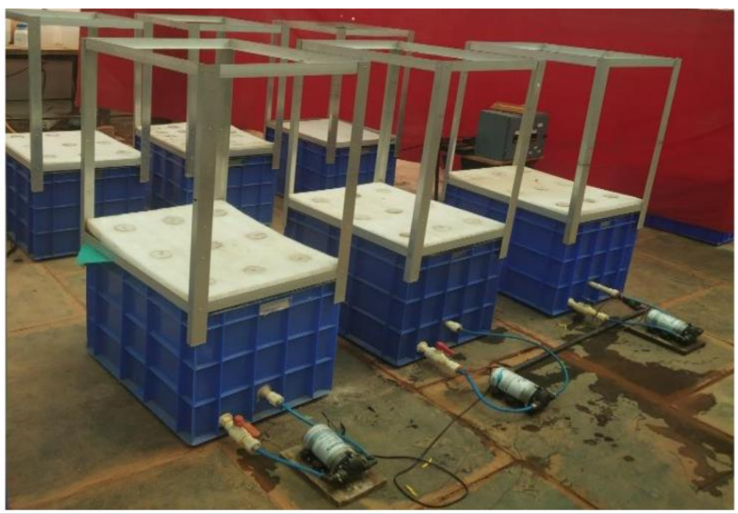

Fig 3: Effect of pH on fruit formation under aeroponic system in tomato

Fig 4: Effect of pH on root growth at 15 DAT in tomato

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