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Effect of Soilless Systems on Nutrients and Water Apply Rate of Potato Plants

Marwa M. Ali[1], Elsayed G. Khater[2] and Samir A. Ali[3]
[1] PhD. Stud., Ag. Eng. Dept., Fac. of Ag. Benha Univ., Egypt.
[2] Assoc.Prof. of Ag. Eng., Fac. of Ag. Benha Univ., Egypt.
[3] Prof. of Ag. Eng., Fac. of Ag. Benha Univ., Egypt.

Abstract

The main aim of this research is to study the effect of different soilless systems (aeroponic and substrate) on nutrients and water apply rate of potato plant to achieve that study, the effect of different soilless systems (aeroponic and substrate) on nutrients and water apply rate during experimental period. Also fresh and dry weight of shoot, roots and tubers were studied at the end of experimental period. The obtained results indicate that the total nitrogen, phosphorus , potassium, calcium, magnesium apply rates were 42.24, 43.53 and 39.24, 18.34, 19.88 and 10.18, 31.69, 32.99 and 33.98, 27.63, 29.35 and 29.35, 24.1, 25.53 and 7.35 mg plant^{-1} for T1,T2 and T3 ,respectively. The water apply were 74.49, 79.48 and 61.90 L plant^{-1} for T1, T2 and T3, respectively. The fresh and dry weight of shoot and roots were increased in aeroponic system better than those of substrate system. The fresh and dry weights of tubers were 294.46, 44.56, 255.15, 42.15 and 227.3, 40.3 g plant^{-1} for T1, T2 and T3 respectively. The average water use efficiency were 22.95, 25.65 and 10.63 Kg m^{-3} for T1, T2and T3, respectively**.**

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

Introduction

Potato (*Solanum tuberosum L.)* is the third most important crop after rice and wheat **(Hancock et al., 2013**). It is grown under broad geographical distributions and climatic conditions **(Schafleitner et al., 2011).** In Egypt potato is a major export crop. The total cultivated area was 176670 hectare and actual production 4896476 ton. Since potato is highly valued as a source of complex carbohydrates and vitamins with an added value of low fat content, it is being considered as a solution to meet the increasing food demand around the world **(Corrêa et al., 2009; Schafleitner et al., 2011).** One of the major cost factors of potato culture is the use of high quality disease free seed tubers. Those account for up to 40–50 % of the crop production cost depending on the production system and region **(Kyamanywa et al., 2011).**Potato tuberization is a distinctive developmental process controlled by many factors; genotypes determine tuber size, number and yield potential, while yield performance is influenced by the physiological status of the seed tuber **(Wang, 2008).** Soilless culture is a technique for crop production using no soil. In this method, crops are grown in the nutrient solution or on a proper medium where crops are planted and nutrient solution is applied (**Ikeda, 2014**)**.** 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. Aeroponics is a soilless method for producing pre basic potato seed ,this 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 **(Otazu, 2010**).

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 **(Otazu, 2010)**.

Each crop has an optimum nutritional requirement. Each potato cultivar may require a different nutrient solution. This also depends on the water chemical quality and the nutrients used for nutrient solution preparation. When we add nutrients to water, the EC goes up. In general we should have an EC not higher than 2.0 MiliSiemens per cm

(mS/cm) if we want to avoid phytotoxicity problems. In hydroponics and aeroponics, sources of nutrients are common fertilizers that can be found on the market. These elements should be dissolved in water so that plants can absorb them through their root system. Aeroponics system also allows the measurement of nutrient uptake over time under varying conditions. 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**).

Little information exists on potato production in aeroponic system and due to gradually increasing of production cost, it is required to maximize the utilization of available resources, therefore, the main aim of this work is to study the effect of different soilless systems (aeroponic and substrate) on nutrients and water apply rate of potato plant.

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 October2019 to March 2020 season.

1. Materials:

1.1. System Description:

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

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. 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)**.

Methods

Treatment:

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

Experiment measurements:

The water samples were taken at inlet and outlet of the culture units for measuring nitrogen, phosphorus, potassium, calcium, magnesium were measured every week during the experimental period . Total content of macro elements were evaluated after being digested according to **Chapman and Partt (1961).** Nitrogen was determined by Kjeldahl digestion apparatus **(Bremmer and Mulvaney, 1982)**. Potassium, Calcium and magnesium were determined by Photofatometer (Model Jenway PFP7 – Range 0 - 160 mmol L^{-1}, USA) and phosphorus (P) was determined colorimetrically following the **Murphy and Riley (1962)** method. The fresh and dry mass of shoot, roots and tubers were measured at the end of the experiment. After measured fresh mass, the plants were oven dried at 70 ºC until constant weight was reached.

Calculations

Water use efficiency (WUE) was determined by the following formula **(Djidonou *et al.*, 2013)**:

$$WUE = \frac{CY}{CWU} \quad (1)$$

Where:-

CY is the crop yield, kg $plant^{-1}$

CWU is the crop water uptake, m^3 plant

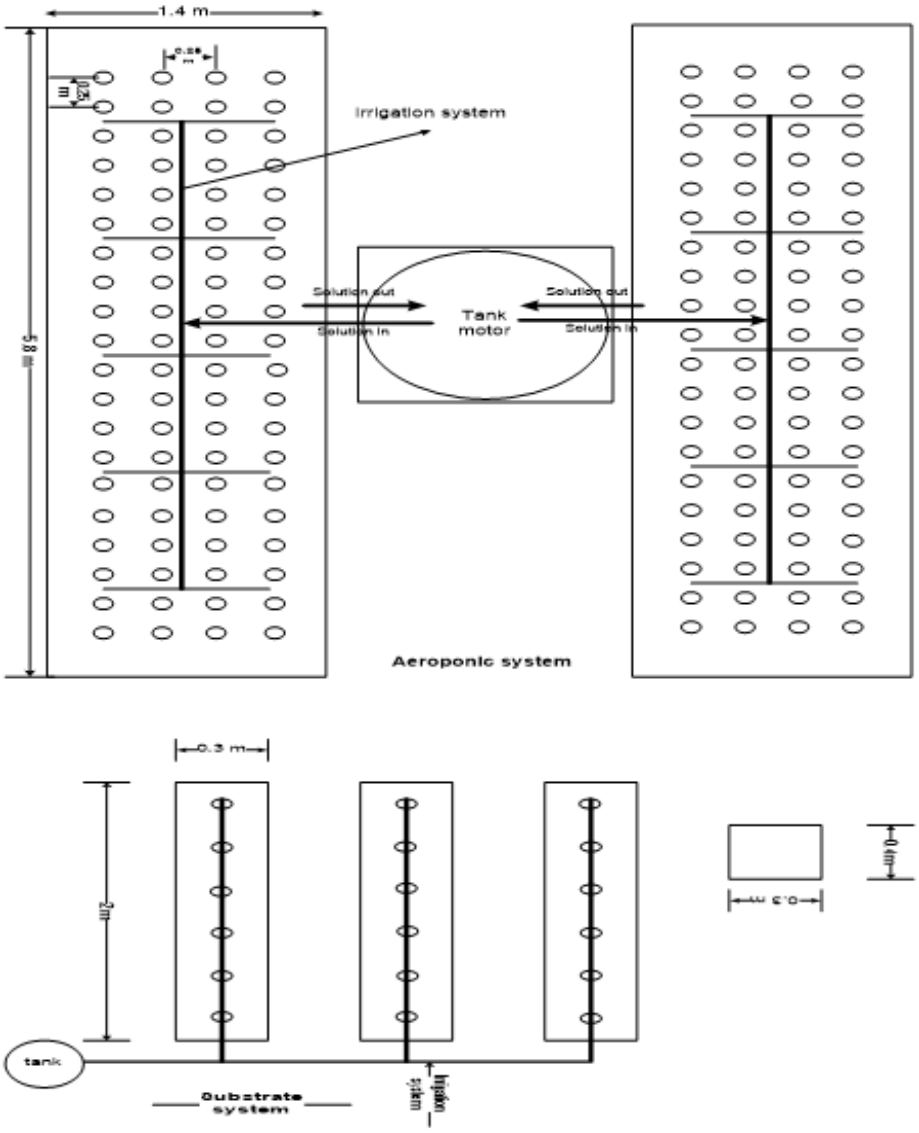

Figure (1): The experimental setup

Results and Discussion

3.1. Nutrients apply rate:

3.1.1. Total nitrogen apply rate:

Figure (2) shows the effect of different soilless systems (aeroponic and substrate) on the nitrogen (N) apply rate from potato plants during the growth period. The results indicate that the nitrogen apply rate was increased in substrate system (T3) over those of aeroponic system (T1 and T2). It result show that the nitrogen apply rate ranged from 19.83 to 43.17 mg plant^{-1} in substrate system after 13 weeks for substrate system. Meanwhile, it ranged from 0.34 to 5.03 mg plant^{-1} after 16 weeks from transplanting for T1 and T2, respectively.

The statistical analysis showed that there was a significant difference between the average nitrogen apply rate of potato plants for all treatments. The results also indicate that the average nitrogen apply rate was 2.64, 2.72 and 40.24 mg plant^{-1} for T1, T2 and T3, respectively. The highest value of nitrogen apply rate 40.24 mg plant^{-1} was found with a treatment of T3, while the lowest value of Nitrogen apply rate2.64 mg plant^{-1} was found with a treatment of T1.

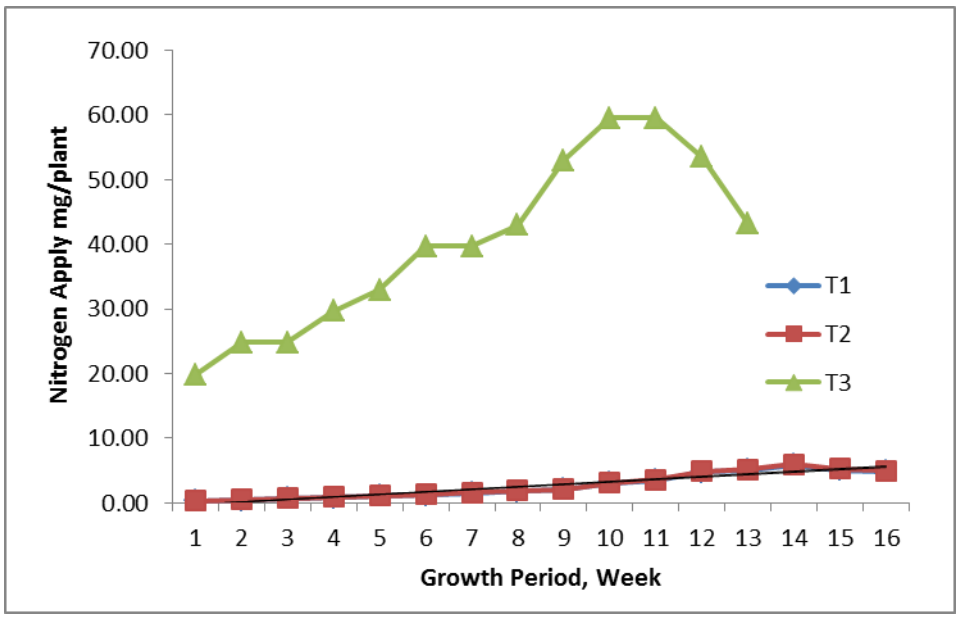

Figure (2): Nitrogen apply rate for potato plants grown in soilless systems.

3.1.2. Total Phosphorus apply rate:

Figure (3) shows the phosphorus apply rate by potato plants during the growth period in different soilless systems (aeroponic and substrate) on. The results indicate that the phosphorus apply rate was increased in both systems under study, with increasing the growth period. The results indicate that the phosphorus apply rate was increased in T1,T2 over those of T3. In the case of substrate system, phosphorus apply rate was 5.17 and 13.67 mg plant^{-1} .In the case aeroponic system it was 0.19and 1.60 mg plant^{-1} .

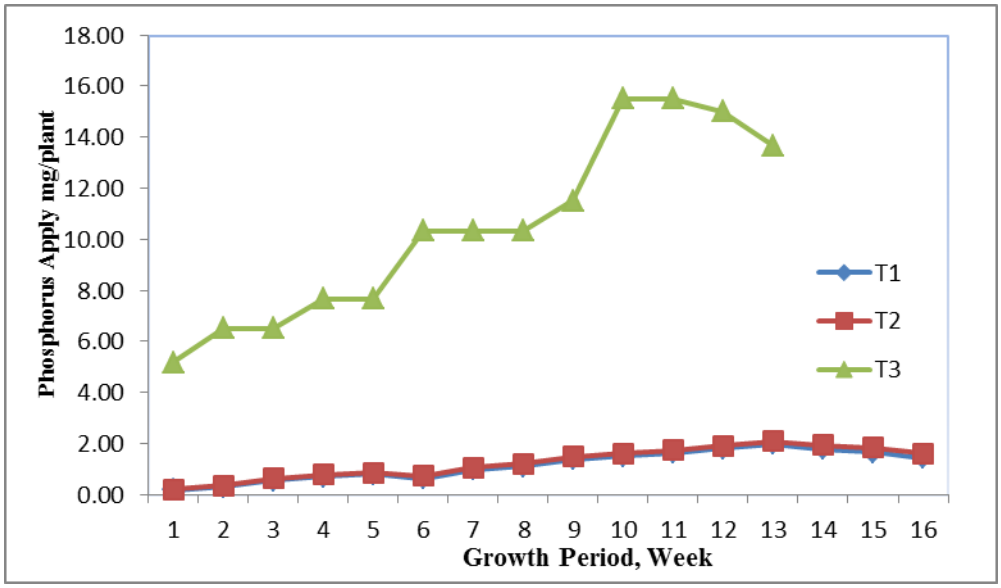

Figure (3): Phosphorus apply rate by potato plants grown under different soilless systems.

The statistical analysis showed that there was a significant difference between the average phosphorus apply rate of potato for all treatments. The results also indicate that the average phosphorus apply rate was 1.15, 1.24 and 10.44 mg plant^{-1} for T1, T2 and T3, respectively. The highest value of phosphorus apply rate was found with a treatment of T3, while the lowest value of phosphorus apply rate was found with a treatment of T1. These results agreed with those obtained by **Genuncio *et al.* (2012)**,

3.1.3. Potassium apply rate:

Figure (4) shows the potassium apply rate by potato plants under different soilless systems during the experimental period. The results indicate that the

potassium apply rate was increased in both systems under study, with increasing the growth period. The results indicate that the potassium apply rate was increased in T3 over those of T1, T2. In the case of aeroponic system, potassium apply rate was 0.25 and 3.78 mg plant^{-1}.In the case substrate system it was 19.33 and 51 mg plant^{-1}.

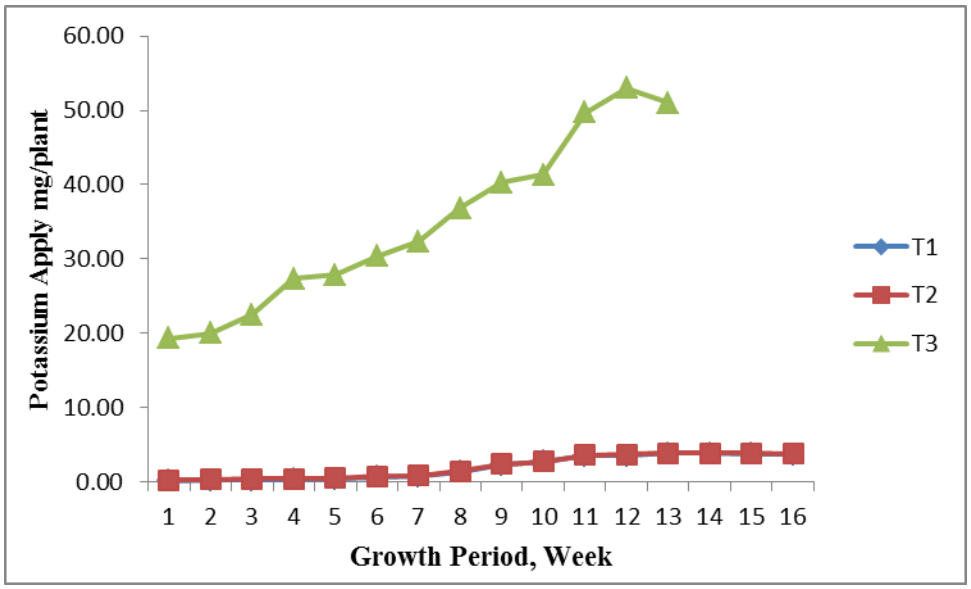

Figure (4): Potassium apply rate by potato plants grown under different soilless systems.

The statistical analysis showed that there was a significant difference between the average potassium apply rate of potato for all treatments. The results also indicate that the average potassium apply rate was 1.98, 2.06 and 34.76 mg plant^{-1} for T1,T2 and T3, respectively. The highest value of potassium apply rate was 34.76 mg plant^{-1} found with a treatment of T3, while the lowest value of potassium apply rate was 1.98 mg plant^{-1} found with a treatment of T1.

3.1.4. Calcium apply rate:

Figure (5) shows the calcium apply rate by potato plants under different soilless systems during the growth period. The results indicate that the calcium apply rate was increased in both systems under study, with increasing the growth period. In the case of aeroponic system T1and T2, calcium apply rate was 0.2 and 2.8 mg plant^{-1}.In the case substrate system (T3) it 16.7and 39.2 mg plant^{-1}.

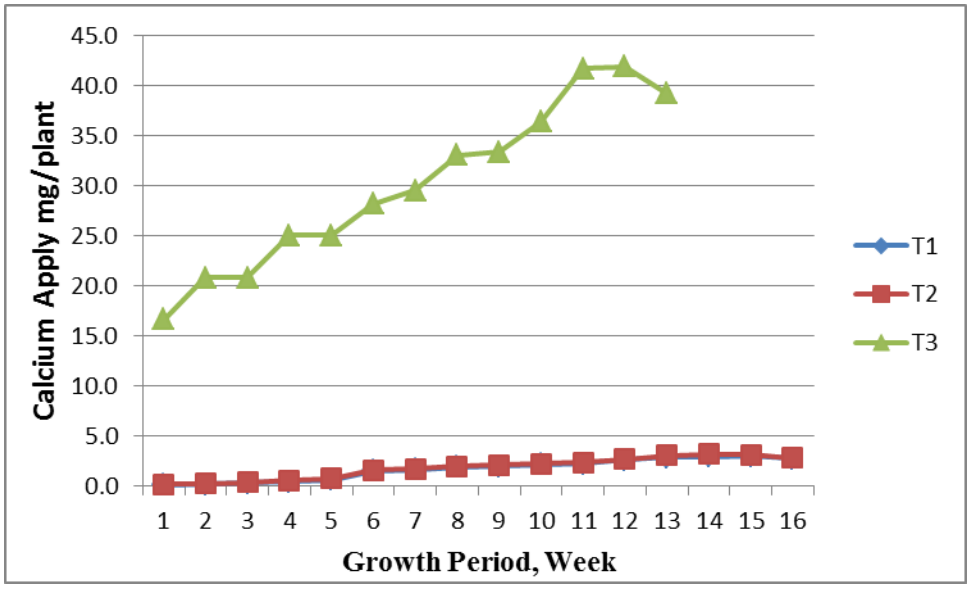

Figure (5): Calcium apply rate by potato plants grown under different soilless systems.

The statistical analysis showed that there was a significant difference between the average calcium apply rate of potato for all treatments. The results also indicate that the average calcium apply

rate was 1.7, 1.8 and 30.1 mg plant^{-1} for T1 ,T2 and T3, respectively. The highest value of Calcium apply rate 39.2 mg plant^{-1} was found with a treatment of T3, while the lowest value of calcium apply rate1.7 was found with a treatment of T1.

3.1.5. Magnesium apply rate:

Figure (6) shows the magnesium apply rate by potato plants during the growth period under different soilless systems. The results indicate that the magnesium apply rate was increased in both systems under study, with increasing the growth period. In the case of aeroponic system T1and T2, magnesium apply rate was 0.3 and 1.9 mg plant^{-1} .In the case substrate system(T3) it was 4 and 14 mg plant^{-1} . .

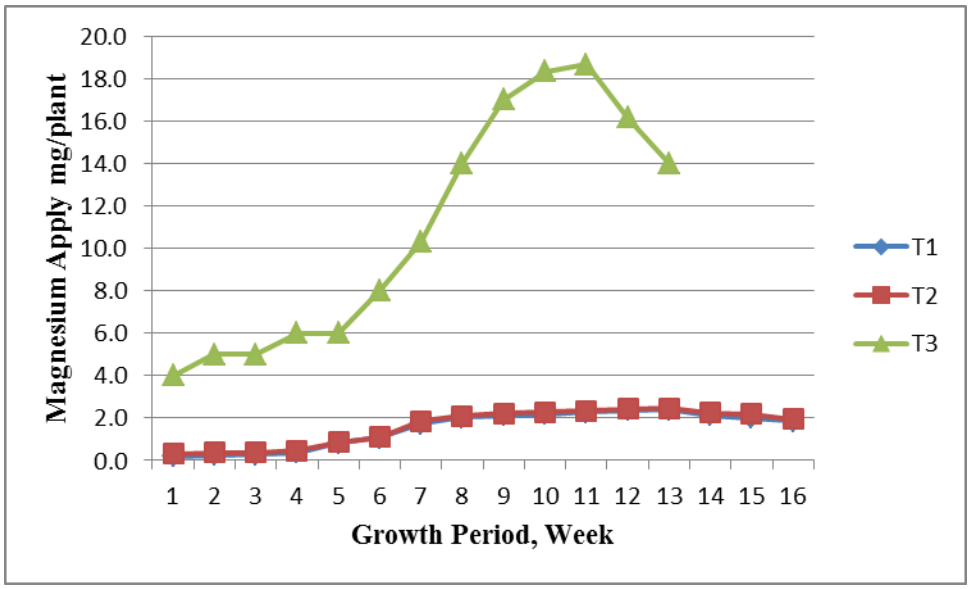

Figure (6): Magnesium apply rate by potato plants grown under different soilless systems.

The statistical analysis showed that there was a significant difference between the average magnesium apply rate of potato for all treatments. The results also indicate that the average magnesium apply rate was 1.5, 1.6 and 11 mg plant^{-1} from T1 to T3, respectively. The highest value of magnesium apply rate was 11 mg plant^{-1} found with a treatment of T3, while the lowest value of magnesium apply rate was 1.5 mg plant^{-1} found with a treatment of T1.

3.2. Water apply:

Figure (7) shows the water apply rate of potato plant grows in aeroponic and substrate systems during the growth period. The results indicate that the average water apply for T1 and T2 were 4.66 and 4.96 L plant^{-1}, respectively, during the experimental period, while it was 4.67 L plant^{-1} for T3 during the growth period.

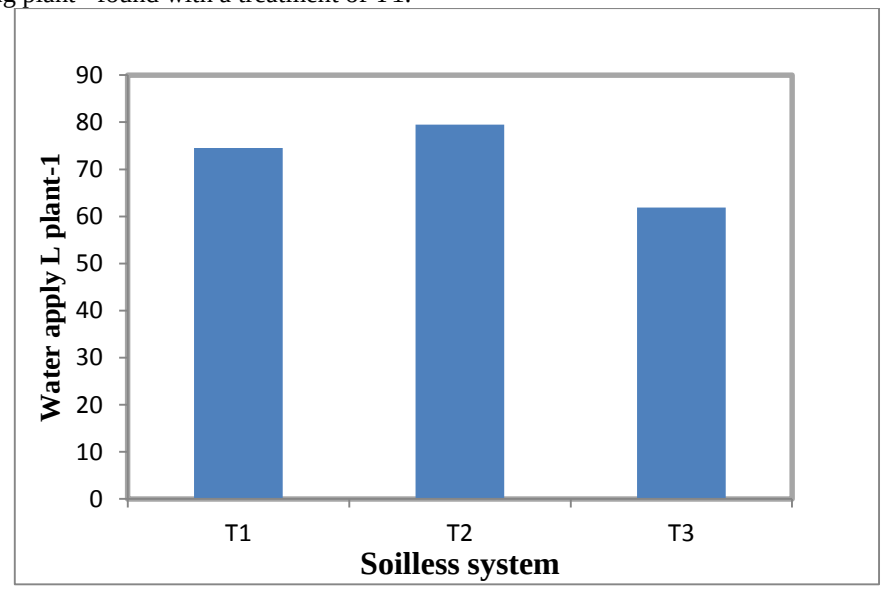

Figure (7): The water apply rate of potato plant grows in soilless systems.

3.3. Water use efficiency :

Figure (8) shows the water use efficiency for potato plants grown under different soilless systems (aeroponic systems and substrate) at the end of growing period. The results indicate that the water use efficiency was increased in aerooponic system over those of substrate system. It could be seen that the average water use efficiency were 22.95, 25.65 and 10.63 Kg m-3 for T1, T2and T3, respectively.

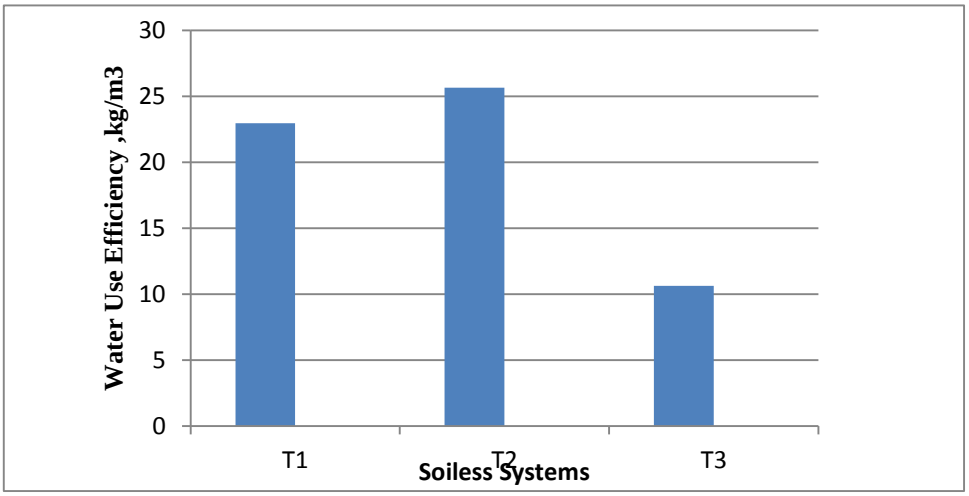

Figure (8): The water use efficiency for potato plants grown under different soilless systems.

3.4. Fresh and dry mass:

3.4.1. Fresh and dry mass of shoot:

Figure (9) shows the fresh and dry mass of shoot of potato plants grown in different treatment T1, T2 and T3 at the end of experimental period. The results indicate that the fresh and dry mass of shoot of plants grown on T1 and T2 system were higher than those of plants grown on T3. It could be observed that the highest values of the fresh and dry mass of shoot (604.83 and 77.85 g plant^{-1}) were found with the aeroponic system T2 whereas, the lowest values of the fresh and dry mass 89.97 and 15.68 g plant^{-1} were found with the substrate system (T3). These results agreed with those obtained by **Martin-Laurent et al. (1997)** whose found that the Plants grown aeroponically were twice as high as those in hydroponics and 4 times taller than those grown in sand. These previous results may be due that the root of aeroponics system s are hanged in mid-air inside containers or chambers at 100% humidity and fed up a fine mist of nutrient solutions. This previous system simulates absorption of roots to much needed oxygen and nutrients. Those increasing metabolism and rate growth comparted with soil (**Lakkireddy et al., 2012**). The results also indicate that the fresh and dry mass of shoot were 226.12, 604.83 and 89.97 g plant^{-1} and 30.67, 77.85 and 17.515.68 g plant^{-1} for T1, T2 and T3, respectively.

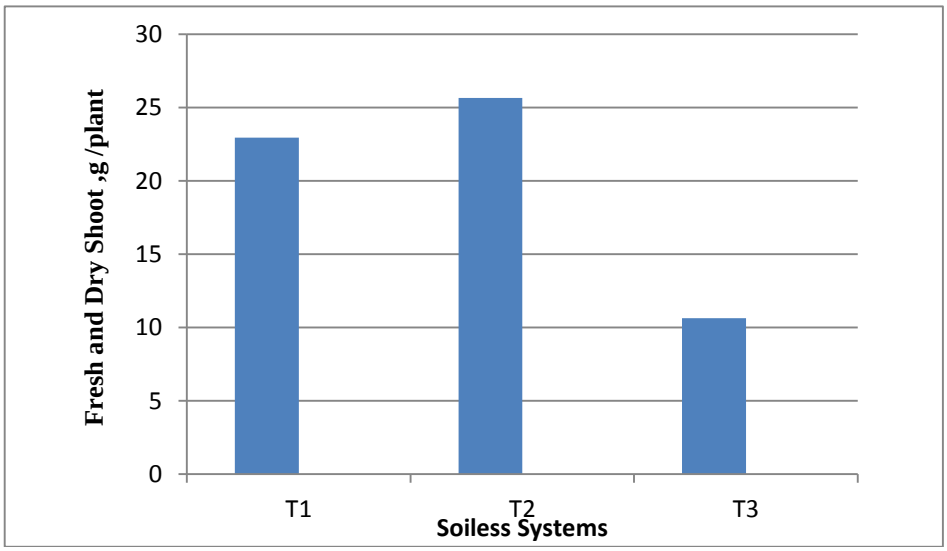

Figure (9): Fresh and dry mass of shoot of potato plants at the end of growing period

3.4.2. Fresh and dry mass of root:

Figure (10) shows the fresh and dry mass of root of potato plants grown in different treatment T1,T2 and T3 at the end of experimental period. The results indicate that the fresh and dry mass of shoot of plants grown on (T1,T2) system were higher than those of plants grown on T1. It could be observed that the highest values of fresh and dry mass of root (320.09 and 16 .94 g plant^{-1}) were found with the aeroponic system T2whereas, the lowest values of fresh and dry mass (21.46 and 2.77 g plant^{-1}) were found with the substrate system (T3). These results agreed with those obtained by **Martin-Laurent *et al.* (1997)** whose found that the Plants grown aeroponically were twice as high as those in hydroponics.

The results also indicate that the fresh and dry mass of root were 141.55, 320.09 and 21.46 g plant-1 and 19.53, 16.94 and 2.77 g plant^{-1} for T1, T2 and T3, respectively.

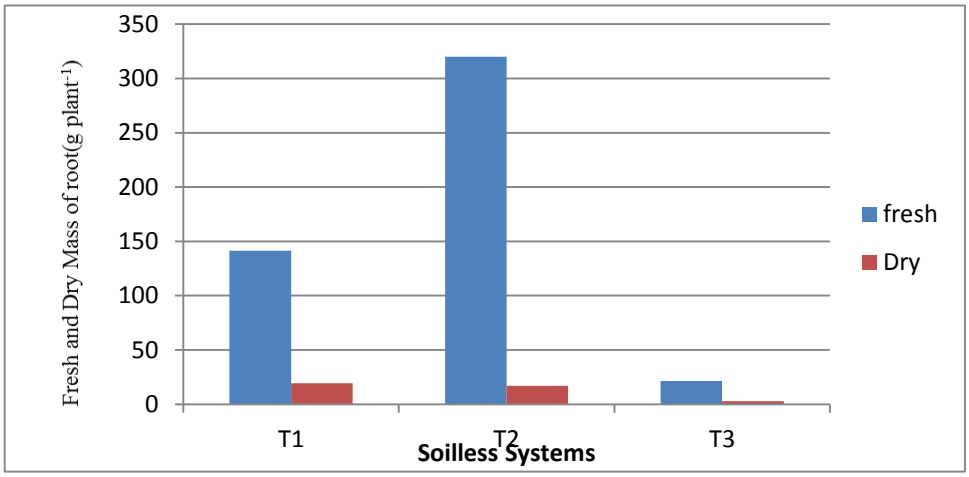

Figure (10): Fresh and dry mass of root production of potato plants at the end of growth period.

3.4.3. Fresh and dry mass of tubers:

Figure (11) shows the fresh and dry mass of potato tubers of potato plants grown in different treatment T1,T2 and T3 at the end of experimental period. The results could be observed that the highest values of fresh and dry mass of potato tubers (294.46 and 44.56 g plant-^{1})) were found with T1, whereas, the lowest values of fresh and dry mass (227.3 and 40.5 g plant^{-1} were found with (T3).

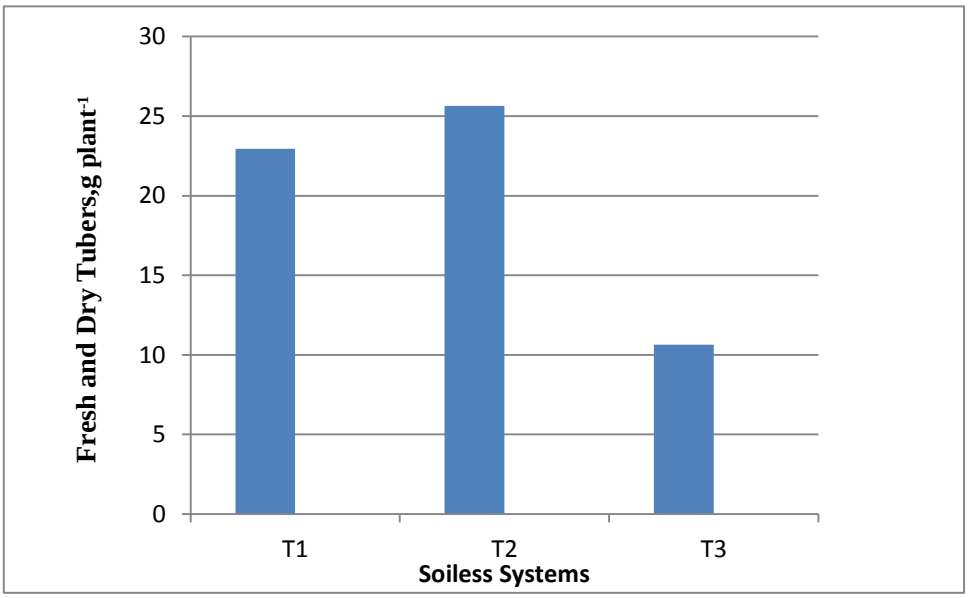

Figure (11): Fresh and dry mass of tubers production of potato plants at the end of growing period.

Conclusion

The experiment was carried out to study was conducted to investigate the effect of different soilless systems (aeroponic and substrate) on nutrients and water apply rate of potato plants. The nutrients and water apply, fresh and dry weight of

shoot, root and tubers and water use efficiency were studied. The obtained results can be summarized as follows:

- The highest value of nitrogen apply rate 40.24 mg plant-1 was found with a treatment of T3, while the lowest value of Nitrogen apply rate2.64 mg plant^{-1} was found with a treatment of T1.
- The highest value of Phosphorus apply rate was 34.76 mg plant-1 found with a treatment of T3, while the lowest value of Phosphorus apply rate was 1.98 mg plant-1 found with a treatment of T1.
- The highest value of potassium apply rate was 34.76 mg plant^{-1} found with a treatment of T3, while the lowest value of potassium apply rate was 1.98 mg plant^{-1} found with a treatment of T1.
- The highest value of Calcium apply rate 39.2 mg plant^{-1} was found with a treatment of T3, while the lowest value of calcium apply rate1.7 was found with a treatment of T1.
- The highest value of magnesium apply rate was 11 mg plant^{-1} found with a treatment of T3, while the lowest value of magnesium apply rate was 1.5 mg plant^{-1} found with a treatment of T1.
- The water apply rate of potato plant grows in aeroponic was higher than substrate.
- The water use efficiency was increased in aerooponic system over those of substrate system
- The highest values of fresh and dry mass of shoot were 640.83 and 77.85 g plant-^{1} were found with aeroponic system, while, the lowest values of fresh and dry mass were 89.97 and 15.68 g plant^{-1} were found with substrate system.
- The highest values of fresh and dry mass of root were 320.09 and 16.94 g plant^{-1} were found with aeroponic system, while, the lowest values of fresh and dry mass of root were 21.46 and 2.77 g plant^{-1} were found with substrate system.
- The highest values of fresh and dry mass of potato tubers (294.46 and 44.56 g plant-^{1})) were found with T1, whereas, the lowest values of fresh and dry mass (227.3 and 40.5 g plant^{-1} were found with (T3).

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تاثير نظم الزراعة بدون تربة علي معدل اضافة المغذيات و المياه لنباتات البطاطس

مروه مصطفي علي[1] ، السيد جمعه خاطر[2]، سمير احمد على[3]

1 طالب دكتوراة – قسم الهندسة الزراعية – كلية الزراعة بمشتهر – جامعة بنها – مصر.

2 استاذ الهندسة الزراعية المساعد – كلية الزراعة بمشتهر – جامعة بنها – مصر.

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

الهدف الرئيسي من هذا البحث هو دراسة تأثير أنظمة الزراعة بدون تربة المختلفة (الهوائية والبيئات) على معدل استهلاك المغذيات ومعدل استهلاك المياه لنبات. كما تم دراسة الوزن الرطب والجاف للساق والجذور والدرنات في نهاية فترة التجربة. تشير النتائج المتحصل عليها إلى أن إجمالي معدلات استهلاك النيتروجين والفوسفور والبوتاسيوم والكالسيوم والمغنيسيوم كانت 42.24و 43.53 و39.24و 18.34 و19.88و 10.18 و31.69 و32.99 و33.98و27.63 و29.35و29.35و24.1 و25.53 و7.35 مجم /نبات في المعاملات المختلفه T1 و T2 و T3 على التوالي. كان استهلاك المياه 74.49 و 79.48 و 61.90 لترًا لكل نبات في T1 و T2 و T3 على التوالي. تمت زيادة الوزن الطازج والجاف للساق والجذور في النظام الهوائي وكانت أفضل من تلك الموجودة في نظام البيئات. كان الوزن الرطب والجاف للدرنات 294.46 و 44.56 و 255.15 و42.15 و 227.3 و 40.5 جم لكل نبات في T1 و T2 و T3 على التوالي. كان متوسط كفاءة استخدام المياه 22.95 و25,65 و10,63 كجم لكل متر مكعب في T1 و T2 و T3 على التوالي .