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Potato Production under Different Soilless Systems

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Abstract

The main aim of this research is to study the comparison between the aeroponic and substrate systems for potato production to reduce production costs and increasing the potato yield. To achieve that study, the effect of different soilless systems (aeroponic and substrate) on plant length, root length, number of leaves, stem diameter, leaf area, leaf length and potato yield. The obtained results refer to the highest value of plant height was 114.33 cm for aeroponic system and the highest value of number of leaves was 15.50 at aeroponic system.. The highest values of stem diameter, number of internode and number of branches were found T2 system. The highest value of leaf area and leaf length (491.26 cm^2 and 32.57 cm) was found with aeroponic system (T2). The highest value of total fresh yield 2039.12 g $plant^{-1}$ was observed with aeroponic system (T2), while the lowest value of total fresh yield (658.37 g $plant^{-1}$) was found with substrate system (T3).

Keywords: Potato, tuber, soilless culture, aeroponic, substrate.

Introduction

Potato (Solanum tuberosum L.) is one of the world's most important non-cereal high yielding horticultural food crop. Being largely a vegetative propagated crop, it is subjected to large number of seed borne diseases responsible for degeneration of seed stocks over the years. It is therefore imperative to use good quality seed for economic production. But, availability of quality seed is a major constraint in potato production especially in developing countries **(Upadhya, 1979).** In a country like India, one major cause of low potato productivity is the use of poor quality seed **(Singh, 2003**) and at present the state and central seed production agencies of the country are able to meet only 20–25% requirement of quality seed **(Kumar et al., 2007).** Aeroponics is a plant culture technique in which mechanically supported plant roots are either continuously or periodically misted with nutrient solution **(Barak et al., 1996).** The international union of soil-less culture defines aeroponics "as a system where roots are continuously or discontinuously in an environment saturated with fine drops (a mist or aerosol) of nutrient solution" (**Nugali et al., 2005)**. The basic principle of aeroponics is to grow plants in a closed or semi-closed environment by spraying the plant's roots with a nutrient rich solution. Ideally, the environment should be kept free from pests and diseases so that the plants may grow healthier and quicker than plants grown in a soil medium. However, because most aeroponic environments are not properly closed, pests and disease may still be a threat. As aeroponics is conducted in air combined with micro droplets of water, almost any plant can grow to maturity because of an abundant supply of oxygen, water and nutrients. Hydroponic systems using different inert substrates **(Navarrete, 2004),** deep water culture systems **(Chang et al. 2000; Lommen, 2007),** the NFT system **(Wheeler et al. 1990; Wheeler 2006)** and hydroponic systems with recirculating nutrient solutions in low volume substrates **(Struik and Wiersema, 1999).** Aeroponics is a soilless culture system, where roots are kept in a dark environment saturated with an aerosol of nutrient solution **(Christie and Nichols, 2004**).

It is an innovative technology that increases biomass and tuber yields **(Otazú, 2010**), optimizes root oxygenation and growth (**Soffer and Burger, 1988**) and minimizes the consumption of water and fertilizers **(Farran and Mingo-Castel, 2006).** Aeroponic culture can be more profitable than conventional seed tuber production systems **(Maldonado et al. 2007).**In horticultural crop production, the definition soilless cultivation encompasses all the systems that provide plant management in soilless conditions in which the supply of water and of minerals is carried out by nutrient solution, with or without a growing medium e.g. rockwool, peat, perlite, pumice, coconut fiber, etc.. Soilless cultivation systems can be divided into: i) systems in the solid medium ie hydroponics, using a substrate to support the plants, ii) systems in the liquid medium ie aeroponics, which do not have other media for the support of plant roots and iii) systems in the aerated medium, the roots of the plants are suspended in a closed chamber and a nutrient solution is sprayed from below. Hydroponic system is a method of growing plants using a mineral nutrient solution in water, without soil. In traditional agricultural methods soil is used as the medium whereby nutrients are dissolved in water, which can then be taken up by the plant roots, although the soil itself is not necessary. If nutrients are added to the water in which the plants are grown, then the soil medium is not needed. The ability to grow plants in areas where soil is not conducive for in-ground agriculture is the great advantage of hydroponics. Also, it is much more efficient in its water use as water stays in the system and can be reused, as opposed to it percolating through the soil and ultimately replenishing the groundwater reserves. Having greater control over nutrient levels results in healthier crops, fertilizers which often contribute to pollution are not used, pesticides are not needed to deal with pests, and ultimately, much higher and more stable crop yields are achieved **(Johanson, 2009).**

Aeroponic culture is an optional device of the soilless culture methods in growth controlled environments such as greenhouse. This method consists of enclosing the root system in a dark chamber and supplying a solution of water and mineral nutrients with a mist device. This technique has been applied successfully for the production of different horticultural species including lettuce **(Cho et al., 1996; Gysi and von Allmen, 1997; He and Lee, 1998)**.

Benefit of aeroponics system is that of easy monitoring of nutrients and pH. Aeroponics system provides precise plant nutrient requirements for the crop, thereby, reducing fertilizer requirement and minimizing risk of excessive fertilizer residues moving into the subterranean water table **(Nichols, 2005)**. Aeroponics system also allows the measurement of nutrient uptake over time under varying conditions. This technique requires soil sterilization leading to high fuel costs. In addition, the technique has a low multiplication rate (6 to 8 tubers /plant) unlike aeroponics (50 to 100 tubers per plant (**Otazu, 2010; Muthoni et al., 2011**).

Aeroponics is a soilless method for producing pre basic potato seed. The method can produce higher yields (up to 10-times higher), more quickly, and at lesser cost than conventional growing methods. The conventional way of producing quality pre basic potato seed is to multiply clean in vitro material in the greenhouse. This method usually produces yields of 5 to 10 minitubers per plant. The conventional method uses a sterile substrate made of soil and a mixture of various components **(Otazi ,2010**).In modern agriculture, methyl bromide has been used as the soil disinfectant of choice, because of its low cost and ability to efficiently eliminate arthropods, nematodes, pathogens and weeds, without altering other soil characteristics. Aeroponics offers the potential to improve production and reduce costs compared to conventional methods or to the other soilless method of hydroponics (growth in water). Aeroponics effectively exploits the vertical space of the greenhouse and air humidity balance to optimize the development of roots, tubers, and foliage. Commercial production of potato seed using aeroponics is already progressing in Korea and China. In the Central Andean Region of South America, the technology has been used successfully since 2006. At the Huancayo, Peru facility of the International Potato Center yields of more than 100 minitubers /plants have been obtained using relatively simple materials. Current efforts are underway to incorporate aeroponics into potato seed systems of some Sub-Saharan African countries **(Otazi, 2010)**. The growing of potato plants in aeroponics system is considered as safe and ecologically friendly for producing natural, healthy plants and crops. Multiplication of seed potatoes using aeroponics has advantages over the other systems or techniques including, conventional seed potato production, hydroponics and plant tissue culture techniques. Reports show that the system is ten times more successful than conventional techniques, tissue culture and hydroponics, which take longer and are also more labour intensive **(CIP, 2008)**.

The main disadvantage of substrate is disposal of artificial grown medium at the end of cultivation. In order to minimize this drawback some action could be adopted prolong as much possible the use of substrate, using new quick test for assessing the real physical ,chemical and the phitopatological properties before to star with anew cultivation . This operating increased production cost, therefore the main aim of this work is to study the comparison between the aeroponic and substrate systems for potato production to reduce production costs and increasing the potato yield.

Materials and Methods

The experiment was carried out at the Agricultural Research and Experiment Center of Faculty of Agriculture, Benha University, Egypt (30° 21` N and 31° 13` E). During the period of October 2019 to March 2020 season.

2.1. Materials:

2.1.1. System Description:

Figure (1) illustrates the experimental setup. It shows aeroponic systems, substrate systems, solution tank, pumps and timer.

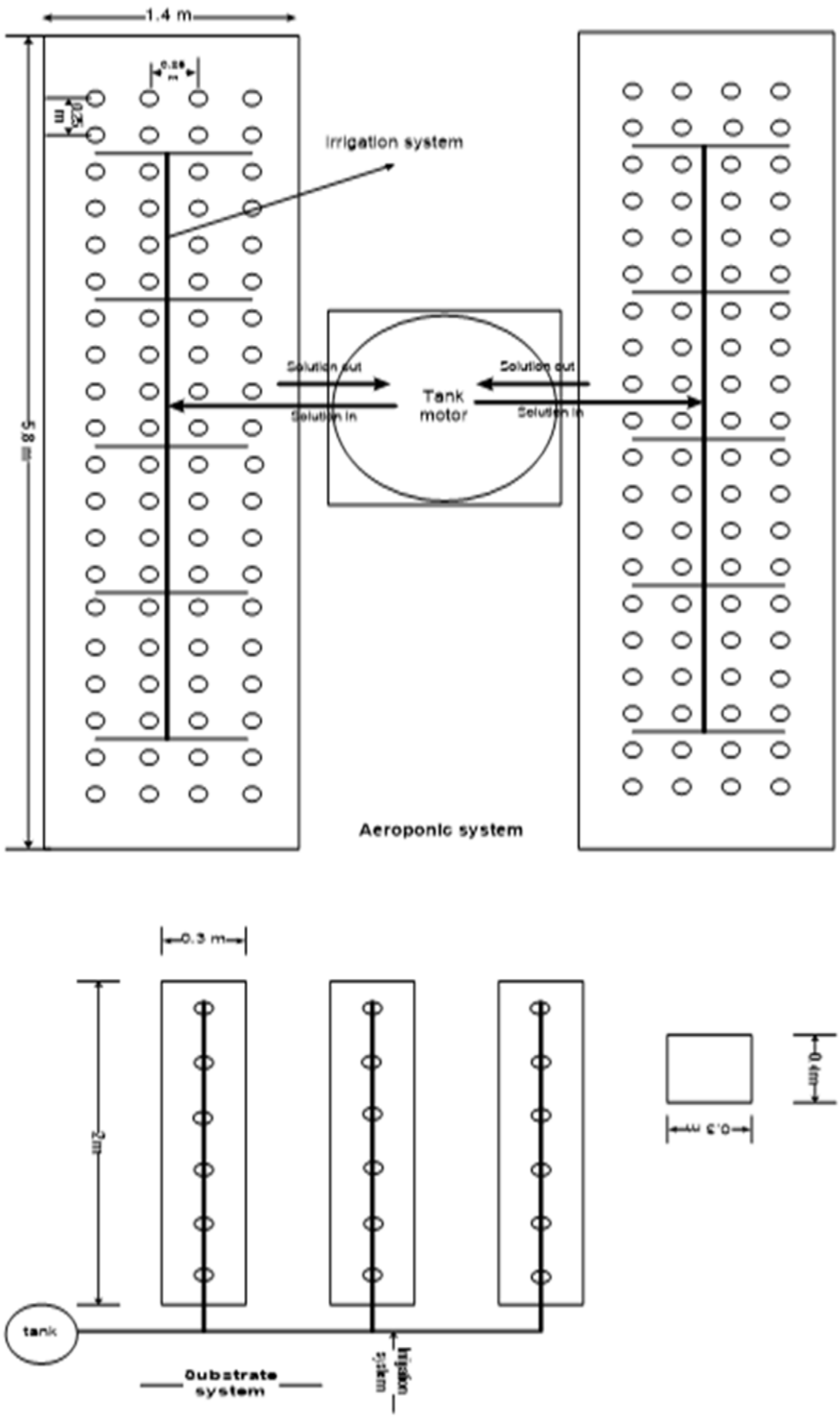

Figure (1): The experimental setup

The Aeroponic units in this study consist of two gullies which made from concrete, lined by plastic sheet and covered with foam boards to support the plants. Dimensions of each unit are 5.80 m long, 1.40 m wide and 0.8m high and have three windows (1m long, 0.4 m wide) on each side. Each aeroponic unit provided of fog nozzles (25 Lh^{-1} discharge) to spray nutrient solution into the tank in order to keep the roots wet. Pipes PVC ¾ " ϕ and tubes 16 mm were used to supply each aeroponic unit with solution discharged of the solution tank in a closed system. The solution was circulated by a pump (Model Sp – Flow rate 20 m^3 hr^{-1} - head 15 m power 1.5 hp, china) in a closed system. The circular polyethylene tank of the nutrient solution system 1000 liter capacity was used for collecting of drained solution by gravity from the ends of the aeroponic system. The chemicals used in the system is KNO_3, $Ca(NO_3)_2$,NH_4NO_3 KH_2PO_4, $MgSO_4$ and micro elements, pH and EC was measured daily .

The substrate system in this study consists of three gullies which made from plastic sheet filled on peatmoss, perlite and vermiculite (1:2:2). Dimensions of each unit are 2 m long, 0.3m wide and 0.4 m high.

2.1. 2. Potato Plants:

Potato tubers were sown in the plastic guiles (2 m length and 0.3 m width) filled with peatmoss, perlite and vermiculite (1:2:2) It was irrigated using water with solution. Four weeks old potato planting was planted in the experimental system. The plant spacing on the row was 0.25 m **(Otazu, 2010)**.

2.1. Methods

2.1.1. Treatments:

The treatments were arranged in a randomized complete design. Three treatments include: **T1**: Aeroponic system is calibrated to mist for 15 min on and 5 min off, **T2**: aeroponic system is calibrated to mist for 15 min on 1 min off, **T3:** substrate system

2.1.2. Experiment measurements:

Plant height, number of leaves, stem diameter, Number of internode, Number of branches, Number of fruits, leaf length ,Root length and leaf area were taken every week for different treatments. Digital planimeter (Model placom kp 90n - Power Ac adapter –Accuracy ± 0.2 percent – Japan) was used to measure plant leaf surface area. Vernier caliper (Model DIN 862_ Range 0-150 mm- Accuracy± 0.05 mm, China) was used to measure the stem diameter.

2.2. Statistical analysis:

The statistical analysis for the obtained data was examined using SPSS software (IBM SPSS Statistics 21, American) and the treatments were compared at 0.05 level probability of significances.

Results and discussion

3.1. Plant height:

Figure (2) shows plant height of potato plants in different soilless systems (aeroponic and substrate) during the growth period plant. The results indicate that the plant height of potato during the growth period which grown in different treatments increases linearly with the time. The results show that the height plant of plants grown on aeroponic system was higher than of those plants grown on substrate system. It could be seen that the potato plant height increased from 21.76 to 114.33 cm and 23.67 and 99 cm for T1 and T2, respectively, during the growth period. While, it increased from 27 to 54 cm during the growth period for substrate system. These results agreed with those obtained by **Tsoka et al. (2008), Otazú (2010) and Hale *et al.* (2015)** who's found that the aeroponics produced fastest growth rates. Also, many studies showed that the aeroponic system enhance the rates of plants growth by promoting the root aeration because of the root system is grown totally suspended at the air, giving the roots systems access to 100% of the available oxygen at the air (**Mehandru et al., 2014).**

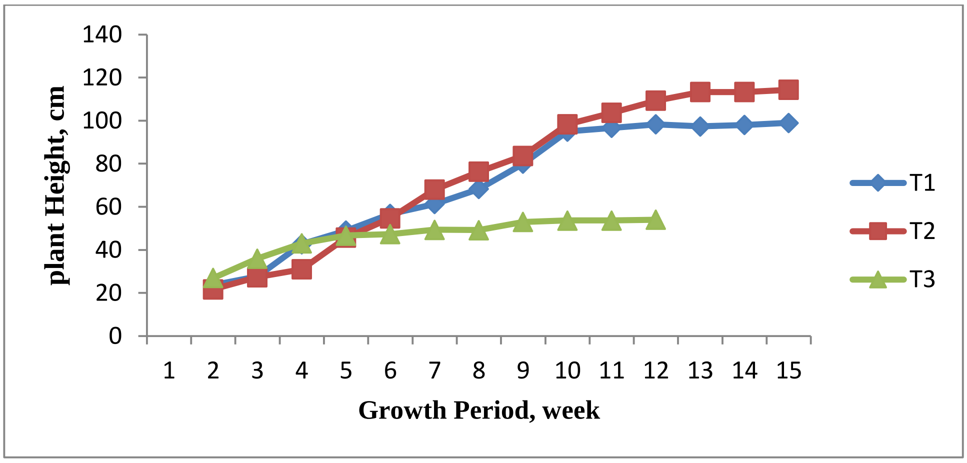

Figure (2): Plant height for potato plants during the growth period plant under different soilless systems.

The statistical analysis showed that there was a significant difference between the average the plant height of potato plant for all treatments. The results also indicate that the average values of plant height were 70.98, 75.76 and 46.62 cm from T1, T2 and T3, respectively. The highest value of the plant height was 75.76 cm found with a treatment of T2, while the lowest value was 46.62 cm found with a treatment of T3.

3.2. Number of leaves

Figure (3) shows the number of leaves of potato plant under different soilless systems (aeroponic and substrate) during the growth period of the plant. The result could be seen that the number of leaves increased from 6.67 to 15.67, 5.0 to 19 and 6.33 to 15 for T1 ,T2 and T3, respectively, after 16 weeks of transplanting . The results show that the number of leaves of plants grown on aeroponic system was higher than of those plants grown on substrate system. In the case of aeroponic system it increased from 6.67 to 15 and from5.0 to 19 cm at the same growth period for T1 and T2. In the case of substrate system it increased from 6.33 to 15 cm after transplanting.

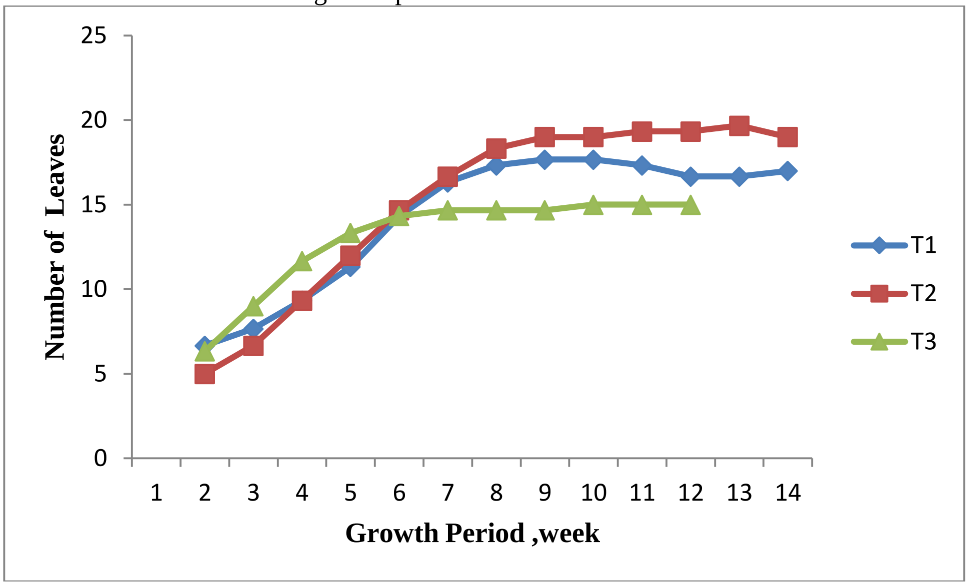

Figure (3): Number of leaves for potato plants during the growth period plant under different soilless systems.

The statistical analysis showed that there was a significant difference between the average numbers of leaves of potato for all treatments. The results also indicate that the average number of leaves was 14.40, 15.50 and 13.06 from T1 ,T2 and T3 respectively. The highest value of number of leaves was 15.50 found with a treatment of T2, while the lowest value of number of leaves was 13.06 found with a treatment of T3**.**

3.3. Stem diameter:

Figure (4) shows the stem diameter of potato plants under different soilless systems during the growth period. The results indicate that the stem diameter of potato increases linearly with the time. It could be seen that the stem diameter increased from 5.95 to 10.55, 6.56 to 11.39 and 5.33 to 7.91 mm for T1, T2 and T3, respectively,

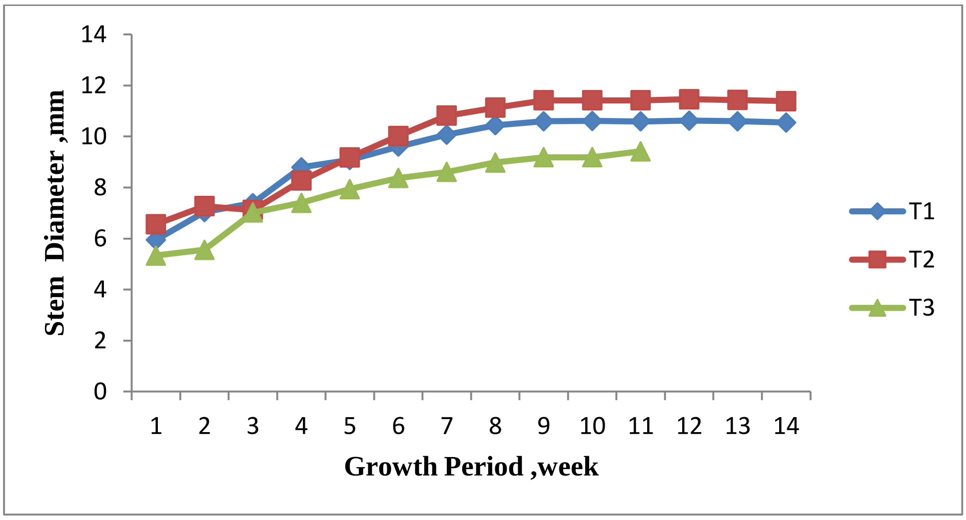

Figure (4): Stem diameter for potato plant during the growth period plant under different soilless systems.

The statistical analysis showed that there was a significant difference between the average the stem diameter of potato for T1, T2 and T3. The results also indicate that the average the stem diameter was 9.42, 9.92 and 7.91 mm for T1, T2 and T3 respectively. The highest value of the stem diameter 11.46 mm was found with a treatment of T2, while the lowest value of the stem diameter 5.33 mm was found with a treatment of T3**.**

3.4. Leaf area:

Figure (5) shows the leaf area of potato plant under different treatments (T1 ,T2 and T3) during the growth period of plant. The results indicate that the leaf area of potato increases linearly with the age. It could be seen that the leaf area increased from 41.33

to 493, 47.67 to 743 and 34.67 to 296 cm^2 for T1, T2 and T3, respectively.

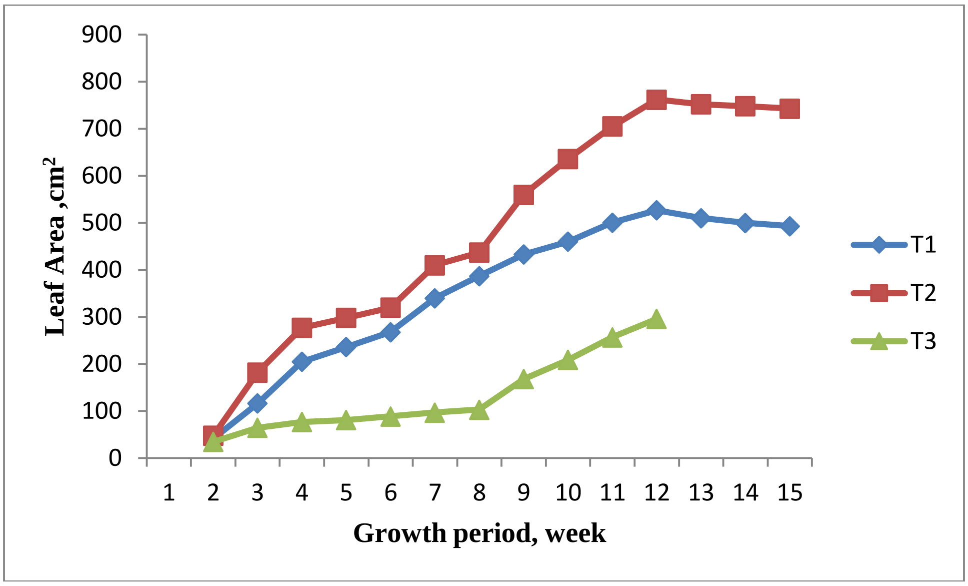

Figure (5): Leaf area of potato plants during the growth period under different soilless systems.

The statistical analysis showed that difference between the average leaf area of potato for all treatments was significant. The results indicate that the average leaf area were 358.40, 491.26 and 134.21 cm^2 for T1, T2and T3, respectively. The highest value of average leaf area 743 cm^2 was achieved with a treatment T2, while the lowest value of average leaf area 296 cm^2 occurred with a treatment (T3).

3.5. Leaf length:

Figure (6) shows the leaf length of potato plant under different treatments (T1 to T3) during the growth period of plant. The results indicate that the leaf length of potato increases linearly with the time. It could be seen that the leaf length increased from 12 to 38.33, 12 to 40.33 and 10 to 25.67 cm for T1 to T3, respectively. We can explain those that the aeroponic system enhance the rates of plants growth by promoting the root aeration because of the root system is grown totally suspended at the air, giving the roots systems access to 100% of the available oxygen at the air **(Buckseth et al., 2016).**

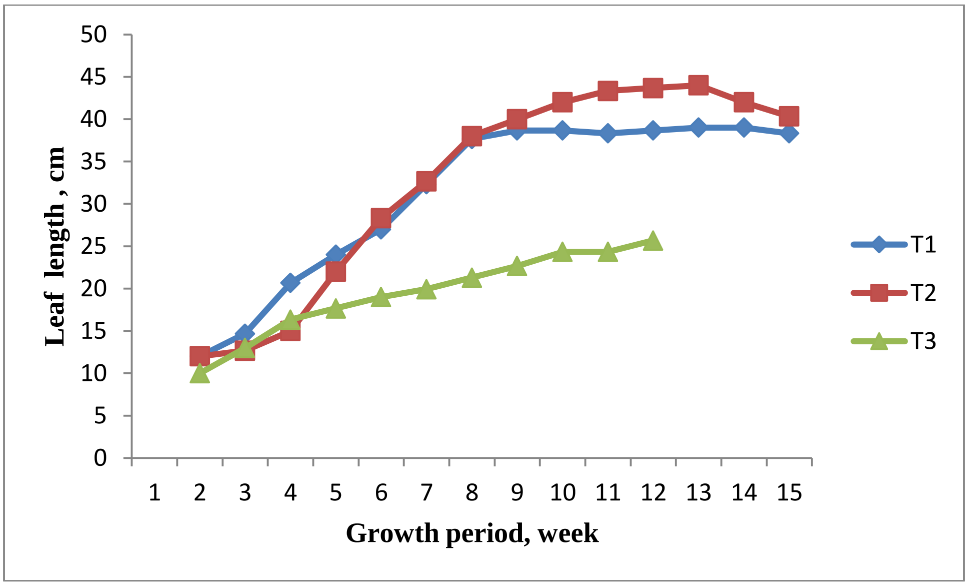

Figure (6): Leaf length of potato plants during the growth period under different soilless systems.

The statistical analysis showed that difference between the average leaf length of potato for all treatments was significant. The results indicate that the average leaf length were 31.36, 32.57 and 19.48 cm for T1 ,T2 and T3, respectively. The highest value of average leaf length (40.33 cm) was achieved with a treatment T2, while the lowest value of average leaf length (19.48 cm) occurred with a treatment (T3).

3.6. Yield of potato plant:

Figure (7) shows the fresh yield of potato under different soilless systems (aeroponic and substrate) at the end of growing period. The results indicate that the total fresh yield values of potato were 1709.78, 2039.12 and 658.37 g plant^{-1} for different treatments. The highest value of total fresh yield (2039.12 g plant-1) was achieved with a treatment T2, while the lowest value of total fresh yield (658.37 g plant^{-1}) was found with a treatment T3. These results agree with those obtained by **Relloso et al. (2000).** Also **Tsoka et al. (2008) and Otazú (2010)** obtained higher yields by aeroponics than using conventional technologies for the production of seed tubers. **Daniels et al. (2000)**, **Otazú and Chuquillanqui (2007),** obtained even up to 60 tubers per plant under aeroponics.

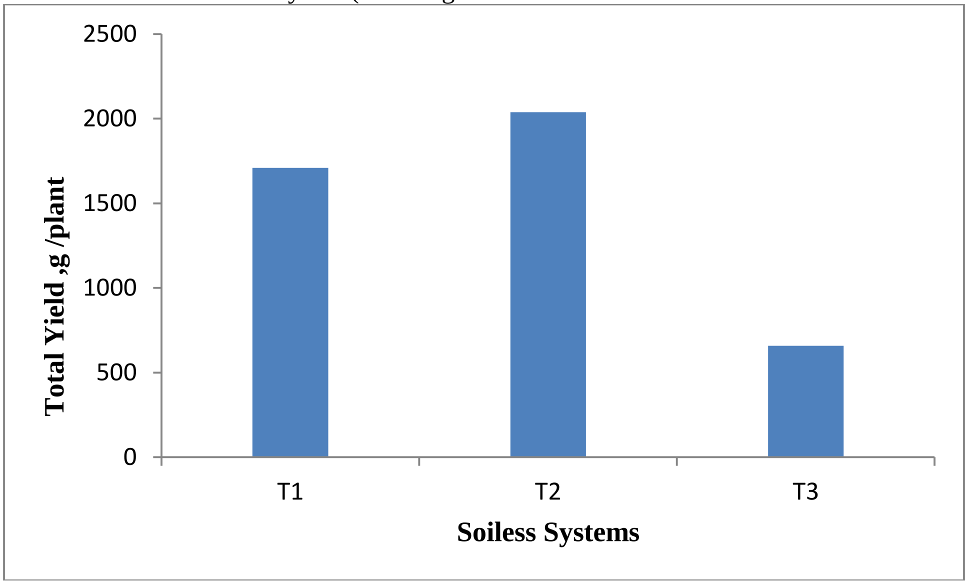

Figure (7): Total yield of potato plants during the growth period under different soilless systems.

Conclusion

The experiment was carried out to study the comparison between the aeroponic and substrate systems for potato production to reduce production costs and increasing the potato yield. The obtained results can be summarized as follows:

The obtained results refer to the highest value of plant height were 114.33 cm for aeroponic system and the number of leaves were 15.50 at aeroponic system. The highest values of stem diameter, number of internode and number of branches were found T2 system. The highest leaf area and leaf length (491.26 cm^2 and 32.57 cm) were found with aeroponic system (T2). The highest value of total fresh yield 2039.12 g plant^{-1} was observed with aeroponic system (T2), while the lowest value of total fresh yield (658.37 g plant^{-1}) was found with substrate system (T3).

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إنتاج البطاطس تحت نظم زراعة بدون تربة مختلفة

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مصر – بنها جامعة – بمشتهر الزراعة كلية – الزراعية الهندسة 3 استاذ

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تشير النتائج .الهدف من هذا البحث دراسة المقارنة بين نظامي الزراعة الهوائية ونظام البيئات لتقيل تكاليف الإنتاج وزيادة محصول البطاطس . ويتراوح طول الجذر من 10.67 إلى 86.67 ومن 3.33 إلى 94.33 المتحصل عليها إلى أن أعلى قيمة لارتفاع النبات كانت 114.33 سم على التوالي. وتشير النتائج الي ان أعلى قيم لقطر الساق وعدد السلميات T3 و T2 و T1سم ومن 5.67 إلى 38.33 سم بالنسبة إلى . وايضا كانت أعلى قيم لمساحة سطح الورقة وطول الورقة (491.26 سم 2 و 32.57 سم) مع نظام الزراعة T2وعددالافرع كانت في المعاملة) ، بينما سجلت أقل قيمة للمحصول الكلي T2). ولوحظت ان أعلى قيمة للمحصول الكلي 2039.12 جرام لكل نبات عند (T2الهوائية ( ).T3(658.37 جم لكل نبات) في نظام الزراعة بالبيئات (