Effects Of Different Cultivation Media On Vegetative Growth, Ecophysiological Traits And Nutrients Concentration...

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Effects Of Different Cultivation Media On Vegetative Growth, Ecophysiological Traits And Nutrients Concentration In Strawberry Under Hydroponic And Aquaponic Cultivation Systems

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Hamid R. Roosta and [2]Simin Afsharipoor: Effects Of Different Cultivation Media On Vegetative Growth, Ecophysiological Traits And Nutrients Concentration In Strawberry Under Hydroponic And Aquaponic Cultivation Systems

ABSTRACT

Aquaponics is the science of integrating the production of fish and plants in a symbiotic environment in which fish waste is used as fertilizer. The characteristics of the materials used as substrate in soilless culture systems, directly and indirectly affect the plant growth and production. Therefore, in order to study the effect of different substrates (various ratios of perlite and cocopeat) on growth and development of strawberry in hydroponic and aquaponic cultivation systems, a greenhouse experiment was conducted as factorial experiment based on a completely randomized design with three replications. The results of statistical analysis revealed that dry weight (leaf, crown and root), the number of runners, leaf area, SPAD index for old leaves, F_v/F_m, the concentrations of N, K, P, Fe and Mg in leaves and the yield was significantly higher in hydroponic than in aquaponic (except for the substrate of sole perlite). The concentrations of Ca, Zn (except for the substrate of sole cocopeat) and Mn (except for the substrates of sole perlite or cocopeat) in leaves and SPAD index of young leaves were higher in aquaponic than in hydroponic. The remaining measured traits were not affected by the culture system. In hydroponic system, the substrates of sole perlite or cocopeat were not recognized as optimum substrates; therefore, it is recommended to use their mixture as substrate, while in aquaponic system, the substrates with higher percentage of perlite had better performance and are recommended for strawberry cultivation.

Key words: aquaponics, substrate, strawberry, soilless culture

Introduction

Strawberry (*Fragaria* sp.) is a crop which is normally propagated in greenhouse in Iran. Therefore, new methods for increasing its yield and quality can contribute to improve the efficiency of greenhouses involved in its production. Soilless culture is a new method for the cultivation of the plants in Iran. The growers do tend to increasingly use soilless culture given its advantages such as the control of plants nourishment, the chance of increasing plant density, the decrease in the occurrence of the diseases and pests, and the quantitative and qualitative enhancement of yield compared with soil culture [38]. This new method uses organic and mineral substrates for the cultivation of the crops. The attributes of different substrates used as the planting bed directly and indirectly affect the growth and production of the crops [40]. In a study on the yield of soil-grown and perlite-grown strawberry cv. Camarosa plants, it was shown that the perlite-grown strawberries had the highest yield in January and February which assured economical return since early-maturing fruits have higher prices. Also, the plants produced fewer runners in perlite than in soil [15]. In a study, the yield and quality of strawberry plants were investigated on substrates composed of different ratios of perlite and zeolite and it was revealed that perlite: zeolite ratios of 1:1 and 3:1 were the most optimum substrates [7]. Inden and Torres (2004) compared the substrates of rockwool, perlite plus carbonized rice hull, cypress bark and coconut coir and reported that the highest tomato yield was obtained on perlite plus carbonized rice hull substrate [16]. Lee *et al*. (1999) reported perlite as well as perlite plus carbonized rice hull as the best substrates for hydroponic cultivation of cucumber among the substrates of perlite, perlite plus rice hull, perlite plus carbonized rice hull

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and sole rice hull [20]. In an experiment for determining the appropriate amount of fish sewage as N source for *Panicum maximum* in Virgin Islands, the U.S. in 1995, the waste of aquaculture was revealed to be able to supply the required water and organic nitrogen for the production of forage in dry seasons [39]. An aquaponics system was constructed in Alberta, Canada which included four rearing tanks and four raft hydroponics tanks. This system resulted in higher yields of tomato and cucumber than their mean yields in conventional hydroponics system [36].

Thus, this experiment was conducted to determine the production capacity of different ratios of perlite: cocopeat in the aquaponic and hydroponic systems. The alterations in growth, eco-physiological characteristics and mineral nutrient content of strawberry plants in different ratios of perlite: cocopeat in two systems were determined as changes observed in root, crown and leaf dry mass, runner number, leaf area, fruit number, yield, SPAD index (chlorophyll content), maximal quantum yield of PS II photochemistry (Fv/Fm), and leaf minerals (N, K, P, Ca, Mg, Fe, Mn, and Zn) content.

Materials and Methods

The study was carried out in hydroponic greenhouse of Agriculture Department, Valiasr University of Rafsanjan, Iran in autumn of 2009. The disinfected plastofoam pots were filled with different ratios of perlite: cocopeat (sole perlite, 75% perlite + 25% cocopeat, 50% perlite + 50% cocopeat, 25% perlite + 75% cocopeat, and sole cocopeat). Three transplants were planted in each pot and three pots of each substrate were irrigated with hydroponic solution (1/2 concentration of Hoagland solution) and three others were irrigated with aquaponic solution (obtained from raft tanks). The pots were manually irrigated with the amount of 300 mL solution three times a day.

Aquaponics system:

Aquaponic system (Fig. 1) was constructed from a fish tank with the volume of 850 liters which consisted of 20 fish of carp, grass carp and silver carp type, each about 300 gr. These special types of fish were selected because carp is very resistant to temperature variations (especially high temperatures) and environment. Their temperature need was 20-30°C. Considering the available water temperature, these warm-water fish species were stocked. The water of fish tank was supplied by tap water with the adjusted temperature of 24°C. The tank was made of galvanized metal and painted by pool-specific paint. An aquarium heater was mounted inside the tank and the tank was covered by a cloth net hatch to prevent fish from jumping out of water. The sewage of the tank consisted of fish waste and uneaten feed. If this sewage enters hydroponic system, it will cover the roots, create an anaerobic environment and interrupt the absorption of the elements which are carried out by active transportation and using oxygen. Therefore, they should be eliminated before entering into hydroponic system. A water pump was mounted under the tank to pump the water to clarifier. The capacity of conical-shaped clarifier was 60 l. The sewage was pumped to clarifier from the upper side and the solid materials deposited to the sides of cone at the bottom of cylinder. These materials were eliminated by opening the water valve once a day which was connected to the tip of the cone. By sole application of only clarifier, much of floating and undeposited solid materials would enter the hydroponic medium. So another system was needed to separate undeposited and fine materials. A 30-litre filtration tank was mounted after clarifier inside which there was a plastic net with fine meshes. Therefore, water entered the filtration system due to the gravity and fine particles which had not been separated in the clarifier removed from water. This net was washed with high-pressure water twice a week. Then, the water entered a 30-litre degassing system to remove the harmful gasses which might have been produced during filtration. Afterwards, it entered a 300-litre hydroponic tank and after the absorption of the required nutrition by plants, the water was passed to the fish tank from the hydroponic bed. The floated hydroponic tank was 20 cm in depth, 200 cm in length and 75 cm in width and was covered by a plastofoam plate with the diameter of 4 cm. Nitrification process is carried out by bacteria nitrosomonas and nitrobacter which is normally created in the system and transforms fish tank water ammonia to nitrite and then, to nitrate. The conformity of nitrification and nutrient availability in aquaponic system is acquired at pH=7. As well, because when water is saturated by soluble oxygen, nitrification has the highest efficiency, several air diffuser were used in tank. Fish were fed three times a day with 20 g fish food containing 46% protein. Given the limiting effect of water temperature on the growth of the fish, it was measured by thermometer. In order to measure leaf, crown and root dry weight, they were put in an oven for 72 hours at 70°C. Then, they were weighed by digital scale. Leaf area was determined by leaf area meter (CI 202). Chlorophyll was measured by SPAD-502 and florescence chlorophyll was specified by chlorophyll fluorimeter (Pocket PEA). The concentration of N in leaves was measured by Kjeldahl method, P concentration by spectrophotometer, K by flame photometer, and Mg, Fe, Zn, Mn and Ca concentrations by atomic absorption method.

The level of chlorophyll in the youngest and the oldest expanded leaves was recorded by taking SPAD (chlorophyll content) readings with a SPAD-502 Chlorophyll Meter (Minolta Camera Co. Ltd., Japan).

Chlorophyll fluorescence parameter (Fv/Fm) was measured with a portable handy Plant Efficiency Analyzer (PEA, Hansatech Instruments Ltd., UK). Three leaves were selected from each pot and pre-adapted to dark period for 20 min by fixing special tags on each leaf blade before measurements were taken. During dark adaptation, all the reaction centers are fully oxidized and available for photochemistry and any fluorescence yield is quenched. After 20 min of dark adaptation, the sensor cup was fitted on the leaf for measurement.

At the end of the experiment the leaf area for each treatment were recorded. Leaf area was measured by leaf area meter (Delta-T. Devices LTD). Then plant organs (leaves, crown and roots) were harvested, weighed and oven-dried at 72 °C for 48 hrs to determine dry mass. After drying, plant material was ground in a coffee grinder (Mr. Coffee, Hattiesburg, MS) for approximately 60 s. Approximately 1 g of grounded-dry plant material placed into a muffle furnace for at least 16 h at 500 °C following AOAC Method 900.02 (AOAC, 1990). Minerals (K, Ca, Mg, Fe, Mn, and Zn) content were determined as described by Perkin-Elmer Corporation (1976) on a 2380 Atomic Absorption Spectrophotometer (Norwalk, CT). The concentration of N in leaves was measured by Kjeldahl method. P concentration was determined by spectrophotometer. The dry ash was allowed to dry for 5 h, in accordance with AOAC Method 900.02 (AOAC, 1990). After the sample was dissolved using 15 mL of 20% HNO_3, the solution was filtered through Whatman 40 grade ashless filter paper (Clifton, NJ) and diluted to a total volume of 100 mL with distilled water; duplicate samples were prepared when possible. One mL of each sample was placed into one of two separate tubes and 10 mL of distilled water was added. To one set of the tubes, 0.5 mL of 5% $LaCl_2$ was added as releasing agent. This tube was used for element quantification.

Analysis of data:

Analysis of variance (ANOVA) was performed using the SAS program. If ANOVA determined that the effects of the treatments were significant (p<0.05 for F-test), then the treatment means were separated by Duncan's Multiple Range Test.

Results:

The results of the analysis of variance showed that hydroponic treatment resulted in significantly higher leaf, crown and root dry weight than aquaponic treatment. In hydroponic system, the higher ratios of cocopeat gave the highest leaf and root dry weight and the substrates of 25% perlite + 75% cocopeat gave the highest crown dry weight. In aquaponic system, the lowest root dry weight was obtained from the substrates of sole perlite and sole cocopeat (Fig. 2). Hydroponic treatment had higher number of runners than aquaponic treatment. In hydroponic treatment, the highest number of runners was obtained from the substrate of 25% perlite + 75% cocopeat and the lowest one from higher ratios of perlite. In aquaponic treatment, higher ratios of cocopeat produced the highest number of runners (Fig. 3). Leaf area was greater in hydroponic treatment than in aquaponic treatment, so that the highest leaf area was obtained from higher ratios of cocopeat (Fig. 4). SPAD index of young leaves of most substrates was higher in aquaponic treatment than in hydroponic treatment. SPAD index in young leaves decreased in aquaponic treatment as the ratio of perlite to cocopeat was decreased. SPAD index of old leaves was significantly higher in hydroponic treatment than in aquaponic treatment. In hydroponic treatment, the highest SPAD index of old leaves was observed in the substrate of sole perlite (Fig. 5). F_v/F_m was significantly higher in hydroponic treatment than in aquaponic treatment and it decreased in aquaponic treatment as the ratio of cocopeat to perlite was increased (Fig. 6). Hydroponic treatment had significantly higher N and K level than aquaponic treatment (Figs. 7 and 8). Hydroponic treatment had significantly higher P level than aquaponic treatment at higher ratios of cocopeat. The highest P level was obtained in the substrate of 50% perlite + 50% cocopeat in hydroponic treatment and the lowest one was obtained from the substrate of sole perlite (Fig. 9). The Ca level of hydroponic treatment was significantly lower than the aquaponic treatment on all substrates unless cocopeat. It sharply decreased in aquaponic treatment on the substrate of cocopeat (Fig. 10). The system and substrate had no specific effect on Mg level. The lowest Mg level of aquaponic system was obtained from the substrate of sole cocopeat (Fig. 11). The highest Fe level of hydroponic treatment was obtained from the substrate of 75% perlite + 25% cocopeat and the lowest one of aquaponic system was observed in the substrate of only cocopeat (Fig. 12). The difference in Mn level was significant between hydroponic and aquaponic treatments, so that it was much higher in hydroponic treatment than in aquaponic treatment (Fig. 13). The difference in Zn level was significant between hydroponic and aquaponic treatments (Fig. 14). Fruit yield in hydroponic and aquaponic systems was significantly different. The highest yield of hydroponic treatment was obtained from the substrate of 25% perlite + 75% cocopeat. In aquaponic treatment, higher cocopeat application resulted in lower yield and the highest yield was produced on the substrate of sole perlite (Fig. 15). The highest number of fruits was obtained on the substrate of sole perlite in both treatments (Fig. 19).

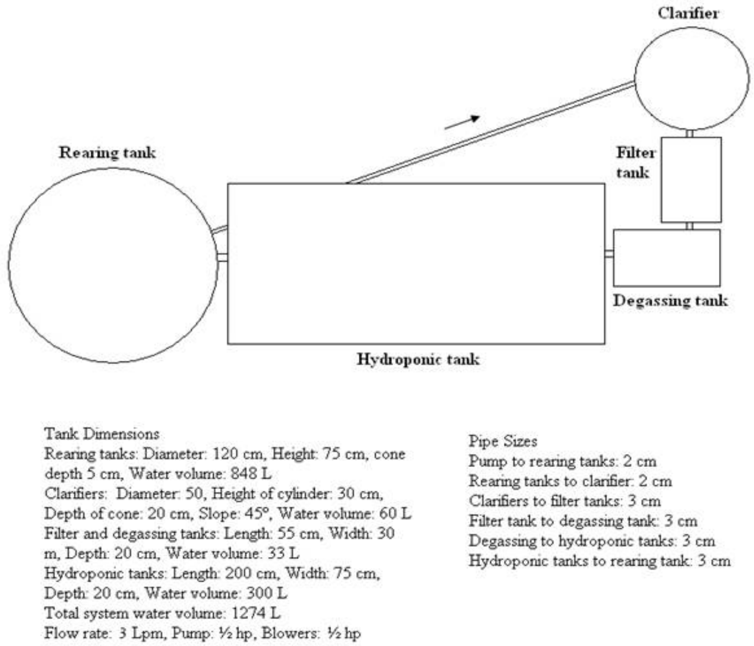

Fig. 1: Scheme of aquaponic system, Vali-e-Asr University of Rafsanjan, Iran.

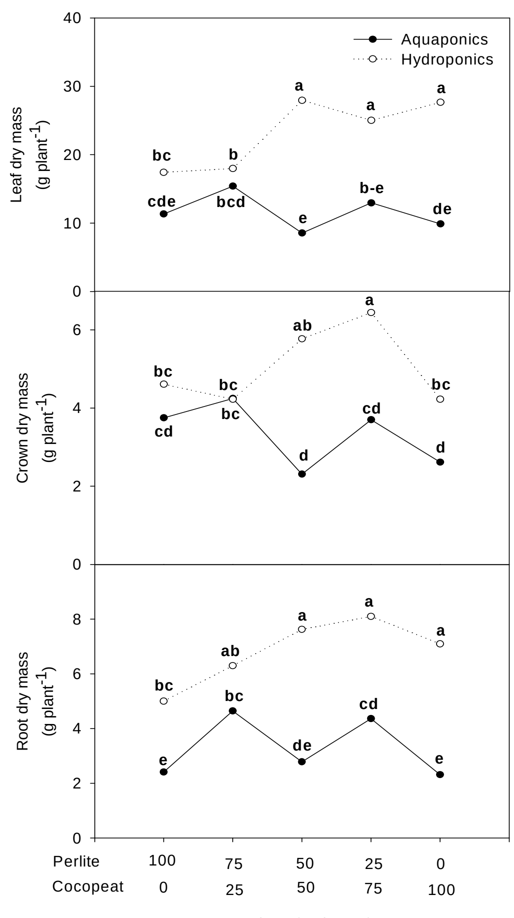

Fig. 2: Interactions of substrates and cultivation systems on leaf, crown and root dry weight of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

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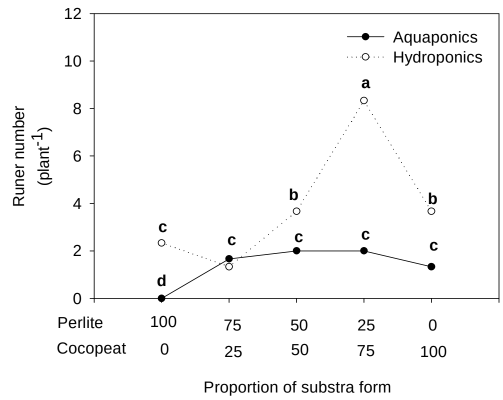

Fig. 3: Interactions of substrates and cultivation systems on the number of runners of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

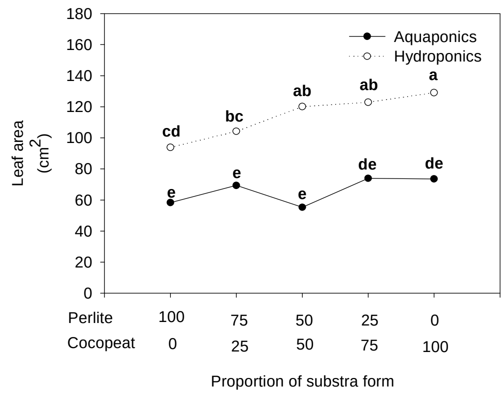

Fig. 4: Interactions of substrates and cultivation systems on leaf area of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

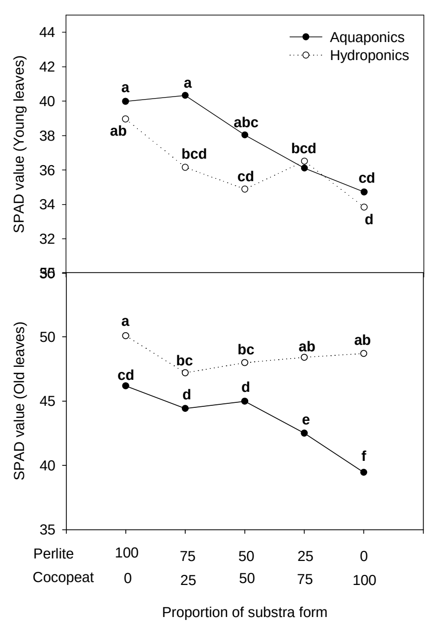

Fig. 5: Interactions of substrates and cultivation systems on SPAD index of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

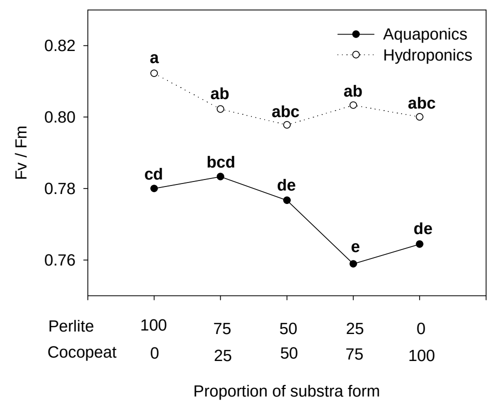

Fig. 6: Interactions of substrates and cultivation systems on Fv/Fm of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

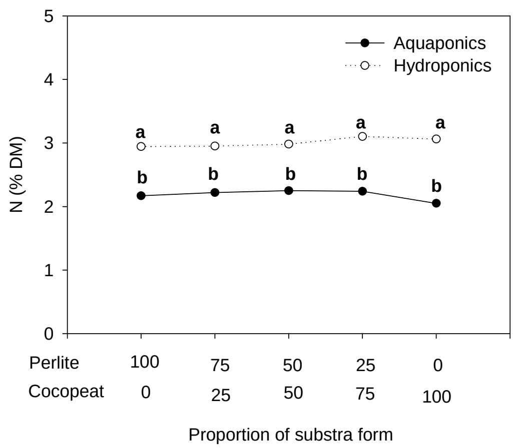

Fig. 7: Interactions of substrates and cultivation systems on N concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

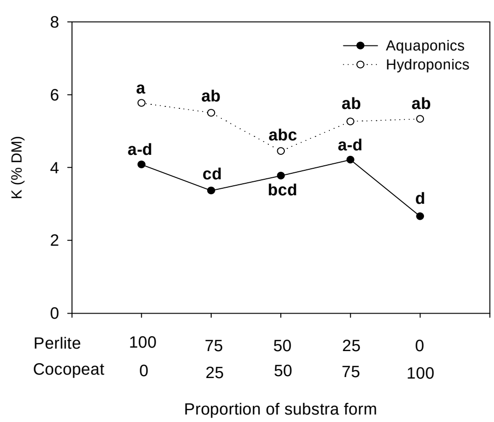

Fig. 8: Interactions of substrates and cultivation systems on K concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

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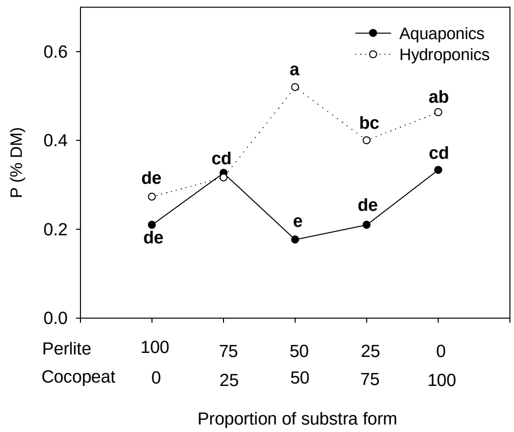

Fig. 9: Interactions of substrates and cultivation systems on P concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

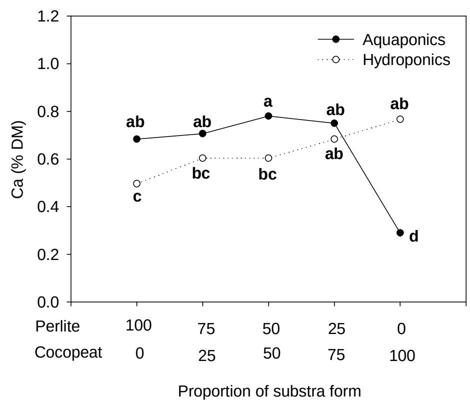

Fig. 10: Interactions of substrates and cultivation systems on Ca concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

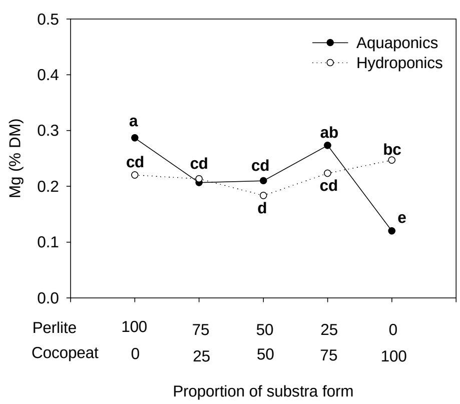

Fig. 11: Interactions of substrates and cultivation systems on Mg concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

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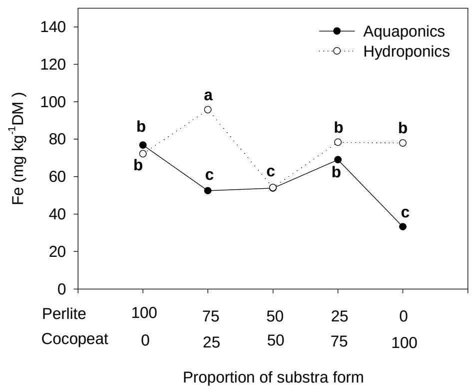

Fig. 12: Interactions of substrates and cultivation systems on Fe concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

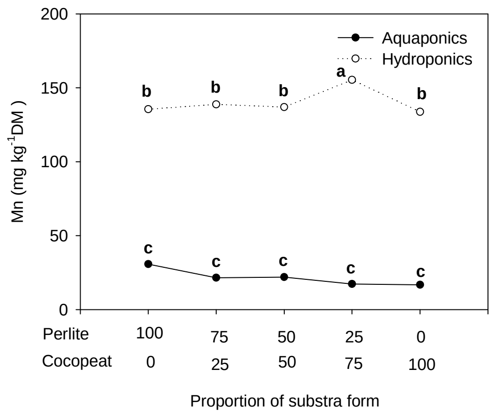

Fig. 13: Interactions of substrates and cultivation systems on Mn concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

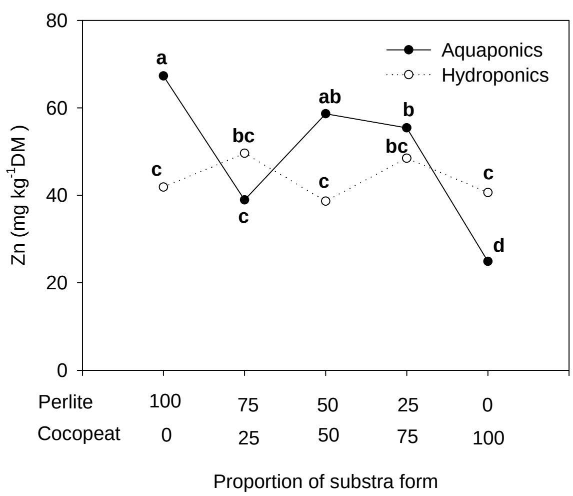

Fig. 14: Interactions of substrates and cultivation systems on Zn concentration in leaves of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

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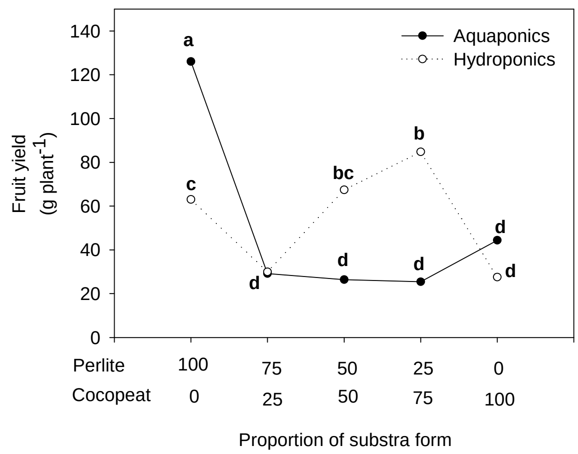

Fig. 15: Interactions of substrates and cultivation systems on fruit yield of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

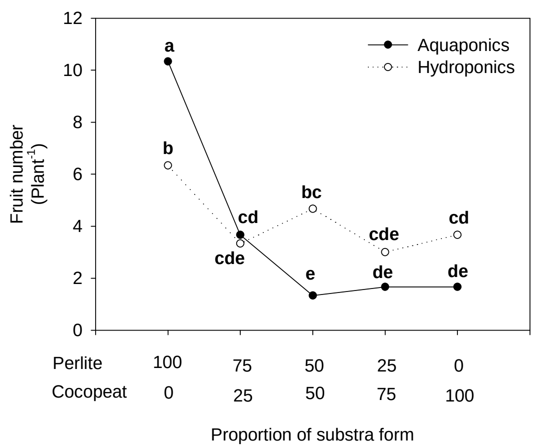

Fig. 16: Interactions of substrates and cultivation systems on fruit number of strawberry. The letters show significant differences at 5% level between treatments (Dancan's test).

Discussion:

The results showed that hydroponic and aquaponic treatments significantly affected N absorption of strawberry and aquaponic-grown plants had lower N absorption than hydroponic-grown plants. Fish usually excretes N and P in dissolved form. The excessive N which is released by fish is in ammonia form which is excreted from the gills in gaseous form. During nitrification, ammonia is bacterially converted to nitrite and then, into nitrate [17,31]. The reason for decreased N absorption in aquaponic system was the low number of fish. Probably, the number of the fish in the current study did not suffice to supply the plants with the required N. Fish often excretes phosphate by urine and waste. The excreted waste and food show that most phosphate is accumulated in the system [17]. P absorption rate was higher in hydroponic treatment than in aquaponic treatment (Fig. 9). Probably, the amount of P released by the fish into water in aquaponic system did not suffice.

The concentration of nutrients in the leaves of the plants nourished with inorganic nutrients was higher than that of the plants nourished with organic fertilizers. The absorption rates of N, P, K, Mg, Fe and Cu were higher in cucumber plants fed with inorganic nutrient solution than in plants fed with organic fertilizer, probably because of lower availability and release of nutrients from organic sources [9]. In this experiment, the absorption rates of N, K, P, Fe and Mg were higher in hydroponic treatment than in aquaponic treatment (Figs. 7, 8, 9, 12, and 13).

The symptoms of the decrease in the absorption of such nutrients as Ca, worsened by Mg, are prevalent in most cases. This decrease occurs at cellular level caused by the inhibition of Ca absorption and the competition between Mg and Ca [14]. In hydroponic treatment, the high rate of Mg absorption might have decreased the absorption of Ca. When the amount of nutrients does not suffice, the growth of leaves and then, leaf area index can be limited due to either the low level of photosynthesis or insufficient cell elongation [12]. The cells of leaves are smaller in plants suffering from N deficiency [29]. These effects arise from the decrease in water conductance which results in water deficiency in the sheaths of growing leaves [28]. Under P deficiency, the sheaths of leaves become smaller and turn to dark green because of the insufficiency of cell elongation as well as redundancy of the number of cells per unit area [12]. The growth of leaf cells is inhibited in plants suffering from P deficiency resulting from decreased water conductance. N deficiency results in smaller leaf cells [28]. The P and N absorption rates were lower in aquaponic treatment and hence, the leaf area was smaller, too (Figs. 7 and 8).

K or N deficiencies increase longitudinal growth and reduce the formation of auxiliary roots [25]. The absorption rate of K and N as well as root dry weight was lower in aquaponic treatment than in hydroponic treatment (Figs. 2, 7 and 8).

N stimulates the vegetative growth especially shoots and turns the color of leaves to dark green. In total, N is a parameter that accelerates the vegetative growth of the plants [23]. As N absorption rate increases, the vegetative growth of the plants is augmented [8, 32]. The deficiency of such elements as Mg and Mn results in decreased vegetative growth [22]. The plants suffering from P deficiency show decelerated growth [12]. The cell elongation rapidly responds to Mn deficiency [30]. Given that the absorption rates of N, P and Mn were higher in hydroponic treatment than in aquaponic treatment, hydroponic treatment exhibited greater growth of shoots and accordingly, increased dry and fresh weight (Fig. 2). The evidence showing the direct impact of N on photosynthesis rate per leaf unit area abounds. Therefore, N mainly influences photosynthesis through increasing light interception. It seems that N application increases dry matter production and leaf area duration [18]. The increase in photosynthesis rate increases growth through keeping the stomata open, enlarging the cells and intercellular space and increasing cell division [13]. In hydroponic treatment, high level of N absorption resulted in higher leaf area (Fig. 7).

SPAD or chlorophyll content shows the N level of leaf tissue [42]. Under N deficiency, the adult leaves of strawberry are discolored to light green and become a little smaller than normal and as N deficiency worsens, the sheaths of younger leaves become greener [37]. The SPAD index of young leaves was higher in aquaponic treatment than in hydroponic treatment and also, N absorption rate was lower in aquaponic treatment than in hydroponic treatment (Fig. 5). The measurement of F_v/F_m can help understanding the photosynthesis-related processes [19]. As photosynthesis increases, the ratio of variable florescence of the chlorophyll to the maximal florescence (F_v/F_m) increases, so that it can be concluded that F_v/F_m is higher in healthy leaves with high chlorophyll content than in old leaves with low chlorophyll content. When photosynthesis tract is stressed, the variable florescence (F_v), which equals F_m-F_0, decreases. N deficiency results in decreased amount of variable florescence (F_v). F_v/F_m decreases because of the increase in F_0 under stress and injury. The decrease in or low level of chlorophyll will increase F_0 because the remaining chlorophyll re-absorbs less light [10, 27]. In hydroponic system because of higher N uptake, the photosynthesis level and F_v/F_m was higher than in aquaponic treatment (Fig. 6).

In the current study, different ratios of perlite:cocopeat significantly affected most measured parameters. Cocopeat is an organic material with moderate ion absorption capacity and high water holding capacity. Perlite has a negligible cation exchange capacity but high capillary property, so that it can store 3-4 times as great water as its weight. These two factors together help high nutrient solution holding capacity, better exchange of elements, particularly cations inside the planting bed, and optimum distribution of moisture throughout root zone. Consequently, they affect the formation of root system, the uptake of nutrients and the growth of the plants. Aeration is an important parameter affecting the growth of the plants. Oxygen is critical for the growth and activities of the cells. If root zone lacks oxygen, the growth of the plants will be damaged. The energy required for the growth of the roots and for the absorption of the ions is supplied through so-called respiration process which needs oxygen. The concentration of oxygen and the distribution of pores in root zone influence the development of hair roots. The aerated conditions improve the roots (e.g. hair roots) by uniformly distributing the water and air in pores [33]. If the pores of a solid substrate uniformly contain water and air, the amount of oxygen will suffice for the normal growth and activity of the roots [5]. Amiri *et al*. (2009) obtained the highest root fresh and dry weight of eggplant from the substrate of sole rice hull and sole perlite and the lowest ones from the substrates of 50% perlite + 50% rice hull [2]. In hydroponic treatment, the lowest and highest root dry weight were obtained from the substrates of sole perlite and 25% perlite + 75% cocopeat, respectively. In aquaponic treatment, the lowest root dry weight was obtained from the substrates of sole perlite and sole cocopeat and the highest one was obtained from the substrates of 25%

perlite + 75% cocopeat and 75% perlite + 25% cocopeat (Fig. 2). Water deficiency decreases the uptake and translocation of nutrients in plants and consequently, reduces the growth and the yield [21]. In hydroponic and aquaponic treatments, as the ratio of perlite to cocopeat was increased, the yield decreased (Fig. 15).

The growth of the runners is triggered by adverse environmental conditions like long, hot days and all energy of the plant is devoted to their growth and so, fewer flowers are born. Thus, the increase in the number of runners is followed by the decrease in flowering and fruit-bearing [4]. In aquaponic treatment, the lowest number of runners was obtained from the substrate of sole perlite which in fact, produced no runner and the plants used whole their energy for bearing flowers and fruits. Therefore, this substrate produced the highest number of fruits (Fig. 3).

The decrease in water and nutrients uptake is related to the decrease in water holding capacity of the substrate [7]. Stomatal conductance is reduces under water deficit conditions and hence, the extent of transpiration is decreases. Since transpiration is a mechanism for the absorption of elements and minerals, nutrients uptake by roots and their translocation from roots to shoots is finally decreased [1]. Saberi moghadam *et al*. (2009) studied the effect of different substrates (perlite, rice hull, cocopeat, mica and zeolite) on the uptake of nutrients by tomato and showed that the concentration of K and Mg was higher in the substrate of cocopeat and the substrates containing zeolite than other beds. The treatments did not show significant differences in the concentrations of N and P [34]. In a study on the effect of substrate perlite and zeolite on the growth of lettuce, Gul (2005) found the lowest head in the substrate of sole perlite and found that as the ratio of zeolite was increased, the growth of head was increased. N and K uptake rate was better in the substrate of sole perlite than in the substrate of zeolite and zeolite + perlite, but different substrates did not show significant differences in Zn uptake rate. The impact of zeolite on the uptake of nutrients was significant [9]. Malopa and Grasopulous (1999) compared the effects of two substrates, perlite and zeolite, and reported that perlite produced higher yield than zeolite [24]. Harland *et al*. (1999) reported that the pepper plants grown in perlite had higher yield than those grown in rockwool, and that zeolite gave higher K and N absorption rate than perlite. stated that mixing perlite with zeolite, clinoptilolite and tuff improved nutrients uptake capacity [9, 11]. The reports show that zeolite has higher cation exchange capacity than perlite but its cation exchange capacity is as high as cocopeat. In hydroponic treatment, K and P absorption rate was higher in higher ratios of cocopeat (Figs. 9 and 10) and the effect of substrate was not significant on N, K and Mg absorption. The substrates of sole perlite and sole cocopeat were not appropriate for nutrient uptake which can be related to lower moisture in sole perlite treatment and lower aeration in sole cocopeat treatment. Mixing perlite with cocopeat enhances the cation exchange capacity of the substrate. The uptake of one element might disrupt the uptake of other elements. The increase in Mg uptake might decrease Ca uptake [35]. It has been reported that cocopeat has a high, active cation exchange capacity which destabilizes the nutrients in root medium [6].

Arenas *et al*. (2002) reported that the fruit yield of tomato was not affected by substrates of peat and coir [3]. With the study of the effect of substrate (different ratios of perlite and cocopeat) in hydroponic cultivation of strawberry, it was shown that the highest yield was obtained from the substrates of sole cocopeat and 50% perlite + 50% cocopeat and the lowest one from the substrate of sole perlite. Fotouhi Ghazvini *et al*. (2007) reported that the highest yield of strawberry was obtained from the substrates with higher percentage of perlite and the lowest one from the sole zeolite substrate [7]. In a study on the effect of substrates and hydrogel on vegetative and reproductive traits of cherry tomato, the highest yield was obtained from the sole perlite substrate [43]. In the current study, the highest yield of aquaponic treatment was produced by the substrate of sole perlite which is in agreement with the results of Yousefian *et al*. (2009) (Fig. 15). Inden and Torres (2004) obtained the highest yield of tomato from the substrate of perlite + rice hull [16]. Lee *et al*. (1999) introduced the mixture of perlite + rice hull as the most optimum substrate for hydroponic cultivation of cucumber [20]. Research has shown that the highest yield of strawberry was obtained from the substrates of 75% perlite + 25% zeolite and 50% perlite + 50% zeolite and the highest number of fruits and yield of strawberry cv. Camarosa was produced by the substrate of 40% cocopeat + 60% perlite [26]. Lettuce had better growth in aquaponic system on gravel bed than in nutrient film technique (NFT) and floating raft. Better growth on gravel bed owned to the better conditions (optimum aeration) for the decomposition of organic matter and nitrification by nitrosomonas and nitrobacter [41]. In the current study in aquaponics system, the performance of the substrate of sole perlite was analogy to gravel bed because of better aeration which resulted in higher yield. The substrates with higher water holding capacity have better production and growth index. In hydroponic treatment, higher percentage of cocopeat (75% cocopeat + 25% perlite) had the highest yield (Fig. 15).

Conclusion:

It is concluded that, in hydroponic system, the substrates of sole perlite or cocopeat were not recognized as optimum substrates; therefore, it is

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recommended to use their mixture as substrate, while in aquaponic system, the substrates with higher percentage of perlite had better performance and are recommended for strawberry cultivation.

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