Scientia Horticulturae 129 (2011) 396–402

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effects of foliar application of some macro- and micro-nutrients on tomato plants in aquaponic and hydroponic systems

Hamid R. Roosta[a,*], Mohsen Hamidpour[b]

[a] Dept. of Horticultural Sciences, Faculty of Agriculture, Vali-e-Asr University of Rafsanjan, Rafsanjan, Iran
[b] Dept. of Soil Science, Faculty of Agriculture, Vali-e-Asr University of Rafsanjan, Rafsanjan, Iran

ARTICLE INFO

Article history:
Received 4 August 2010
Received in revised form 5 April 2011
Accepted 6 April 2011

Keywords:
Aquaculture
Aquaponic
Foliar application
Hydroponic
Tomato

ABSTRACT

An aquaponic system was designed to investigate effects of foliar applications of some micro- and macro-nutrients on tomato growth and yield in comparison with a hydroponic system. Common carp, grass carp and silver carp were stocked in the rearing tanks at 15, 20 and 15 fish m^{-3}, respectively. The fish were fed three times daily with a pellet diet containing 46% protein. Fourteen days old tomatoes seedlings were transplanted on to growth bed units of aquaponic and hydroponic systems after stocking of carp fish for 2.5 months in the rearing tanks. Foliar nutrients application began 30 days after transplantation. Eight treatments were used, untreated control, foliar application at the rate of 250 mL $plant^{-1}$ with 0.5 g L^{-1} K_2SO_4, $MgSO_4{\cdot}7H_2O$, Fe-EDDHA, $MnSO_4{\cdot}H_2O$, H_3BO_3, $ZnCl_2$, and $CuSO_4{\cdot}5H_2O$. Plants were sprayed twice a month. The results showed that biomass gains of tomatoes were higher in hydroponics as compared to aquaponics. Foliar application of K, Mg, Fe, Mn, and B increased vegetative growth of plants in the aquaponics. In the hydroponics, only Fe and B had positive effects on plant growth. Cluster number per plant in aquaponics was lower than in hydroponics treatments, but it increased with foliar application of elements. There was no difference in fruit number and yield between aquaponics and hydroponics grown plants in the control treatments. Except Cu, foliar spray of all elements significantly increased plant fruit number and yield in the aquaponics in order of: K > Fe > Mn > Zn > Mg > B. In the hydroponics, foliar application of K, Mg and Zn increased fruit number and yield of plants compared to control. These results indicated that foliar application of some elements can effectively alleviate nutrient deficiencies in tomatoes grown on aquaponics.

1. Introduction

Aquaponic is the integration of hydroponic plant production into recirculating fish aquaculture systems (Nelson, 2008). In the aquaponic system, nutrients which are excreted directly by the fish or generated by the microbial breakdown of organic wastes are absorbed by plants cultured hydroponically. Aquaponics has several advantages over other recirculating aquaculture systems and hydroponic systems that use inorganic nutrient solutions. The hydroponic component serves as a biofilter, and therefore a separate biofilter is not needed as in other recirculating systems. Aquaponic systems have the only biofilter that generates income, which is obtained from the sale of hydroponic produce such as vegetables, herbs and flowers (Rakocy and Hargreaves, 1993). Fish feed provides most of the nutrients required for plant growth. Majority of fish species utilize 20–30% of nitrogen (N) supplied by the diet (Penczak et al., 1982; Hall et al., 1992; Shpigel et al., 1993; Piedrahita, 2003; Schneider et al., 2005). This means that about 70–80% of the N supplied by the feed are being released as waste into the water (Krom et al., 1995). Ammonia is the major end product in the breakdown of proteins in fish. Fish digest the protein in their feed and excrete ammonia through their gills and in their feces. Ammonia also enters the system from bacterial decomposition of organic matter such as uneaten feed or dead algae.

The most common recirculating aquaponic systems employ either a media filled raised bed, nutrient film technique (NFT), or floating raft system (Anonymous, 1997; Diver, 2006; Lennard and Leonard, 2006; McMurtry et al., 1997; Rakocy et al., 2006, 1997; Watten and Busch, 1984) for the plant growing area. Among them, the floating raft system was selected for tomato production in this experiment.

It is reported that aquaponic systems that rely solely on fish waste to supply nutrients for plants have low levels of phosphorus (P), potassium (K), iron (Fe), manganese (Mn) and sulfur (S) (Adler et al., 1996; Seawright et al., 1998; Graber and Junge, 2009). Thus, optimizing plant production may require fertilizer supplementation in aquaponic systems (Rakocy et al., 1997). On the other

* Corresponding author. Tel.: +98 3913202031; fax: +98 3913202042.
E-mail address: roosta_h@yahoo.com (H.R. Roosta).

0304-4238/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.scienta.2011.04.006

hand, the management of a tomato crop is somewhat more difficult than leafy crops because the nutrient demands of the plant change during different stages of plant growth. From germination through the development of the first flowers (about 6 weeks), the needs of the plant are fairly constant. Once the plant starts setting fruit, it requires more Ca, Mg and K (Nelson, 2008). At this time the nutrients can be applied to the growing medium or as a foliar spraying, which is recognized by some of the researchers as a very efficient method of plant nutrition during the intensive growth stage (Chauduni and De, 1975; Giskin et al., 1984; Komosa, 1990). Foliar applications of Mg, Zn, and Mn can effectively alleviate deficiencies in fruit and vegetable crops grown on calcareous soils with a pH of 7.4–8.4 (Li, 2001).

Little information is available about effects of foliar application of nutrients on tomato yields and growth in aquaponic systems. The objectives of this research were: (i) to investigate effects of foliar applications of some micro- and macro-nutrients on tomato growth and yield (ii) to compare plants growth in aquaponic and hydroponic systems.

2. Materials and methods

2.1. Aquaponic system

An aquaponic system was designed based on the Rakocy/UVI model (Rakocy et al., 1997) in the Vali-e-Asr University of Rafsanjan, Iran (Fig. 1). Our aquaponic system consisted of 3 individual, identical aquaponic units. Each aquaponic unit consisted of one fish rearing tanks, a clarifier, a filter tank, a degassing tank and a plant growth bed unit. The tap water, which was located near the rearing tanks, supplied water from a short distance to the fish rearing tank. A water pump continuously delivered water from the fish-rearing tanks to the rest of unit. Water from plant growth bed unit was returned to the rearing tank, which was located in the lowest point of the system. A plastic meshes covered the tank to prevent fish jumping from the tank.

Each of plant growth bed unit and fish-rearing tank had 10 air diffusers (2 L min^{-1}), which were cleaned monthly. There were also three air diffusers in the degassing tank. Settleable solids were removed from the clarifiers one time daily by opening a ball valve. Fine solids were collected by netting plastic screens in the filter tanks and were removed two times monthly by draining the tank and washing the netting. There was also a plastic screen at the entrance of degassing tank which prevented fish fry to reach to the hydroponic tank.

The pH value of water was not adjusted during the experiment; it was in the range of 7.0–7.7. Water loss through evaporation, transpiration and sludge removal was replenished with tap water in the rearing tank and a valve in the rearing tank was used to control the water flow so as to produce a constant water level in the rearing tank.

The aquaponic unit operated continuously with a known density of fish biomass to maintain stable bacterial populations. Common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmichthys molitrix*) were stocked in the rearing tanks (diameter 1.2 m, water depth 0.75 m, and water volume 848 L) at 15, 20 and 15 fish m^{-3}, respectively and cultured for 6 months. The mean mass of fishes stocked ranged from 160 to 180 g. The fish were always fed three times daily with a pellet diet containing 46% protein at a mean rate of 3% of body weight per day (Table 1). The fish were fed and defecated entirely within the fish tank. Water from the fish tank was continuously (24 h day^{-1}) pumped to the system via the water pump, thus biological filtration of the culture water was constant. Tanks were harvested after 6 months. The fishes were weighed and counted.

Table 1
Proximate composition (%) of the fish feed used in the experiment.

Composition	% FW
Protein	46
Fat	13
Ash	13
Fiber	2.5
Phosphorous	1.5
Moisture	11

2.2. Plant

Tomato seedlings were grown in pots containing perlite as a medium for 14 days. After that, pots were transferred to the growth bed components of aquaponic and hydroponic systems. Plants grown in hydroponic systems were nourished with a nutrient solution consisted of: 2.5 mM $Ca(NO_3)_2{\cdot}4H_2O$, 0.2 mM KH_2PO_4, 0.2 mM K_2SO_4, 0.3 mM $MgSO_4{\cdot}7H_2O$, 0.1 mM NaCl, 20 μM Fe-EDDHA, 7 μM $MnSO_4{\cdot}H_2O$, 0.7 μM $ZnCl_2$, 0.8 μmM $CuSO_4{\cdot}5H_2O$, 2 μM H_3BO_3, and 0.8 μM $Na_2MoO_4{\cdot}2H_2O$. Solutions were changed completely every week in the first couple of weeks and subsequently every 4th day in hydroponic system. Deionized water was used for nutrient solution making in hydroponic system. Tape water was used in aquaponic system. The only nutrient supplementation in plant growth bed unit of aquaponic systems was Fe, which was added in a chelated form (Fe-EDDHA) at a concentration of 2 mg L^{-1} once every two weeks. Eight plants were growing together in each growth bed unit of aquaponic and hydroponic systems. Foliar nutrients application began 30 days after transplantation by which time plants had attained enough leaf area for effective foliar application. Eight treatments were used, untreated control, foliar application at the rate of 250 mL $plant^{-1}$ with 0.5 g L^{-1} K_2SO_4, $MgSO_4{\cdot}7H_2O$, Fe-EDDHA, $MnSO_4{\cdot}H2O$, H_3BO_3, $ZnCl_2$, and $CuSO_4{\cdot}5H_2O$. Plants were sprayed twice a month. Tomato plants were trellised to overhead wires and pruned to a single leader stem. Fruit were harvested every week after 84–106 days after transplanting. Early yield, fruit number, cluster number and single fruit mass were calculated from fruits in the first three harvests.

The plants were grown in a greenhouse with 13 h light phase (26 ± 3 °C) and 11 h dark phase (22 ± 3 °C). Greenhouse temperature was controlled using cool air following into greenhouse from central cooler. The relative humidity was 52.4–63.2%.

The experiment was conducted for 108 days. At the end of the experiments, the shoot length (SL), node number (NN) and the leaf number (LN) were recorded. The plant organs (roots, leaves, and stems) were harvested, weighed, oven-dried (48 h at 72 °C) for determination of leaf fresh mass (LFM), stem fresh mass (SFM), root fresh mass (RFM), leaf dry mass (LDM), stem dry mass (SDM) and root dry mass (RDM).

2.3. Chemical analysis

Standard methods were used to measure pH, total alkalinity, total dissolved solids (TDS), total ammonia-nitrogen (TAN), nitrite-nitrogen and nitrate-nitrogen once every week at two locations in the systems. Dissolved oxygen (DO) and water temperature were measured periodically. Samples for water quality analysis were collected at the influent and effluent of the growth bed tanks.

The level of chlorophyll in the youngest expanded leaves and old leaves was recorded by taking SPAD (chlorophyll content) readings with a SPAD-502 Chlorophyll Meter (Minolta Camera Co. Ltd., Japan). Chlorophyll *a*, chlorophyll *b* and carotenoids were extracted from leaf tissue with methanol and estimated according to Lichtenthaler and Wellburn (1983). Second leaves from top (young leaves) and bottom (old leaves) were used for the measurement of chlorophyll fluorescence using a Plant Efficiency Analyzer,