International Journal of Research in Agronomy 2026; 9(1): 609-615

E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(1): 609-615
Received: 12-10-2025
Accepted: 17-11-2025

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Biometric parameters of crops grown under different substrates and concentration of nutrient solution in hydroponics

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DOI: https://www.doi.org/10.33545/2618060X.2026.v9.i1i.4746

Abstract
Using the Nutrient Film Technique (NFT), this experiment was carried out to determine the ideal substrate and nutrient solution content for the mass production of sweet basil. The research work conducted in different seasons (Season1_April and May, Season2_August and September, Season3_October and November and Season4_January and February) for treatments four nutrient solutions and four substrates is presented in this paper. The final results revealed that the height of plant was highest 36.8 cm in T_2 (1000 ppm), using rock wool (M1). Among all the seasons, season2 showed better growth. The number of branches in vermiculite showed a higher value (18 no.) in T_3 (1100 ppm) in season2. The number of leaves in in vermiculite (M4) showed higher no. of leaves (136 no.) in T_3 (1100 ppm) in season2. The mean diameter in T_3 (1100 ppm), basil plant diameter grown using perlite was higher (6.74 mm) when compared to those grown in clay balls, vermiculite, and rockwool in season2. The ideal nutritional solution in four different seasons is T_3 (1100 ppm) and the substrates differ depending on the season due to various characteristics.

Keywords: Hydroponics, biometric parameters, substrates and nutrient solution

Introduction

Urban agriculture has gained attention as a means of achieving global food security in the context of climate change and global industrialization (Wielemaker *et al.* 2019) [1]. Concerns about food insecurity have increased as a result of the current COVID-19 pandemic, which has impeded regional food transportation due to pandemic-induced controls. However, this has also brought attention to one of the main benefits of urban agriculture: the capacity to produce food locally. In the agricultural sector, the usage of pesticides, fertilizer, and genetically modified crops has significantly expanded in order to guarantee output rates. Both our ecosystem and our health are negatively impacted by these actions. In both urban and rural regions, high-performance growth technologies other than soil-based culture are rapidly gaining popularity as modern farming practices (Lakhiar *et al.* 2018) [2].

Hydroponic comes from the Greek words hydro (water), and ponos (labour): hydroponic is literally "water working" (Fernandes 2017) [3]. Plant roots are immersed in a water-nutrient solution in a reservoir for the whole growing cycle in hydroponic systems (Karol and Bowen 2016) [4]. In addition to using water efficiently and avoiding the need for pesticides, hydroponic culture eliminates soil-borne disease (Ragaveena *et al.* 2021) [5]. The objective of maximizing food production per unit area of farmland through the use of smart technology is thus gaining attention (Ragaveena *et al.* 2021) [5].

The crop that was used in the present experiment was basil. One of the most popularly planted herbs in many climatic zones is basil (*Ocimum basilicum*), a member of the Lamiaceae family, so demand from consumers is increasing. Basil is utilized in medicine, cosmetics, and culinary preparation (Nurzyńska-Wierdak 2012) [6]. It is also employed as an ornamental scent plant in landscape design (Makri & Kintzios 2008) [7]. Ascorbic acid, carotenoids, polyphenolics, and essential oils (0.1-0.2%) are among the biologically active substances with antioxidant qualities that have been demonstrated to accumulate in basil plants (Kwee & Niemeyer 2011; Surveswaran *et al.* 2007) [8, 9]. For the basil crop, experiments are carried out using different growing media and fertilizer solutions. The precise selection of growing media is a disadvantage of hydroponic cultivation (Ragaveena *et al.* 2021) [5].

The growing media or substrate is an essential component of soil-less cultivation, as it is used for the total plant growing cycle from germination to harvest. The properties of the substrate material should be suitable for soil-less culture according to plant type, atmospheric conditions, and total arrangement of the growing cycle (Juneau *et al.* 2006) [10]. Growing media used in hydroponics systems provide the plant shoots and roots continuous support throughout the growing cycle and distribute macro and micro-nutrients efficiently to the plant roots from a water-nutrient reservoir (French and Roth 2019) [11]. The substrate must allow roots to get enough water, oxygen, and nutrients for satisfactory plant growth (Juneau *et al.* 2006) [10], should provide enough storage for water-nutrients for the plant roots, and at the same time should maintain proper aeration (Wallach 2008) [13].

Materials and Methods

The naturally ventilated polyhouse constructed at the Dr. NTR College of Agricultural Engineering, Bapatla, with dimensions of 20 m x 12 m was used in the current study (Rani, R.S. *et al*. 2022) [14]. Here there are openings in the sides that can be closed or opened to let in cold air, and the warm air goes out. Planning of experiment is the four nutrient solutions i.e., T_1(900), T_2(1000), T_3(1100) and T_4 (1200) and four substrates i.e., M1(Rock wool), M2(Clay balls), M3(Vermiculite) and M4(Perlite).

Growing Mediums in hydroponics

In most hydroponic systems, growers use different types of hydroponic media to help support their roots and maintain a good water/oxygen ratio.

Rock wool

Rock wool is among the most widely used media in hydroponics (melted balsamic rock spun into fibre). It is biologically and chemically inert, making it free of any potential pests, diseases and weed seeds (Putra and Yuliando, 2015) [15]. It is an inert substrate for both free drainage and re-circulating systems. It has a large water retention capacity, and also holds sufficient air. It holds a lot of water which gives an advantage against power or equipment failures as shown in Fig.1.

Clay balls (Hydroton)

Hydroton or expanded clay aggregate are suitable for hydroponic systems in which all nutrients are carefully controlled in water solution. It is made by baking the clay pellets and known under the trade name of 'Hydroton' or LECA (lightweight expanded clay aggregate) as shown in Fig.2. The clay pellets are inert, pH neutral and do not contain any nutrient value. The clay is formed into round pellets and fired at high temperatures (1200 ˚C) in rotary klins. This makes the clay to pop-up and become porous. The main advantage of hydroton is it is light in weight and does not compact over time.

Perlite

The perlite originates from a silicone mineral which forms in volcanoes and is very light in weight (Hussain *et al.*, 2014) [16]. It holds less water and more air. It is a fusion of granite, obsidian, pumice and basalt (George and George, 2016) [17]. Perlite is a porous substance it offers excellent water retention and drainage capabilities both important in hydroponics shown in Fig.3. Perlite is an inert and sterile medium which means it's safe to use without the fear of tracking in pests, and which is always the risk with soil. Perlite is made from volcanic rock after being superheated into very lightweight expanded glass pebbles.

Vermiculite

Like perlite, vermiculite is another mineral that has been superheated until it has expanded into light pebbles. Vermiculite holds more water than perlite and has a natural "wicking" property that can draw water and nutrients in a passive hydroponic system as shown in Fig.4. The physical properties like bulk density and porosity of bedding materials used are presented in Table.1.

Fig 1: Rock wool

Fig 2: Clay balls (Hydrotons)

Fig 3: Perlite

Fig 4: Vermiculite

Table 1: Bulk density and porosity of growing media

Substrates	Bulk density (kg/m^3)	Total porosity(%v/v)
Vermiculite	90-150	90-95
Perlite	80-120	85-90
Rockwool	80-90	94-97
Expanded clay	600-900	85-90

Source: Pardossi *et al.* (2011) [18]

Nutrient Solution

For proper growth, plants must be supplied with combination of macro and micro nutrients i.e. nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, boron, zinc, copper, molybdenum, and chlorine. Within certain limits of composition and total concentrations, there can be a rather wide range in the nutrient solutions suitable for plant growth. Usually, the small amount of minerals in the water supply can be ignored. When nutrients are deficient or present in excess in the solution, however, the plants will suffer.

Fig 5: Monitoring of preparation with nutrient solution A&B

Raising of nursery

For growing of nursery, proportion of 60% cocopeat, 20% perlite and 20% vermiculite is mixed thoroughly. The plug trays having 105 cells of size 2.7 cm in diameter and 3.37 cm depth used to grow nursery. These trays were filled with the premixed cocopeat upto 1½ inches. The

sowing was done by placing each seed in a hole at a depth of 0.5 cm and covered with thin layer of cocopeat/growing medium. The trays were watered lightly and placed in a sheltered place. The plastic sheet was covered on the trays up to 3 days, after 3 days the plastic cover is removed and water is sprayed with spray cans in the morning/ evening daily without disturbing the seed. After one week, the nutrients solution was sprayed until the plant roots reach the bottom of the cube in about fifteen days. The seedlings were ready for transplanting 15 days after sowing as shown in Fig.6.

The germinated seedlings were transplanted into hydroponic A-frame along with net cups were placed in the platform where thin film of various nutrient solution circulates. The net cups were filled with media (Rock wool, clay ball, perlite and vermiculite) was around the seedling. The plants within net cups that were inserted into the NFT channels as shown in Fig.7. According to Rani, R.S. *et al.* (2022) [14], the NFT's operation is explained.

Fig 6: Basil after 15 days of sowing

Fig 7: Plant supported with media in net cups and transplantation in NFT channel

Biometric Characteristics of Plant

The biometric observations observations such as plant height, number of leaves, number of branches per plant and stem diameter. Individual plant height was measured in centimetre (cm) from bottom to the point where growth of leaves starts. The plant height was measured by using measuring scale. The manual measurement of number of leaves was done. One plant of each replication was selected for manual measurement of number of branches. With the digital Verniercalliper, the stem diameter of the plant was measured.

Fig 8: Basil crop

Results and Discussion

Height of the Plant

In season1 the plant height observations in different concentrations and media are shown in Fig.9. After 30 DAT in T_3 (1100 ppm), for basil, plant height using vermiculite (M4) were higher (39 cm) when compared to those grown in clay balls, perlite, and rock wool. This may be due to the reason that vermiculate media showed more moisture retention characteristics even in summer.

For season2, the plant height observations in different treatments and media are shown in Fig. 10. After 30 DAT in T_2 (1000 ppm), basil plant grown using rock wool (M1) showed a higher value (36.8 cm) when compared to those grown in clay balls, perlite, and vermiculite. Overall, for the third concentration, all the media gave consistently higher yields compared to others. Inden and Torres (2004) [19] reported that utilization of rockwool and perlite in hydroponics culture results in higher yields as compared to other inert materials. Although sand is cheap and easily available, it is heavy and does not drain well (Hydroponics Gardening Information, 2007) [20]. This reduced drainage in sand probably caused the significant reduction in cut flower stem length when compared to plants grown in sawdust and vermiculite.

For season3, the mean height of the plants in different treatments and media is shown in Fig.11. After 30 DAT in T_3 (1100 ppm), basil plant heights grown using rockwool (M1) were higher (39.06 cm) when compared to those grown in clay balls, vermiculite, and perlite. A maximum reduction was observed when plants were exposed to a high nutrient concentration level.

For season4, the plant's height in various treatments and media are shown in Fig. 12. After 30DAT in T_3 (1100 ppm), basil plants grown using rockwool (M1) showed a higher value (30.63 cm) when compared to those grown in clay balls, vermiculite, and perlite.

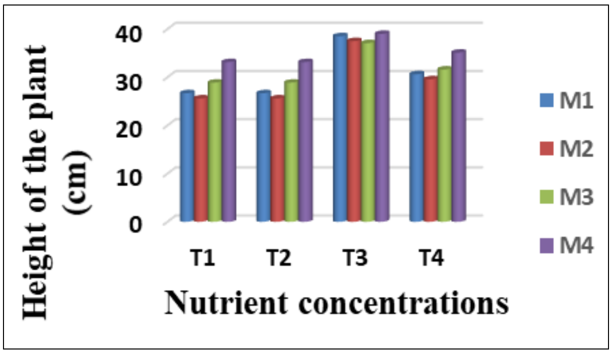

Fig 9: Plant height in different nutrient concentrations and media at 30 DAT

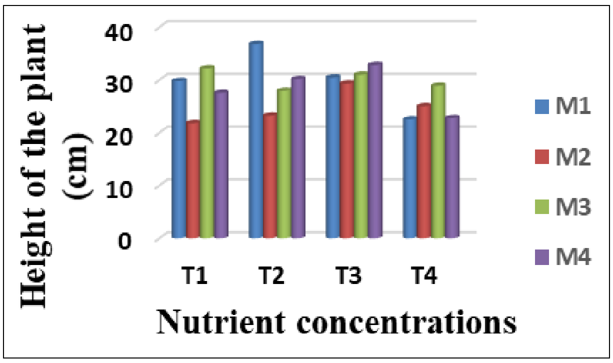

Fig 10: Plant height in different nutrient concentrations and media at 30 DAT

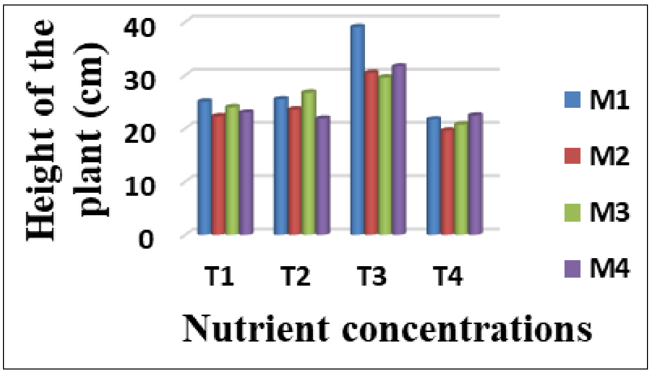

Fig 11: Plant height in different nutrient concentrations and media at 30 DAT

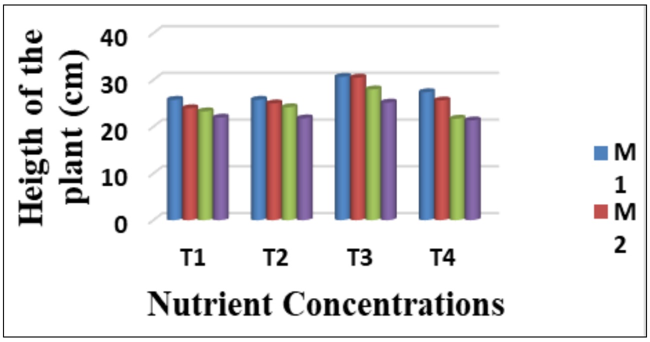

Fig 12: Plant height in different nutrient concentrations and media at 30 DAT

Number of Branches

For season1, the number of branches in different treatments and media is shown in Fig. 13. Basil plants grown in vermiculite showed higher value (12 no.) after 30 DAT in T_3 (1100 ppm) than those grown in clay balls, perlite, and rockwool. Wahome *et al*. (2011) [21] reported that high number of branches/flowers of gypsophila grown using sawdust and vermiculite could probably be due to higher water holding and nutrient holding capacities of the medium as compared to sand.

For season2, the number of branches in different treatments and media is shown in Fig.14. Basil plants grown in vermiculite showed a higher value (18 no.) after 30 DAT in T_3 (1100 ppm) than those grown in clay balls, perlite, and rockwool.

For season3, the number of branches of the plant in different treatments and media is shown in Fig.15. After 30 DAT in T_3 (1100 ppm), rockwool (M1) showed higher no. of branches (13 no.) when compared to those grown in clay balls, vermiculite, and perlite.

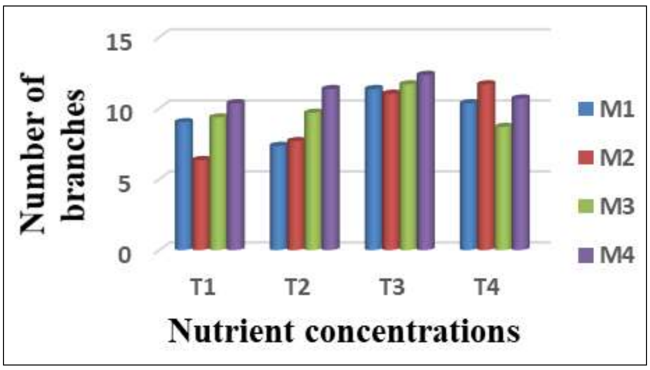

Fig 13: No. of branches in different nutrient concentrations and media at 30 DAT

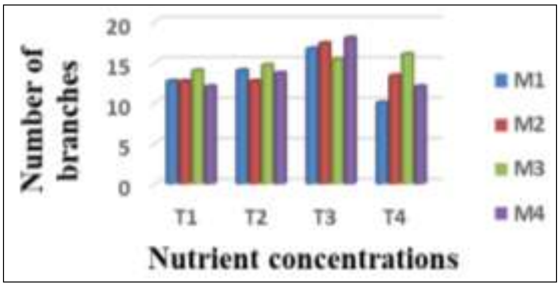

Fig 14: No. of branches in different nutrient concentrations and media at 30 DAT

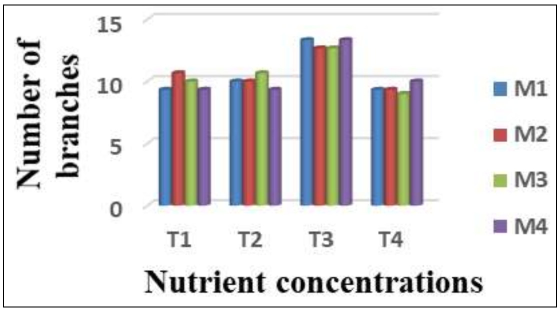

Fig 15: No. of branches in different nutrient concentrations and media at 30 DAT

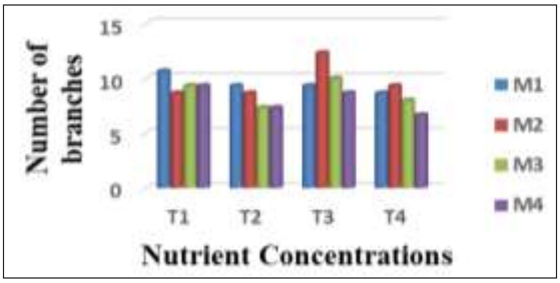

Fig 16: No. of branches in different nutrient concentrations and media at 30 DAT

For season4, the number of branches of the plant in different treatments and media is shown in Fig.16. After 30 DAT in T_3 (1100 ppm), number of branches grown using clay balls (M2) was higher (8 no.) when compared to those grown in rockwool, vermiculite, and perlite.

Number of Leaves

For season1, the observations of number of leaves are taken in regular intervals starting from 10 DAT, 20 DAT and 30 DAT. The number of leaves in different treatments and media is shown in **Fig. 17.** After 30 DAT in T_3 (1100 ppm), basil plants grown using rockwool (M1) showed higher no. of leaves (80 no.) when compared to those grown in clay balls, perlite and vermiculite.

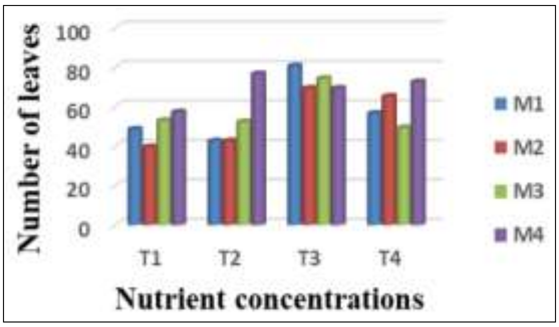

Fig 17: No. of leaves in different nutrient concentration and media at 30 DAT

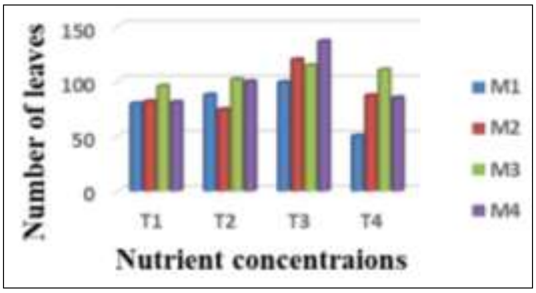

Fig 18: No. of leaves in different nutrient concentrations and media at 30 DAT

For Season2, the number of leaves in different treatments and media is shown in Fig.18. Basil plants grown in vermiculite (M4) showed higher no. of leaves (136 no.) after 30 DAT in T_3 (1100 ppm) than those grown in clay balls, perlite, and rockwool.

For season3, the number of leaves of the plant in different treatments and media is shown in Fig.19. After 30 DAT in T_3 (1100 ppm), using rockwool, no. of leaves (90 no.) was higher when compared to those grown in clay balls, vermiculite, and perlite.

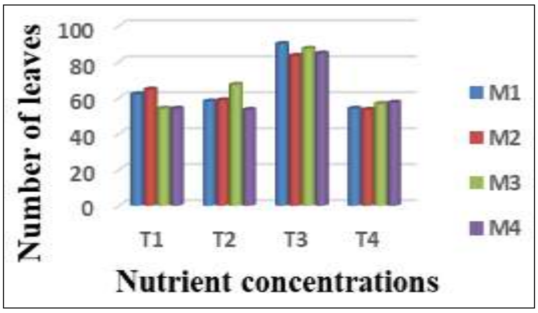

Fig 19: No. of leaves in different nutrient concentrations and media at 30 DAT

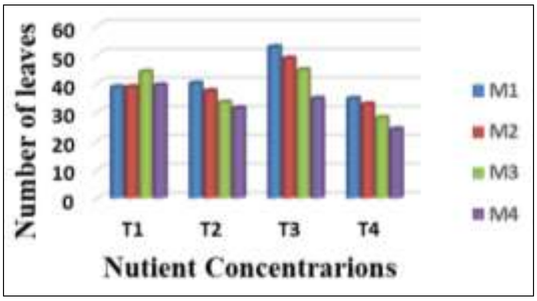

Fig 20: No. of leaves in different nutrient concentrations and media at 30 DAT

For season4, the number of leaves of the plant in different treatments and media is shown in Fig.20. At 30 DAT in T_3 (1100 ppm), the number of leaves of basil plants grown in rockwool (M1) was higher (52 no.) than those grown in clay balls, vermiculite, and perlite.

Stem Diameter

For season1, the mean diameter of the plant in different treatments and media is shown in Fig. 21. Basil plant diameter grown in vermiculite (M4) was higher (5.16 mm) after 30 DAT in T_3 (1100 ppm) than those grown in clay balls, perlite, and rockwool.

For season2, the mean diameter of the plant in different treatments and media is shown in Fig.22. After 30 DAT in T_3

(1100 ppm), basil plant diameter grown using perlite was higher (6.74 mm) when compared to those grown in clay balls, vermiculite, and rockwool.

For season3, the diameter of the plant in various treatments and media is shown in Fig.23. Basil plant diameter grown in rockwool (M1) was significantly higher (5.31mm) after 30 DAT in T_3 (1100 ppm) than those grown in clay balls, vermiculite, and perlite. For season4, the mean diameter in different treatments and media is shown in Fig.24. It was observed that the maximum stem diameter occurred at 30 DAT for the treatment with concentration nutrient solution of T_3 (1100 ppm) using rockwool (M1) was higher (4.18 mm) when compared to those grown in clay balls, vermiculite and perlite. A maximum reduction was observed when plants were exposed to a higher concentration level. The mean values of data showed that the minimum had the maximum reduction of plant diameter under stress. The saline stress still inhibits plants growth by osmotic effect, restricting the availability of water by toxicity and nutritional disorder besides it induct morphological, structural and metabolic modifications (Viana *et al.*, 2004) [22].

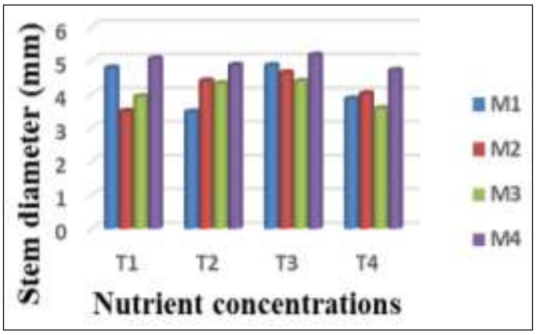

Fig 21: Stem diameter in different nutrient concentrations and media at 30 DAT

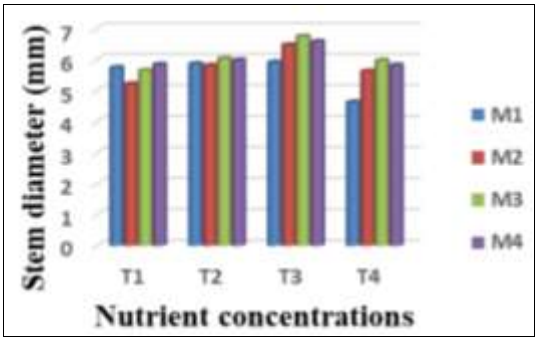

Fig 22: Stem diameter in different nutrient concentrations and media at 30 DAT

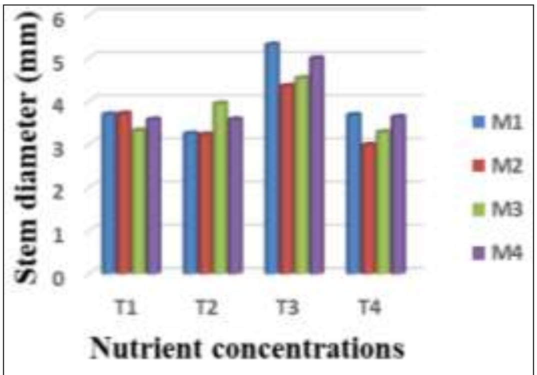

Fig 23: Stem diameter in different nutrient concentrations and media at 30 DAT

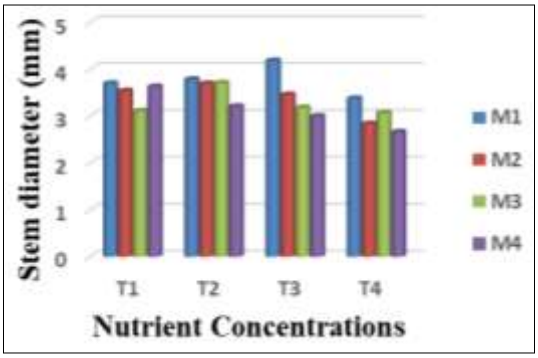

Fig 24: Stem diameter in different nutrient concentrations and media at 30 DAT

The results obtained were similar to the Heidari (2012) [23] and Bione *et al*. (2014) [24], the authors observed in their research with basil under hydroponic cultivation a significant reduction of fresh biomass when using salinized nutrient solution. Reboucas *et al.* (2013) also reported significant influence of salinity of irrigation water on coriander fresh biomass under hydroponic cultivation, causing a decrease of this variable from 0.48 to 0.13 for electrical conductivities of 2.55 to 12.34 dS/m, respectively.

Conclusion

Hydroponics technology is possibly the most intensive and a versatile method of growing crops production at present as it allows optimum utilization of nutrient solution, water and space, as well as a better substrate of plant protection. T_3 has the best nutrient solution when compared to T_1, T_2, and T_4. Seasons have an impact on the substrates. Due to its greater potential to hold water than the other substrates, vermiculite performs best during season 1 (summer). Therefore, select the appropriate substrates before beginning crop cultivation to increase production. Finally, concluded that the nutrient solution 1100ppm and Rock wool is the best in the experiment among the all nutrients and substrates.

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