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Full Length Research Paper

The effect of different nutrient solutions on some growth indices of greenhouse cucumber in soilless culture

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Today, greenhouse cultivation of vegetables, especially cucumber in soilless culture has been developed in different parts of the world. Soilless culture creates the possibility that farmers in a shorter time with less effort produce more yield. This research was done in the greenhouses center in Islamic Azad University of Khorasgan with three kinds of nutrient solutions and so completely randomized block design with three replication and five bushes per every replication was done. The media was composition of perlite and cocopite (v/v = 50%). Plant height, stem diameter, intensity of leaf colour, leaf area index, stiffness of fruit tissue, yield of fruits, dry matter weight were measured in every treatments. Comparison of means of cucumber fruit yield showed that there are no significant difference between solutions No 3, 2 and 1 in 5% level. The results showed that No 3 nutrient solution had most effect on the intensity of leaf colour, stem diameter, plant height and leaf area index as compared with other nutrient solutions during the growth season. No 2 nutrient solution had most effect on the weight of plant dry matter, weight of fruit dry matter and stiffness of fruit tissue. The height means of cucumber plants in treatments had no significant difference at 5% level. The comparison of stem diameter means showed that No 3 and 2 nutrient solution had significant difference at 5% level with No 2 solution but it had not any significant difference with No 1 nutrient solution at 5% level. The weight means of dry matter of fruit and green colour intensity of leaves had no significant difference between No 3 and 1 nutrition solutions but this nutrition solutions had significant difference with No 2 solution at 5% level. The comparision of leaf area index means showed that all of nutrient solutions had no significant difference at 5% level. The results showed that stiffness of fruit tissue in No 3 and 1 nutrient solutions had not any significant differences but between No 3 and 2 nutrient solutions had significant difference in 5% level. The means of dry matter weight of plant in No 3, 2 and 1 nutrient solutions had no significant difference in 5% level.

Key words: Nutrient solutions, greenhouse cucumber, soilless culture, yield.

INTRODUCTION

In recent years, some problems in soil culture (such as salinity and unsuitable soil characteristics) and limitation of water resources in many countries, especially in Iran, causes the expansion of soilless culture. Soilless culture is an artificial means of providing plants with support and a reservoir for nutrients and water. The use of soil in protected agriculture is facing many limitations in this country. After years of cultivation, deterioration in soil fertility and increase in soil salinity, in addition to the incurrence of soil-borne diseases and limited productivity of crops, have often been observed. Therefore, utilizing substrate-based agriculture is a logical alternative to the

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current soil-based production approach in the country. Hydroponic scientist with a lot of examination had resulted that the growth of plant have not needed soil if grower supply nutrient elements for plants by fertilization and fertigation (Papadopolus, 1994).

Probably, no aspect of hydroponic/soilless growing is as misunderstood as the constitution and use of nutrient solutions. Most texts simply provide the reader with a list of nutrient solution formulas, preferred reagent sources, and the necessary weights and measures. Although such information is essential to properly prepare the nutrient solution, a soundly based understanding of its management is as important, if not more so, for successful growing. This same thought can be echoed by many who have struggled with the selection and use of the many nutrient solution formulations found in the hydroponic literature. Poor yields, scraggly plants, high water and reagent costs, indeed most of the hallmarks of a less than fully successful growing operation can be directly linked to faulty formulations and the mismanagement of the nutrient solution. There are, unfortunately, no absolute pat prescriptions or recipes that can be given to growers by any hydroponic advisor. Growers will have to experiment with their own systems, observing, testing, and adjusting until the proper balance between composition and use is achieved for their particular situation and specific crop. Over a five-year period, a greenhouse hydroponic tomato grower began growing in perlite bags, then switched to perlite in buckets, and then finally to composted milled pine bark in buckets, changing the nutrient solution formulations several times with each system. However, none of these changes had any significant effect on fruit yield and quality, although one significant improvement occurred. There were fewer nutrient element insufficiencies when the milled composted pine bark was the rooting medium. Even today that grower is still questioning what should be the next change to bring about significant improvement in fruit yield. Although much is not known about how best to formulate and manage a nutrient solution, there are many good clues as to what should or should not be done. Growers using these clues will have to develop a scheme of management that best fits their environmental growing system and crops. They will have to experiment with various techniques to obtain maximum utilization of the nutrient solution while achieving high crop yields of top quality. The use of a particular nutrient solution formulation should be based on three factors include:

(1) Hydroponic growing technique
(2) Frequency and rate of nutrient solution dosing of plant roots
(3) Crop nutrient element requirements (Benton, 2005)

Although a nutrient solution formula may be modified to suit particular requirements for its use, the critical requirements for proper management are either over looked or not fully understood. The hydroponic literature is marked by much comment on nutrient solution composition in terms of the concentration of the elements in solution but is nearly devoid of instructions as to how the nutrient solution is to be used in such simple management terms as the volume per plant and frequency of application. Knowledge about the necessity of micro nutrients for plant growth was mainly gathered in the first half of the 20th century (Marschner, 1995), when the purification of fertilizers and chemicals were improved. The first systematic description for the preparation of nutrient solutions was given by Hoagland and Arnon (1950) and since then in many publications reference is given to them, when one or another nutrient solution is used to grow plants in soilless cultivation systems. For some substrates, like peat, the quantities of micro nutrients applied in advance are considerable in relation to the total absorption (Sonneveld and Wim, 2009), but it cannot be exactly predicted whether these elements will be sufficiently available for the whole growing period. When soilless culture in the greenhouse industry started on a large scale with the growing systems mentioned soon it appears that the development of nutrient solutions specific to crops and growing conditions was necessary. The use of the Hoagland solutions mentioned and the so called universal nutrient solutions (Steiner, 1961, 1984) are only suitable in small scale experiments and if a regular replacement of the solution is carried out. Therefore, in line with the development of soilless cultivation in the seventies of the 20th century nutrient solutions for specific crops in relation to growing conditions have been developed (Sonneveld and Straver, 1994).

In the first comprehensive review of the hydroponic method, which covered more than a century, Hewitt (1966) gave the composition of over 100 nutrient solution formulas, showing their historical development beginning in 1860. Muckle (1993) lists 33 "General and Historical Formulas" covering the time period from 1933 to 1943 as well as formulas designed for use when growing carnations, lettuce, strawberry, and tomato. Resh (1995) lists 36 formulas gathered from the literature covering the time period from 1865 to 1990, Jones (1998a) published 22 major element formulas plus three micronutrient formulations gathered from the literature beginning in the late l800s to more recent times, and Yuste and Gostincar (1999) listed 34 unnamed formulas plus six named formulas (Hoagland; Turner and Herry; Ellis and Swaney; Mier-Schwart; Kiplin-Laurie; and Steiner), covering the time period from 1865 to 1960. From these and other sources, it is interesting to note the ranges in elemental concentration in various nutrient solution formulas, ranges that are given in the books by Muckle (1993),

Table 1. Composition of final nutrient solutions (treatments) that used in fertigation method.

N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B	Mo
No 1 nutrient solution formula (ppm)											
212	69	313	95	25	66	1.4	0.4	0. 08	0.02	0.26	0.012
No 2 nutrient solution formula (ppm)											
216	58	286	185	185	43	6.85	1.97	-	0.07	0.7	0.05
No 3 nutrient solution formula (ppm)											
247	43	239	116	46	77	1.38	0.9	0.14	-	-	-

Table 2. Some physicochemical charectristics of substrats.

Media	ρb (g/cm^3)	Pp (g/cm^3)	Porosity (%)	WHC (cm^3/cm^3)	pH	EC ds/m	CEC (Cmol/kg)
Cocopeat	0.11	3.00	97	0.87	5.7	2.9	64.4
Perlite	0.15	1.35	88	0.56	4.0	1.6	00.0

Barry (1996), Jones (1997) and Yuste and Gostincar (1999), However, the ranges in element concentration seem unusually large, and perhaps difficult to justify.

Smith (1999) provides a nutrient formulation that he identifies as a "basic nutrient formula for general use". Bradley and Tabares (2000a, b, c, d) have given a nutrient solution formation that has been used in "many developing nations and with more than 30 species of vegetables, ornamental plants, and medicinal herbs", More recently, Morgan (2002a) has given the ingredients for what she has identified as a "general purpose hydroponic solution". Hershey (1990) also has given what he describes as the "composition of some common nutrient solutions". Lorenz and Maynard (1988) published four researchers' nutrient solution formulas, identifying their use only for commercial greenhouse vegetable production. So other autors include Hogland (1956), Thomas (1993), Papadopolus (1996), Foulkner (1998a), Johnson (2002a, b, c, d) and Morgan (2004) peresented different formuls of nutrient solutions for some plants.

Some of these nutrient solution formulas maybe prefer as compared with others for a speacial plant that related to local factors include light radiation, ET level, kinds of plant media, water and substrate quality and finally management of grower and so combination of nutrient elemnts and their ratio is affected. Object of this study is comparsion of some nutrient solutions for greenhouse cucumber in soilless culture and their effects on plant growth indices in Isfahan area in Iran.

MATERIALS AND METHODS

This research was done in the greenhouses center in Islamic Azad University of Khorasgan with three kinds of nutrient solutions (treatments) as presented in Table 1 include; No 1, 2 and 3 nutrient solutions that porposed for cucumber plant by Papadopolus (1994), Morgan (2002a) and FAO experts (for Iran, 2004), respectively. In this research, the completely randomized block design with three replications and five bushes per replication was done. Polyetilen pots (17 L) were used for cultivation. Plants were transported to pots when they had 3 leaves. The tempreture and humidity were constant in growth season (20 to 25°C and 75%, respectivly). Fertigation method was used and leaching fraction in every pots were 20%. The media was the composition of perlite and cocopeat (v/v = 50%). The pH of nutrient solutions adjusted to 6.5 for treatments in every fertigation.

In this research, the physiochemical characteristics of cultivation substrates like bulk density (BD) and water holding capacity measured. Total porosity have measured by Baruah and Barthakur method (1998). Also EC and pH are measured by Rhoades (1988) method, CEC by Rhoades (1982) method. Also, in this research, the amount of mineral nitrogen in different part of plants was measured by Keeny and Bremmner (1996) method, phosphorus by Olsen (1982) method, K by Kudsen and Peterson (1982) method, Ca and Mg by direct titration. The concentration of micronutrient elements in leaves of plant were measured by atomic absorbtion. In the end of plant growth period, some growth indices include plant height, stem diameter, intensity of leaf colour, leaf area index, stiffness of fruit tissue, yield of fruits and dry matter weight were measured in every treatments. Statistical analysis and the comparison of means were done by MSTAT-C and LSD, respectively.

RESULTS AND DISCUSSION

Properties of substrats

Some physicochemical properties of substrats is presented in Table 2. Amount of bulk density (ρb) in substrates were low and so porosity in them were high,

Table 3. Comparison means of some growing indices of cucumber in different nutrient solutions.

Nutrient solution	Yield (kg)	Biomass (g)	Height (cm)	LAI (cm^2)	FDW (g)	FS (kg/cm^2)	SD (mm)	ILC (%)
No 1	10.67^a	84.2^a	208.1^a	483.6^a	96.49^b	1.84^{ab}	11.73^a	41.67^a
No 2	9.96^a	85.3^a	203.8^a	474.8^a	97.47^a	1.94^a	11.4^b	41.35^b
No 3	11.77^a	86.3^a	210.7^a	479.9^a	95.58^b	1.75^b	12.02^a	42.64^a

Diffinision: PH = plant height , LAI = leaf area index, FDW = fruit dry weight, FS = fruit stiffness, SD = stem diameter , ILC = intensity of leaf colour.

Table 4. Concentration of nutrient elements in cucumber leaf in different nutrient solutions.

Nutrient solution	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)
No 1	5.83^a	0.58^a	2.27^a	2.53^a	0.61^b	56.13^a	54.33^a	11.47^a	62.93^b
No 2	5.70^a	0.57^a	2.08^a	2.84^a	1.08^a	50.27^a	55.53^a	12.33^a	51.33^c
No 3	6.03^a	0.53^a	2.35^a	2.56^a	0.54^b	52.33^a	55.80^a	9.33^a	98.40^a

therefore root areation is sufficient and residence of substrate to root penetration is low. As result the cucumber root as well as penetrated in media and root expanding sufficiently was done that led to increasing in water and nutrient elements uptake. Amount of water holding capacity (WHC) in cocopeat was higher than perlite but when these substrate mixed (v/v = 50), it had sufficient condition. Amount of EC in combination was low and for prevention of salt accumulation about 20% leaching fraction was done. Amount of CEC in mixed substrate for plant supporting was sufficient.

Growth indices

Effects of nutrient solutions on fruit yield, plant biomass, height of plant and LAI that is showed in Table 3 had no significant difference at 5% level. Amount of FDW (fruit dry weight) and FS (fruit ftiffness) in No 2 nutrient solution was maxima and had significant difference at 5% level as compared with other nutrient solutions. The stem diameter (SD) in No 3 nutrient solution was higher than other treatments and had significant difference at 5% level. Amount of intensity leaf colure (ILC) that related to chlorophyll content in No 3 nutrient solution was higher than other treatments and had significant difference at 5% level with No 2 nutrient solution but had not any significant difference with No 1 nutrient solution. Amount of P and K elements in the No 1 nutrient solution was extreme and they decrease in the other nutrient solutions gradually. Cucumber plant needs high amount of K that affects on fruit increment, meanwhile, P element affects on fruit yield. Therefore, maybe the change of fruit yield in these treatments are related to P and K concentration in nutrient solutions.

Amount of nitrogen in No 3 nutrient solution was higher than other treatments then the increasement in arial body growth of plant in this treatment can be ralated to nitrogen element (Benton, 2005). Amount of P in No 1 nutrient solution is high, therefore stem diameter in this treatment is more than other nutrient solutions (Benton, 2005). Increasing of ILC in No 3 treatment can be ralated to nitrogen content (Kotsiras et al., 2002). Although, No 2 treatment had high amount of Mg and Fe than other treatments, but amount of ILC in this treatment was lower than others. Corresponding to role of Mg and Fe in leaf chlorophll, this result is not clear. Maximum amount of leaf area index are related to No 1 treatment that can be infered related to P and K concentration in nutrient solutions (Benton, 2005; Barker, 2007).

The concentration of nutrient elements in leaves and fruit

The concentration of nutrient elements in cucumber leaves in different nutrient solutions is presented in Table 4. Amount of N, P, K, Ca, Fe, Zn and Mn in cucumber leaves in different treatments had no significant difference at 5% level. Most amount of Mg was in No 2 treatment that had significant difference at 5% level as compared with other treatments. The concentration of Mg in No 2 nutrient solution was higher than other nutrient solutions (185 ppm) and it led to increasing in Mg uptake by plant. The most amount of Mn in leaves related to No 3 treatment that had significant difference at 5% level as

Table 5. Concentration of nutrient elements in cucumber fruit in different nutrient solutions.

Nutrient solution	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)
No 1	4.23[a]	0.72[a]	3.02[a]	0.32[a]	0.27[a]	47.4[a]	48.07[ab]	6.07[a]	21.27[a]
No 2	4.24[a]	0.67[a]	3.45[a]	0.29[a]	0.29[a]	46.6[a]	52.93[a]	6.53[a]	21.47[a]
No 3	4.95[a]	0.65[a]	3.10[a]	0.27[a]	0.27[a]	53.1[a]	40.27[b]	4.40[a]	25.87[a]

compared with other treatments. Although the concentration of Mn in No 2 nutrient solution was higher than other nutrient solutions but the concentration of Mn in leaf in this treatment was less than No 3 treatment because amount of Fe in No 2 nutrient solution was high (6.85 ppm) and it prevented to Mn uptake by plant. The concentration of P in No 3 nutrient solution was lower than other nutrient solutions and maybe antagonism effect of P on Mn uptake by plant was decreased. Although concentration of Fe in No 2 nutrient solution was very high as compared with other nutrient solutions but its concentration in leaf and fruit had no significant difference as compared with other treatments that related to antagonism process. Concentration of Ca and Mg in cucumber leaf in No 2 treatment was higher than other treatments and these elements caused the stiffness increment of fruit tissue. In the No 3 treatment, nitrogen content is higher than other treatments and stiffness level is low. The increasing in N causes to increscent in water absorbtion by fruit tissue and as a result, stiffness of fruit tissue increased. These results are similar to Jones (1998b) reports.

The concentration of nutrient elements in cucumber fruit in different nutrient solutions presented is in Table 5. Amount of N, P, K, Ca, Mg, Fe, Cu and Mn in cucumber fruit in different treatments had no significant difference at 5% level but amount of Zn element in different treatments had significant difference at 5% level and most amount related to No 2 nutrient solution. Although, No 3 and No 2 nutrient solutions were free of Cu and Zn elements, respectively, the leaf and fruit of cucumber had sufficient amount of Cu and Zn that their source was substrate.

Conclusion

Although macro and micro elements concentration in nutrient solutions (treatments) were different, but some important growth indices as fruit yield had no significant difference between treatments.Therefore, these nutrient solutions were not prerfered as compared with each other, but total solids in the No 3 treatment that used for nutrient solution are lower than other treatments thus by attention to the economical view point and production cost, No 3 treatment can be porposed for cucumber.

In the open system of greenhouse culture, the concentration of nitrate ion in drained water can create pollution hazard so No 1 treatment is better and it will be porposed to growers for using as a sufficient nutrient solution since the amount of nitrate in this treatment is lower than others.

Abbreviations: MS, Murashige and Skoog medium (1962); **TDZ,** thidiazuron (N-phenyl N'1, 2, 3-thidiazol-5-ylurea); **BA,** 6-benzyladenine; **IBA,** indole-3-butyric acid.

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