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Effect of Different Concentration of Major and Minor Nutrients on the Growth and Yield of Strawberry (*Fragaria x ananassa* L.) Grown under Aeroponic System

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Strawberry is a perennial fruit crop of high importance in the market. It is highly recommended both as table and processed fruit due its nutrient content. The growth period of strawberry is short and hence doesn't require much time for its growth and development. Aeroponic on the other hand seems to provide a better hand in cultivation of annual species in controlled conditions in a meticulous way. A field experiment was conducted at Horticulture Research Farm, Department of Horticulture, Naini Agriculture Institute, Sam Higginbottom university of agriculture, technology and science, Prayagraj, U.P during the year 2022-2023. The experiment comprised of eight different

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treatments with one control T1(3g NPK + 16g micronutrient), T2(6g NPK+14g micronutrient) T3(9g NPK+12g micronutrient), T4(12g NPK+10g micronutrient), T5(15g NPK+8g micronutrient) T6(18g NPK+6g micronutrient), T7(21g NPK+4g micronutrient), T8(24g NPK+2g micronutrient), T0 control (water). Based on the outcome of the current experiment, it can be concluded that treatment T6-(18gNPK+6gmicronutrient) produced the greatest results. It was determined to have the greatest growth traits with highest - Plant height(19.74cm), Number of leaves per plant (25.90), Plant spread(26.43cm) and Root length(28.35cm). It was also found best in terms of yield and yield attributing characters i.e., Total no flowers per plant (31.73), Fruit set (68.2 %) No of fruits per plant (21.58), Fruit weight (39.77g) Average yield (0.86kg).

Keywords: Strawberry; aeroponic; NPK; micronutrient.

1. INTROUDUCTION

1.1 Strawberry

Strawberry is widely distributed fruits in the whole world due to its genotypic diversity, broad range of environmental adaptations and highly heterozygous nature [1]. Although it mostly cultivated in temperate climate, but some varieties are available which can be cultivated in tropical and sub-tropical climate. China is the leading country in Strawberry fruit production with approximate yield of (2.99 million MT) [2]. Followed by USA (1.36 million MT), Mexico (0.37 million MT), Turkey (0.37 million MT), Spain (0.31 million MT. India has total cultivated area of about 1000 ha under strawberry cultivation with 5000 MT production [3]. It is most commonly grown in hilly regions of India. Maharashtra is the state with the most strawberry production. Mahabaleshwar (Maharashtra), Jammu and Kashmir, Bangalore, and Kalimpong (West Bengal) are the other major areas of cultivation. Strawberry has been successfully cultivated in the plain parts of the nation in recent years.

Strawberry (*Fragaria* × *ananassa* Duch.) belongs to family Rosaceae and the genus *Fragaria.* It is basically a small herbaceous perennial plant and thrives well in temperatures ranging from 22 °C to 25 °C during the day and 7 °C to 13 °C in night [4]. Strawberry is a perennial fruit crop of high importance in the market. It is highly recommended both as table and processed fruit due to its nutrient content. The growth period of strawberry is short and hence doesn't require much time for its growth and developmentt. It is used in making excellent ice cream, crush, pies, Jam, fruit juices and milk shakes on account of its rich aroma. The strawberry contains 89.9 per cent water, 8.4 per cent carbohydrates, 1.3 per cent fibre, 0.7 per cent protein, 0.5 per cent ash, 0.5 per cent fat, 164 mg potassium, 21 mg calcium, 1.0 mg sodium, 1.0 mg iron, 60 I.U. vitamin A, 59 mg/ 100 g vitamin C, 0.03 mg thiamine, 0.07 mg riboflavin and 0.6 mg niacin [5]. It is rich in anthocyanin content and possesses high antioxidant activity [6]. It requires well drained medium loamy soil with enough of organic matter having pH range from 5.7 to 6.5 i.e., acidic in nature. Soil is generally the most important growing medium for plant growth and development. It provides air, anchorage, water, nutrients etc. for successful plant growth. However, soils do possess some serious limitations for both plant growth and development like presence of unfavourable soil compaction, unsuitable soil reaction, poor drainage, degradation due to erosion, disease causing organisms and nematodes etc in addition, conventional crop growing in soil is somewhat difficult as it involves large space, large volume of water and lot of labour. Moreover, in metropolitan areas, soil is not often available for crop growing due to high population density and in some areas, scarcity of fertile cultivable arable lands is major problem due to their unfavourable topographical or geographical conditions. Another serious problem experienced in conventional open field agriculture is to hire labour. Under such circumstances, soil-less culture can be introduced successfully.

1.2 Aeroponics

Aeroponic on the other hand seems to provide a better hand in cultivation of perennial species in controlled conditions in a meticulous way. Aeroponic is the most advanced form of protected cultivation where roots are hang in the air and are misted with nutrient solutions the misting are usually done every few minutes , to keep the moisture in roots .the sprayed nutrient solution that is not absorbed by the roots is usually re-sprayed using re-circulation system [7] .As the basic principle of aeroponic is to growing is to grow plants suspended in a closed or semi-closed environment by spraying the plants

dangling roots and lower stem with atomized or sprayed ,nutrient -rich water solution .This technology has not only reduced cost of input on a broader prospect but also has enhanced quality of produce [8]. Strawberry cultivation in India is restricted to some parts in our country which produces a less yield and productivity. In order to enhance the area and productivity of strawberry aeroponics can be a handy solution to this. Aeroponic shall not only enhance yield and productivity but shall pave farmers to enhance the quality and bring a surge in their income. Aeroponic is a modern soilless culture technique for growing agricultural plants by providing a nutrient solution in the air without soil. Plant roots receive a nutrient spray mist from an atomizing nozzle. Improved food production spaces and water-saving methods under soilless culture have led to promising results around the world. This approach uses relatively lower amounts of water input per unit of planted area, making it a safe and environmentally friendly way to grow plants and control the rhizosphere. Using this approach, plant roots can be quickly nourished under controlled conditions. Water is made more available for plant absorption in aeroponic systems which reduce water irrigation use; as a result, more nutrient absorption reflects more strawberry yield, quality and productivity. So, optimization of macro and micronutrients in the aeroponic system plays a major role in strawberry production [9]. As a result, this experiment was designed to determine optimum macronutrients and micronutrients concentration.

2. MATERIALS AND METHODS

The present investigation was carried out during the year 2022-2023 at Horticultural Research Farm, Naini Agricultural Institute, SHUATS, Prayagraj. The objective was to find out the growth and yield and quality of strawberry with different treatments using aeroponic technology.

2.1 Assembly of Different Component of the Aeroponic System

As per the experiment details the design applied was Complete randomized design (CRD) with 3 replications there were total eight treatments with one control. Strawberry (*Fragaria* × *ananassa*) cv. Winter Dawn transplants were placed in sponge-filled netting cups. Plants were placed in a greenhouse for three weeks in a deep-water culture filled with a thin layer of diluted nutrient solution until complete rooting occurred. After rooting, plants were moved into the aeroponic system. In aeroponic cultivation spacing between plants to plant was kept 15 cm. Based on this spacing a plastic tote box of size 35.56 cm x 32 cm x 20.32 cm was taken for growing of three plants per box. The transplanted plants were put with clay balls in net pots to facilitate efficient and free root growth without any obstacles. Holes were made on a thermocol sheet and the net pots containing plants were placed in the holes and then it was put over the aeroponic growing chamber. As all the plastic boxes were connected with motors in which two foggers were attached in each box which were spraying water nutrient solution to the hanging roots of aeroponic unit plants. The whole aeroponic system was connected to the electric timer which were working for twenty five seconds at five minutes interval. The main function of the irrigation and fertigation system is to send pressurized water and nutrient solution to the growing chambers. The capacity of pump is dependent on the system's production capacity. Controllers or timers were usually connected to the pump using valves to help regulate the flow and distribution of water and nutrients. The nutrient solution was provided in cyclic rotation through a sequence of separate tanks, filters and valves before final distribution to the plant roots through the nozzle. The aeroponic system utilised a high-pressure pump which was used to atomize the water through small orifice nozzles to create water droplets of 30-100 microns in diameter.

2.2 Concentration of Different Macro and Micro Nutrient in Aeroponic System

As nutrient feeding is the application of fertilizers to crops through water in recommended ratio. Nutrient feeding is also described as the application of fertilizers in the right combination, concentration, EC and pH for every fertigation cycle. For aeroponic systems, nutrient solution can be provided through the use of pumps, pipes, filters, irrigation timers, emitters and other irrigation equipment . And the nutrient solution was standardized as per treatment details before putting the strawberry transplants on to the aeroponic growing chamber. The different concentrations of nutrients as per treatment T0 Control (Water),T1(3gNPK+16g micronutrient),T2 (6g NPK+14g micronutrient),T3 (9g NPK+12g micronutrient), T4 (12g NPK+10g micronutrient), T5(15g NPK+8g micronutrient),T6 (18g NPK+6g micronutrient), T7 (21g NPK+4g micronutrient), T8(24g NPK+2g micronutrient). The micronutrients were provided through a product named Combi-2. It provides eight essential

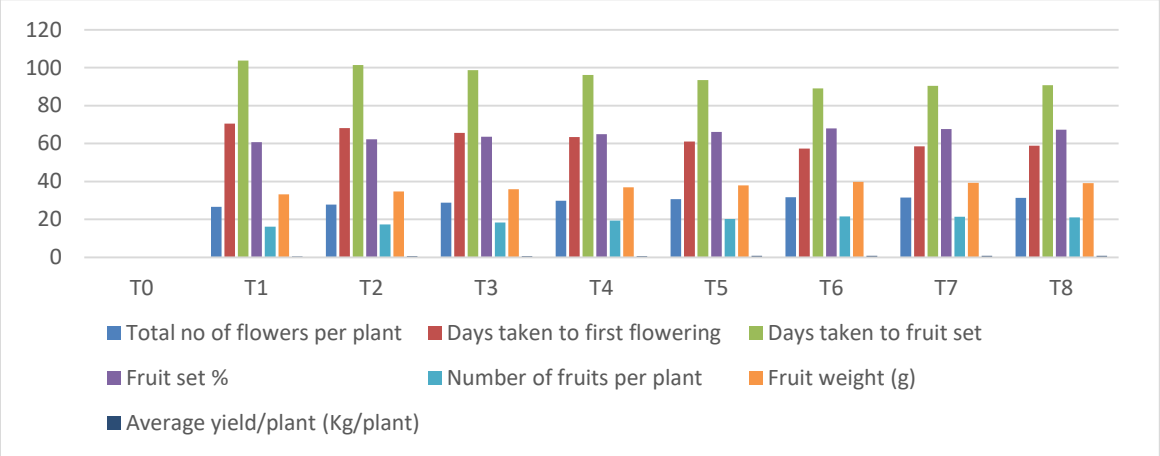
micronutrients together in optimum dose to crops. It is chealeted with EDTA and thus assures fast absorption of all individual micro-elements in to the plants. The composition of Combi-2 is Zn 4.0%, Fe 2.0%, Mn 0.5%, Cu 0.3%, B 0.54%, Mo 0.1%, S 2.5%, Mn 2.5%.

2.3 Standardization of pH

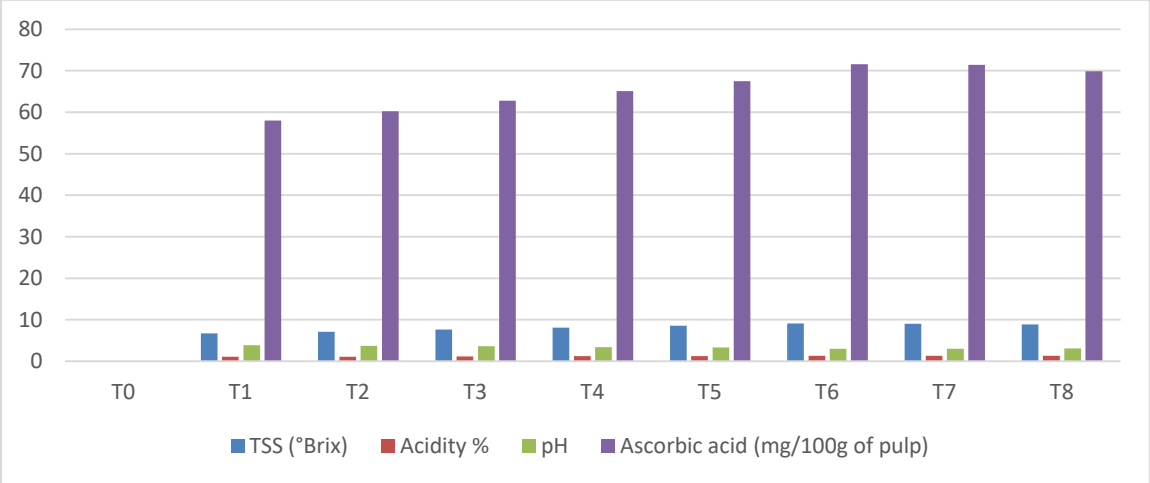
A pH meter is an instrument that measures the hydrogen-ion activity in water nutrient solutions that indicate its acidity or alkalinity expressed as pH. The pH value of nutrient solution for strawberry was maintained between 5.6 to 6.0. The pH value higher or lower than this affected the growth of plants. The pH of nutrient solution was measured using pH meter (potentiometric method) for every 6 days intervals and pH was adjusted when fresh nutrient solutions were added to the system.

3. RESULTS AND DISCUSSION

As per my results, the observation in term of plant height (cm), number of leaves/plant, plant spread (cm), root length(cm) , total no flowers per plant , days taken to fruit set ,fruit set % , number of fruits per plant , fruit weight(g), average yield /plant(kg/plant) due to effect of different concentration of major and micronutrients on strawberry (*Fragaria x ananassa* L.) was statistically analysed and has been presented in Table 1 and Table 2.



Graph 1. Effect of different concentration of major and micro nutrients on flowering and fruiting of strawberry (*Fragaria* x *ananassa* L.) grown under Aeroponic system



Graph 2. Effect of different concentration of major and micro nutrients on quality parameters of strawberry (*Fragaria* x *ananassa* L.) grown under Aeroponic system

Table 1. Effect of different concentration of major and micro nutrients on vegetative parameters of strawberry (*Fragaria* x *ananassa* L.) grown under aeroponic system

Treatment symbol	Treatment details	Plant height (cm)				Number of leaves/plants				Plant Spread(cm)				Root Length(cm)			
		30 DAS	60 DAS	90 DAS	120 DAS	60 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
T0	Control(water)	6.91	*	*	*	7.84	*	*	*	13.87	*	*	*	4.44	*	*	*
T1	3g NPK +16g Micronutrient	8.66	11.50	15.01	16.57	10.27	13.53	17.37	19.96	16.94	22.24	22.36	23.58	5.23	14.04	19.97	26.00
T2	6g NPK +14g Micronutrient	9.12	12.47	15.74	17.11	10.66	14.65	19.05	20.99	17.31	22.52	23.01	24.11	5.53	14.46	20.33	26.40
T3	9g NPK +12g Micronutrient	9.59	13.32	16.47	17.65	10.97	15.81	20.67	22.05	17.64	21.86	23.48	24.67	5.87	14.83	20.70	26.80
T4	12g NPK +10g Micronutrient	10.00	14.23	17.21	18.20	11.31	16.78	22.08	23.12	18.02	22.16	24.03	25.20	6.20	15.16	21.07	27.23
T5	15g NPK +8g Micronutrient	10.42	15.36	17.99	18.74	11.62	17.77	23.48	24.06	18.34	22.47	24.50	25.71	6.61	15.47	21.41	27.62
T6	18g NPK +6g Micronutrient	11.14	16.94	19.33	19.74	12.16	19.55	25.77	25.90	18.91	22.92	25.26	26.43	7.11	15.98	21.94	28.35
T7	21g NPK +4g Micronutrient	11.02	16.61	19.03	19.62	12.05	19.05	25.12	25.50	18.85	22.84	25.10	26.33	7.01	15.90	21.86	28.16
T8	24g NPK +2g Micronutrient	10.94	16.30	18.80	19.41	11.97	18.86	24.78	25.10	18.73	22.77	24.97	26.17	6.93	15.81	21.77	28.08
	F-Test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
	CV	2.05	3.43	2.13	1.42	1.29	2.83	3.10	2.06	0.79	0.59	0.84	0.84	2.33	1.00	0.67	0.63
	S.E. (m) (±)	0.12	0.29	0.21	0.15	0.08	0.28	0.40	0.28	0.08	0.08	0.12	0.12	0.08	0.09	0.08	0.10
	CD (5%)	0.34	0.87	0.64	0.45	0.24	0.83	1.19	0.83	0.24	0.23	0.35	0.37	0.24	0.26	0.25	0.30
	CD (1%)	0.47	1.19	0.88	0.62	0.33	1.15	1.65	1.15	0.33	0.32	0.48	0.50	0.33	0.36	0.34	0.41

Table 2. Effect of different concentration of major and micro nutrients flowering and fruiting of strawberry (*Fragaria* x *ananassa* L.) grown under aeroponic system

Treatment symbol	Treatment details	Total no of flowers per plant	Days taken to first flowering	Days taken to fruit set	Fruit set %	Number of fruits per plant	Fruit weight (g)	Average yield/plant (Kg/plant)
T0	Control(water)	*	*	*	*	*	*	*
T1	3g NPK +16g Micronutrient	26.68	70.49	103.82	60.81	16.23	33.26	0.54
T2	6g NPK +14g Micronutrient	27.81	68.14	101.38	62.18	17.29	34.73	0.60
T3	9g NPK +12g Micronutrient	28.79	65.72	98.72	63.67	18.33	35.87	0.66
T4	12g NPK +10g Micronutrient	29.93	63.40	96.11	64.91	19.43	36.99	0.72
T5	15g NPK +8g Micronutrient	30.67	61.05	93.50	66.16	20.29	38.02	0.77
T6	18g NPK +6g Micronutrient	31.73	57.29	89.06	68.02	21.58	39.77	0.86
T7	21g NPK +4g Micronutrient	31.53	58.58	90.47	67.69	21.34	39.32	0.84
T8	24g NPK +2g Micronutrient	31.34	58.85	90.85	67.41	21.13	39.09	0.83
	F-Test	**	**	**	**	**	**	**
	C.V	1.27	1.96	1.50	1.00	2.22	1.27	3.47
	S.E. (m) (±)	0.22	0.71	0.83	1.00	0.25	0.27	0.01
	CD (5%)	0.66	2.14	2.47	0.38	0.75	0.82	0.04
	CD @ (1%)	0.90	2.94	3.41	1.13	1.03	1.12	0.06

Table 3. Effect of different concentration of major and micro nutrients on quality parameters of strawberry (*Fragaria* x *ananassa* L.) grown under aeroponic system

Treatment symbol	Treatment details	TSS (°Brix)	Acidity %	pH	Ascorbic acid (mg/100g of pulp)
T0	Control(water)	*	*	*	*
T1	3g NPK +16g Micronutrient	6.71	1.09	3.90	57.98
T2	6g NPK +14g Micronutrient	7.10	1.12	3.70	60.21
T3	9g NPK +12g Micronutrient	7.63	1.18	3.60	62.78
T4	12g NPK +10g Micronutrient	8.08	1.22	3.40	65.09
T5	15g NPK +8g Micronutrient	8.53	1.26	3.30	67.52
T6	18g NPK +6g Micronutrient	9.11	1.32	3.00	71.54
T7	21g NPK +4g Micronutrient	9.00	1.30	3.00	71.38
T8	24g NPK +2g Micronutrient	8.90	1.29	3.10	69.84
	F-Test	**	**	**	**
	C.V	1.98	0.82	2.96	2.10
	S.E. (m) (±)	0.09	0.01	0.06	0.80
	CD (5%)	0.28	0.02	0.17	0.17
	CD (1%)	0.38	0.02	0.24	0.24

3.1 Effect of Different Concentration of Major and Micro Nutrients on Vegetative and Flowering of Strawberry (*Fragaria* x *ananassa* L.) Grown Under Aeroponic System

The treatment T_6 containing (18g NPK and 6g micronutrient) respectively recorded highest plant height i.e., (19.74). This might be due to the optimal availability of macronutrients and micronutrients for enhanced plant development [10]. The treatment T_6 containing (18g NPK and 6g micronutrient) respectively recorded highest number of leaves per plant at 30, 60, 90 and 120 days of observation was i.e., (25.90). This is because the aeroponic solution spray made all the necessary nutrients easily accessible to the plant roots. Nitrogen is the most crucial component in plant growth, and plants that received more of it had more leaves overall [11]. The treatment T_6 containing (18g NPK and 6g micronutrient) respectively recorded highest plant spread i.e., (26.43). As aeroponic systems, with their carefully maintained pH levels, allowed plants to quickly and efficiently absorb all of the nutrients they needed to grow [12]. The treatment (T_6 containing 18g NPK and 6g Micronutrient) respectively recorded highest root length at 30, 60, 90 and 120 days of observation i.e., (28.35) The greatest root length may be attributable to an abundance of phosphorus, which stimulates root expansion [13]. It was observed that the total no of flowers per plant of strawberry (*Fragaria ananassa*) cv. Winter Dawn were significantly influenced by different treatments. The Treatment T_6 containing 18g NPK and 6g Micronutrient respectively recorded earliest flowering. The early appearance of flowers in this treatment combination might be due to the fact that the optimum availability of micronutrients (especially boron) and other macronutrients might have played a role in catalysing the biosynthetic pathway through which floral development becomes faster as compared to the normal plants The optimal nutrient availability leads to increased vegetative as well as reproductive growth of plant. Similar reports of early flowering were also reported while working on potatoes and while working on cherry tomato hydroponics [14].

It was found that Treatment T_6 (18g NPK+6g micronutrient) recorded the maximum total no of flowers per plant i.e., 31.73 over all other treatments. It was found that Treatment T_6 (18 g NPK+6g micronutrient) recorded the minimum days taken to first flowering i.e., 57.29 days over all other treatments where-as the maximum days taken to first flowering i.e., 70.49 days).

3.2 Effect of Different Concentration of Major and Micronutrients on Fruit Set, No of Fruits per Plant and Quality Attributes of Strawberry (*Fragaria* x *ananassa* L.) Grown Under Aeroponic System

It was found that Treatment T_6 (18g NPK+6g micronutrient) recorded the minimum days taken to fruit set i.e., 89.06 days over all other treatments where-as the maximum days taken to fruit set i.e., 103.82 days was recorded in treatment T_1 (3g NPK+16g micronutrient). The Treatment T_6 containing 18g NPK and 6g Micronutrient respectively recorded earliest fruit set. The shorter time from blooming to fruit set may be attributable to optimal NPK and micronutrients application, which facilitated photo-assimilate synthesis and deposition. This may have resulted in enhanced development, fruit bud differentiation (FBD), and blooming [15].

It was observed that the number of fruits per plant of strawberry (*Fragaria ananassa*) cv. Winter Dawn were significantly influenced by different treatments. It was found that Treatment T_6 (18g NPK+6g Micronutrient) recorded the maximum number of fruits per plant i.e., 21.58 over all other treatments. It was followed by Treatment T_7 (21g NPK+4g micronutrient) with 2^{nd} best number of fruits per plant i.e., 21.34. It was observed that the fruit weight (g) of strawberry (*Fragaria ananassa*) cv. Winter Dawn were significantly influenced by different treatments. It was found that Treatment T_6 (18g NPK+6g micronutrient) recorded the maximum fruit weight (g) of 39.77g over all other treatments [13]. It was followed by Treatment T_7 (21g NPK+4g micronutrient) with 2^{nd} best fruit weight (g) with 39.32g. It was observed that the average yield/plant (Kg/plant) of strawberry (*Fragaria ananassa*) cv. Winter Dawn were significantly influenced by different treatments. It was found that Treatment T_6 (18g NPK+6g micronutrient) recorded the maximum average yield/plant (Kg/plant) of 0.86 kg over all other treatments. Treatment T6 (18gNPK+6g micronutrient**)** was also found best in quality attributes TSS (9.11° B) Acidity (1.32%) Ascorbic acid (71.54mg/100g of pulp) [16-18].

4. CONCULSION

- Based on the findings of this study, it can be concluded that plants grown utilising the aeroponic system of cultivation with NPK and micronutrients maximise yield in addition to displaying the highest growth and quality.
- Based on the outcome of the current experiment, it can be concluded that treatment T6-(18gNPK+6gMicronutrient**)** produced the greatest results. It was determined to have the greatest growth traits with highest - plant height(19.74cm**),** number of leaves per plant (25.90), plant spread(26.43cm) and root length(28.35cm). It was also found best in terms of yield and yield attributing characters i.e., Total no flowers per plant (31.73), fruit set (68.2 %) No of fruits per plant (21.58), fruit weight (39.77g) average yield(0.86kg).
- Treatment T6 (18gNPK+6g Micronutrient) was also found best in quality attributes TSS (9.11° B) Acidity (1.32%) Ascorbic acid (71.54mg/100g of pulp)
- As per the result of my experiment T6 (18gNPK+6gMicronutrient) was the best followed by T7 (21gNPK+4gMicronutrient) and the lowest was T0 (control).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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