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*Full Length Research Paper*

# Effect of soil acidification on growth indices and microelements uptake by greenhouse cucumber

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**Based on the climate condition of Iran and most of its soils that are calcareous, it is important to prepare the nutritional requirements of cucumber and decrease the growth and development limitations of greenhouse cucumber. In this way, notation to pH properties is essential. Optimum pH for plants production is slightly acidic such that it is necessary to correct soil pH to a more suitable range in order to increase nutrients availability for plants. The goal of this research is to assess the effect of irrigation water pH changes on yield and nutrient uptake especially on micro nutrients by plant. The experiment consisted of three treatments of pH (5.5, 6.5 and 7.5). The experiment was carried out in a factorial design in the research greenhouse of Khorasgan University. During growth season, Ca and micronutrients were not used. After sampling different nutrients, concentrations were measured. At the end of growth season, growth indices were measured. The evidences provided by this experiment indicated that pH changes did not have significant effect on fruit yield and dry weight of plant shrub. Also, irrigation water pH did not have effect on chlorophyll amounts, LAI and stem diameter, significantly. However, the highest amount of LAI was achieved in pH = 5.5. The pH changes in irrigation water had significant effect on nutrients uptake, though micronutrients uptake was increased and the optimum concentration of nutrients was extracted in plant leaves and fruits by decreasing the pH to 5.5. The maximum uptake of Ca and Mg was obtained when the pH = 7.5 and the maximum uptake of N, P and K was obtained when the pH = 6.5.**

**Key words:** Acidification, cucumber, micro and macro nutrients, growth indices.

## INTRODUCTION

Cucumbers are heavy feeders, but they can easily suffer root damage from fertilizer overdose or extreme fluctuations in fertilizer supply. Unbalanced nutrition regime may cause excessive vegetativeness or over-bearing of the plant resulting in sub-optimal performance of the crop (Papadopoulos, 1994). On the other hand, undesirable conditions of soil like high pH, high amounts of $CaCO_3$ (Shaaban et al., 2004, 2007, 2008) and antagonistical relations between soil, micro and macronutrients can affect availability of some soil nutrients by plant roots. Micronutrients are essential for all plants so that their balance is very important (Marschner, 1995). Mechanisms that control plant availability to soil microelements often depend on soil properties such as: soil texture, pH, cation exchange capacity (CEC), $CaCO_3$, organic matter, clay amount, soil oxidation and reduction condition, mannering system, plants species and their nutritional requirements (Stevenson, 1991; Tan, 1998; McBride et al., 2003). In general, relative availability to these nutrients can be controlled by creating chemical equilibrium between soil solution, organic matter and CEC with soil minerals (Stevenson, 1991; Chen and Stevenson, 1986). Maximum uptake of nutrients is often done at the pH range of 5.5 to 6.5. When pH is more than 7, it causes decreased phosphorus and micronutrients solubility, whereas extremely acidic pH causes toxicity generation due to micronutrients especially Mn and Al. Soil pH have significant effect on Fe, Mn, Zn and Cu availability (Prasad and Sinha, 1982). In acidic soils, Ca and Mg are less available, while in alkaline soils, Fe, Mn and Zn are less available. In alkaline soils, high concentration of

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bicarbonate in soil solution increases soil pH, decreases micronutrients concentration in soil solution and prevents the transfer of Fe, Zn, Mn, Cu and even P from root to stem and from stem to leaf. Micronutrients play a role in oxidation-reduction system and in many major processes of plant cell activities as coenzyme (Hall and Williams, 2003; Salama and Shaaban, 2000), such that microelements deficiency can cause problems in plant cell metabolism, which in turn causes growth path deferment and yield decrement (El-Fouly et al., 2008; Shaaban et al., 2007). Based on the studies of Milani et al. (1999), the alkalinity of most agronomical soils of Iran and the existing bicarbonate in irrigation water that are provided by subsurface water resulted to an increase in pH to 7 and more increase in cell sap, especially in fruit trees, such that most of the nutrients like P, Fe, Zn, Mn and Cu are precipitated in the trunk and branches of fruit trees as unavailable. By acidifying cell sap, using $H_2SO_4$ in irrigation water and/or by direct usage of $H_2SO_4$ in soils, nutrients availability in soil and plant can be increased. Decreasing the acidity of whole soil is not possible and economical in many conditions (Bindra, 1983). Thus, irrigation by acidified water has high effect on chemical component of soils and changes the compound of reactionable phases and available nutrients for plant (Van et al., 2008).

By decreasing irrigation water pH, soil solution pH decreased and the solubility of different nutrients especially micronutrients increased, and as a result, available micronutrients increased for plants (Nourgholipoor et al., 2000). Advantages of acidifying soils consist of increasing nutrients, decreasing diseases and pests, drowsing nitrification by decreasing water pollution, soil pollution improvement and availability of some metals and P (Summer et al., 1986, 2002), such that by adding 20 mg/l $HNO_3$ or urea to water, anthurium plant showed best apparent and growth (Li et al., 2002). Nourgholipoor et al. (2000) showed that by increasing pH in irrigation water from 5 to 8, dry weight and length of cucumber linearly decreased in hydroponic culture. Production and marketing were more in pH = 5, but pH change did not have any effect on total yield. In another research, acidifying irrigation water in zea planting caused an increase in zea yield and phosphate uptake by plant (Nourgholipoor and et al, 2000). Growth and nutrients uptake by rice, wheat, bean and cowpea was assessed in 6 levels of pH (4.1, 4.7, 5.3, 5.9, 6.6 and 7). Results showed that dry weight of roots and top parts of rice, zea and cowpea was high in acidic range while by increasing pH in wheat and bean, these amounts increased. In all species, by decreasing pH, the uptake of Ca and Mg decreased and the uptake of Fe, Mn and Zn increased. By increasing the pH, N, P and K uptake decreased in rice and increased in wheat, zea and bean (Fageria, 1998). In another study, soil pH did not have direct effect on the dry weight of potato but had an effect on total dry weight/ha (Kellock, 1995). Gookang (2004) tested the effect of nutrient solution pH (4.4 - 8) on *Salvia officinalis* and reported that the pH did not have any effect on growth parameters (dry weight, leaf area, and leaf chlorophyll concentration) and physiological parameters. One research assessed *Linum usitatissimum* L. with treatments of applying irrigation water without acid (pH = 8.3), acidic water (pH = 6 and pH = 2.3) and also *Medicago sativa* with treatments of water, lack of acid and irrigation water with pH = 4. The yield of *S. officinalis* increased in acidic plots than in control plots but its production was not significant. In a study on macrophyte plants in swamp under acidic regimes (pH = 4.3) with control treatment (pH = 6.5), it was found that death was low among treatments and almost all plants blossomed and bud biomass was larger under more acidic treatments (Wendy et al., 1992).

Based on the study of Kreij et al. (1992), optimum concentration of nutrients in greenhouse cucumber consist of Ca (2.2 to 2.4%), Mg (0.4 to 0.7%), Fe (85 to 300 ppm), Mn (55 to 300 ppm), Zn (50 to 140 ppm), B (50 to 76 ppm), Cu (5 to 17 ppm) and Mo (1 to 2 ppm), and the deficiency signs of Ca, Mg, Zn, B, Cu and Mo respectively appeared in concentrations of 1.2 and 0.37%, and 26, 43, 5 and 0.29 ppm.

More than half of the area of our country has arid and semiarid climate and because of lacking precipitation, almost half of the cultured area needs irrigation. In most areas of Iran, water resources consist high amounts of Ca, Mg and bicarbonate and water reaction is alkaline by pH = 7.2 to 8.5. Based on the climate condition of Iran and its most soils that are calcareous, it is important to prepare the nutritional requirements of cucumber and decrease the growth and development limitations of greenhouse cucumber. Therefore, the objective of this study is to find answers to the following questions: If microelements are not used in fertigation system, can acidification of irrigation water be able to support micronutrient requirements for cucumber plant in soil culture? What is the optimization level of pH? What is the effect of applying the three levels of irrigation water pH on micronutrient uptake, yield and growth indices of greenhouse cucumber?

## MATERIALS AND METHODS

This research was carried out in a research greenhouse of Islamic Azad University, Khorasgan branch, using a factorial design with three treatments and nine replications. The treatments included three levels of pH (5.5, 6.5 and 7.5) used in nutrient solution and under the fertigation method. After cucumber plants reached the five-leaf stage, pH treatments were applied. Nutrient solution formula that was proposed by FAO experts (for Iran 2004) for cucumber plant was used. The fertilizers used in the nutrient solution were $KNO_3$, $NH_4NO_3$, $KH_2PO_4$, $MgSO_4$ and $MgNO_3$, as such, no solute of Ca and micronutrients was used. The temperature (20 to 25°C), humidity (75%), irrigation water volume and diseases control management were similar during growth season for all treatments. Leaching fraction in every pot was 20%. PH and electrical conductivity (EC) was measured with the method of Verdonck (1998). Nitrogen was analyzed by Kjeldahal method (Bremner and Mulvaney, 1982) and organic carbon was measured

**Table 1.** Nutrient elements concentration and soil chemical properties before and after the planting period under three pH treatments.

| Sampling time | OC (%) | CEC (Cmol/kg) | EC (ds/m) | $CaCO_3$ (%) | N (%) | P (mg/kg) | K (mg/kg) | Ca (me/l) | Mg (me/l) | Fe (mg/kg) | Mn (mg/kg) | Zn (mg/kg) | Cu (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BP | 1.5 | 14 | 3.5 | 52.2 | 0.3 | 54 | 890 | 26.8 | 38.4 | 26.4 | 12.58 | 4.22 | 3 |
| AP-7.5 | 0.82 | 11.94 | 4.4 | 50 | 0.19 | 15 | 320 | 15.6 | 7.2 | 28 | 9.11 | 3.1 | 2.64 |
| AP-6.5 | 0.84 | 13.68 | 4.5 | 49 | 0.16 | 27 | 400 | 13.2 | 8.6 | 33.6 | 9.97 | 3.83 | 2.77 |
| AP-5.5 | 0.91 | 12.29 | 4.8 | 47.5 | 0.1 | 12 | 300 | 11.2 | 6.8 | 38 | 10.8 | 4.6 | 2.83 |

Definitions: BP= Before planting, AP= after planting under different pH.

with Walklyblack methods. Also, phosphorus and potassium was measured by the methods of Olsen (1982) and Kudsen et al. (1982), respectively. Acetate sodium method was used for determining the CEC and $CaCO_3$ were measured before and after cultivation by titration method. Some growth indexes including fruit yield, stem diameter and leaf area index (Rossini, 2004) were measured at the end of the growth period. The concentration of micro-nutrient elements in soil, fruit and leaves of plants were determined using atomic absorption spectrophotometer, Model PE 5100.

Chlorophyll percentage was measured by Hansatech-Instruments (CL-01 model). The analysis of all data was done by MSTAT statistical software, and Duncan's multiple range test was used for comparison of treatment means when F values were significant at $p < 0.05$, and so Excel software was used for drawing graphs.

## RESULTS AND DISCUSSION

### Soil properties variations

The chemical properties of soil, before and after planting, have been presented in Table 1. With decreasing pH in the treatments, calcite amount decreased such that it is probably related to lime dissolution by acid. The amount of EC in soil increased by decreasing nutrient solution pH because soil minerals dissolved with increasing $H^+$ ion in soil and therefore dissolved salts increased naturally. The amount of organic matter in soils treated with pH decreased as compared with that before treatment because the fertigation process provided microorganisms requirements (same water and nutrients) and led to increase in organic matter mineralization and decrease in O.M treatments. The concentration of Ca, Mg and K in the soils that were treated with pH strongly decreased in comparison with soils before planting that its reason may be related to nutrients uptake by plants and or leach them from soil profile. Although, in the fertigation process, nitrogen element was added to the soils, its concentration in soils that were treated with pH decreased as compared to those before planting. It seems nitrogen uptake by plants and leaching of nitrogen from soils was higher than N added to soil by fertigation and mineralization process. Accordingly, nitrogen storage in soils decreased.

As against adding phosphorus to soil under fertigation process and also by dissolving phosphate minerals, soil phosphorus extremely decreased in pH treatments than before planting. In low pH of soil, it seems Fe and phosphate ions have been combined and then precipitated. There was little difference in the concentration of Mn, Cu and Zn in the soils that were treated with pH as compared to that treated before planting and it showed that the uptake amount of Mn, Cu and Zn elements by plants was equal to their released amount of manganese, copper and zinc minerals dissolution. Decrease in soil pH led to increase in Fe concentration and so in the cultivation period of plant with regards to Fe requirement, the decrease in pH strongly led to dissolution of iron minerals in soils. The results of Nourgholipoor et al. (2000) showed that soil acidification led to dissolution of soil minerals especially microelement minerals. Summer et al. (2002) reported that soil acidification causes increase in concentration of some nutrient elements, especially phosphorus.

### Concentration of nutrient elements in leaves

Concentration of micro and macro elements in cucumber leaves is presented in Figure 1. The results showed that the amount of nitrogen in cucumber leaves decreased by a decrease in the nutrient solution pH, but these variations in treatments did not show any significant differences at 5% level. Based on Illinoise University reports, decrease in soil pH causes decrease in nitrification process, as such, the best pH for nitrification process is 7. When the soil pH is obtained as 5.5, biological denitrification occurs, but when it is below 5.5, chemical denitrification occurs (Kinsolla, 2000).

The highest amount of potassium in cucumber leaves was observed in the treatment with nutrient solution, where the pH was obtained as 6.5 and it had significant difference at 5% level with other treatments. In this pH, potassium minerals in soil dissolve and thus available K in soil increase and leads to increase in K uptake by plants. The maximum uptake of K by plants was obtained in the pH range of 6 to 6.5. As a result, cucumber plant could uptake high amount of K with a pH of 6.5. Although potassium minerals in soil under treatment with pH 5.5 dissolves very fast and thus available K in soil greatly increases, but in this treatment, K uptake decreases by plant because $H^+$ ion accumulation in root rhizosphere causes a decrease in $H^+$ release of roots, and then K uptake by roots and its replacement by $H^+$ in roots decrease. The highest amount of phosphorus in cucumber leaves was observed in treatment with pH 6.5

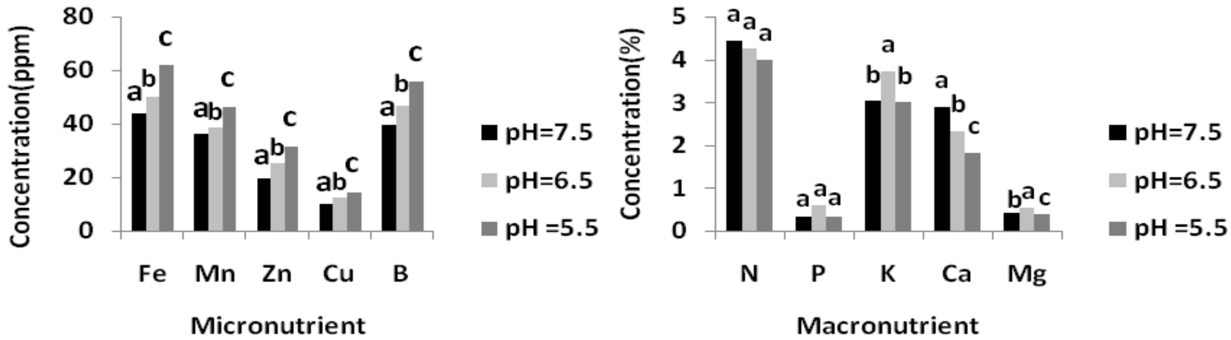


**Figure 1.** Macro and micro nutrients in leaf of greenhouse cucumber.

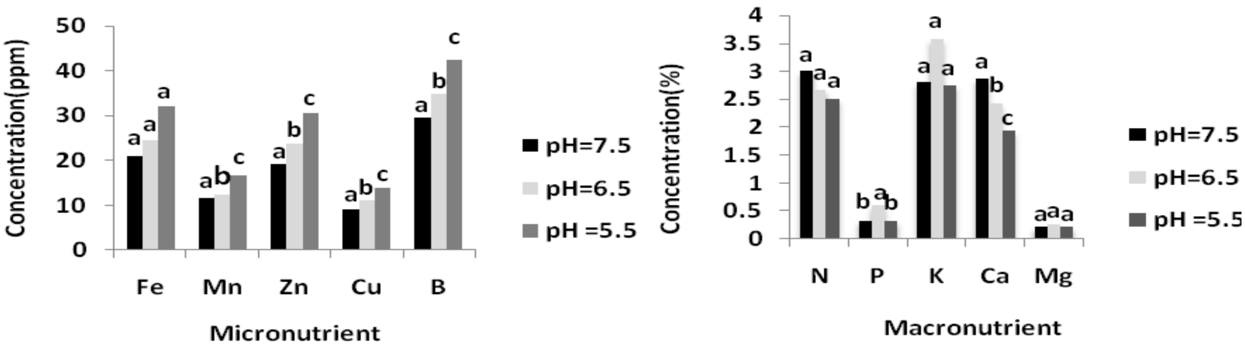


**Figure 2.** Macro and micro nutrients in fruit of greenhouse cucumber.

and it had no significant difference at 5% level with other treatments. The highest amount of available P in soil was observed in pH = 6.5, whereas the highest and lowest amount of pH for phosphate ion was precipitated with Ca and Fe or Al ions, respectively (Lindsay, 1991). Noorgholypoor et al. (2000) reported that acidifying irrigation water in corn planting caused an increase in corn yield and P uptake by plant. Ca concentration of cucumber leaves had significant difference under 3 levels of pH and the highest amount of Ca uptake occurred in pH = 7. The decrease in Ca uptake caused by decreasing pH can be related to some reasons: 1. acidification of rhizosphere which causes dissolution of Ca minerals and other minerals consisting of Ca such that Ca can be easily leached from the soil profile; 2. acidification of rhizosphere which causes a decrease in the active uptake of cations, especially Ca ion; and 3. soil acidification which causes an increase in K amount in the rhizosphere that leads to the creation of antagonismic relations between Ca and Mg ions with K (Barber, 1995). Most amounts of Mg in leaves were related to the pH treatment of 6.5 which had significant difference with other treatments. This case is related to the sufficient uptake of Mg in soil pH = 6.5 (Papadopolus, 1994), where antagonismic relationships were found between K and Mg.

The amount of Cu, Fe, B, Mn and Zn elements in leaves increased with decreasing pH in treatments and it had significant differences. The highest and lowest amount of micro elements in leaves was related to treatments with pH = 5.5 and 7.5, respectively. This was the reason why any micronutrient fertilizer did not add to the soil in all treatments. It means that soil acidification caused increase in dissolution of minerals containing micro elements. Availability of Fe and Mn in plants depends on the amount of pH + $p^e$ in soils, as such, if pH + $p^e$ is decreased in soils, available Fe and Mn increases (Lindsay, 1991). Absorbance of Boron by plants in $H_3BO_3$ form and increase in soil pH causes dissociation of $H_3BO_3$ and transformation of it into $H_2BO_3$ form (Barber, 1995), and finally decreases Boron uptake by plants. Hence, by increasing the pH, B uptake is decreased. The concentration of micro elements in cucumber leaves in pH treatment = 5.5 was almost similar with the sufficient level that was reported by Kreij et al. (1992); therefore, it seems soil acidification to a pH range of about 5.5 enhanced the provision of micronutrient requirements for cucumber plant. Fageria (1998) reported that decrease in pH of irrigation water caused increase in micro nutrient uptake.

## Concentration of nutrient elements in fruits

The concentration of micro and macro elements in cucumber fruit is presented in Figure 2. Results showed

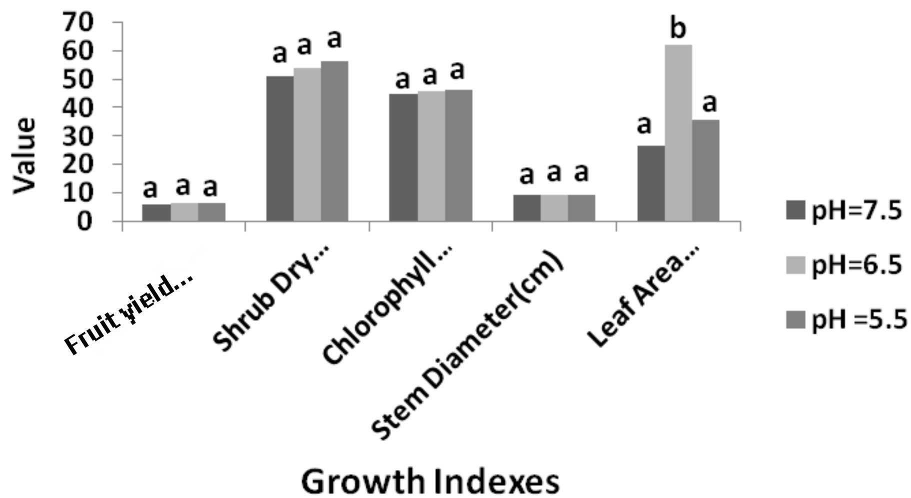


**Figure 3.** Growth indices assessment of plant under three treatments of pH.

that Nitrogen amount in cucumber fruit decreased with a decrease of the pH in nutrient solution, but these variations in treatments did not have any significant differences at 5% level. High amount of N in fruit was observed in pH treatment = 7.5 but decreased in 6.5 and 5.5 pH treatments. This may be related to the addition of $NO_3$ ion to the soil under the fertigation system that led to increase in $NO_3/NH_4$ ratio, and then by decreasing nutrient solution pH, some $NO_3$ ions transformed to $NH_4$ ions and $NO_3/NH_4$ ratio decreased as compared to that observed in the previous stage. These processes led to a decrease in N uptake by the plant having the highest amount of $NH_4$ ion in lower pH. The highest amount of phosphorus in fruit was in pH treatment = 6.5 and it had significant differences with other treatments at 5% level. The highest amount of available P in soil was observed in the pH range of 6.5, though the highest and lowest amount of pH for phosphate ions was deposited with Ca and Fe or Al ions, respectively (Lindsay, 1991). Nourgholypoor et al. (2000) reported that soil acidification caused increase in corn yield and P uptake by plant. On the other hand, N uptake as $NO_3$ is more in acidic pH and NO3 uptake puts a stop to phosphate uptake by plants at the end of plant growth stages (Kafkafi and Halevy, 1974; Johnson and Hickman, 1984). K and Mg concentration of cucumber fruit was the highest with pH = 6.5, but it had no significant differences at 5% level with other treatments. There was significant difference in Ca amount of cucumber fruit among treatments in 5% level and the highest and lowest amount of Ca were respectively related to pH = 7.5 and pH = 5.5. It was observed that Fe concentration in cucumber fruit had no significant differences at 5% level in different treatments, but by decreasing pH in treatments, the amount of Fe increased in fruits. Cu, Zn, Mn and B amounts in fruit affected by nutrient solution pH and their amounts had significant differences at 5% level in different treatments. The highest and lowest amount of these elements was respectively found in pH treatments of 5.5 and 7.5 since they decrease soil pH and increase the dissolution of minerals as well as the availability of Cu, Zn, Mn and B elements in plant. However, Gunes (2002) found that Zn concentration in fruit increased with decreasing soil pH.

## Some growth indices

Figure 3 shows that pH changes have an effect on optimal uptake of micronutrients but did not have any significant effect on fruit yield and shrub dry weight among the three treatments. However, fruit yield and shrub dry weight was obtained mostly in pH = 5.5 than in other treatments, thus, it has a better uptake of micronutrients in this pH. In 2008, Tyson reported that greenhouse cucumber can grow in pH ranges of 5, 6, 7 and 8 with leaf spray, but dry weight of plant stem, plant height and N and P amount in plant were similar during the 14-day period of planting in the pH range of 5 to 7. It was observed that leaf spray did not have any effect on fruit yield of cucumber in different amounts of pH. Early yield of cucumber plant was observed more in pH = 5 than in pH = 8, as such, the total yield was low in pH. Hochmuth declared in 2009 that the total expected yield directly followed the duration length of plant cultivation. Yield range was 1 to 3 lb for every plant per week and it was in the duration length of peak harvest.

Chlorophyll amount in leaves is an important index that determines photosynthesis rate. The obtained results of chlorophyll amount in cucumber leaves did not show significant difference among different treatments of pH at5% level (Figure 3). However, chlorophyll amount in cucumber leaf was more in pH = 5.5 than in the other two pH treatments. In 2006, Duchovskis et al. reported that chlorophyll amount of *L. esculentum* leaves that were under fertilizing treatment decreased by increasing the culture media alkalinity, while the highest amount of chlorophyll in leaves belonged to the growing plants in acidic media and in pH = 4.5.

Stem diameter is an important index for water uptake by plant which can determine plant transpiration rate. The relationship between the balanced temperature of leaf explaining the transpiration process and stem diameter shows turgesence of stem cells, nutrition of mineral nutrients, photosynthesis, transpiration, transportation and metabolism of photosynthetic products (Ilnitskaya et al., 1997). However, Figure 3 does not show significant difference among different treatments about stem diameter. It can be concluded that pH change in media had no effect on photosynthesis rate, transpiration, transportation and metabolism of photosynthetic products. Leaf area index (LAI) is a key for determining plant productivity which has much effect on water and energy exchange between the plant and atmosphere. Figure 3 shows that there is no significant difference in LAI among different treatments. The highest amount of LAI is related to pH = 6.5 because the highest amount of available nutrients for plant is observed at this pH of soil. Nonetheless, Christoph et al. (2006) reported that LAI of *Fagus orientalis* is basically observed under physiological factors, relating to plant age; though the effect of soil chemistry and precipitation are very low on LAI.

## Conclusions

Decrease in irrigation water pH caused increase of micronutrients concentration in cucumber leaf and fruit. As against the non-addition of micro fertilizers to soil, increase of $H^+$ ion in root zone caused an increase in the uptake of soil minerals containing micronutrients by plant. By acidifying soil, micronutrient uptake was increased by plant and the concentration of these nutrients increased to the optimum level in leaves and fruits. Because of high pH in alkaline soils, fertilizing micronutrients has low efficiency and causes waste of money. However, acidifying soils can provide plant nutritional requirements, control environmental pollution and decrease cost.

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