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Effect of organic waste and humic acid on some growth parameters and nutrient concentration of pistachio seedlings

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ABSTRACT

Pistachio crops in Iran are grown in soil with low soil organic matter. Therefore, a field experiment was conducted at Izadyaran Company, Sirjan, Iran to study the effects of municipal solid waste compost (MSWC), cow manure, and methods of humic acid application (soil and foliar) on growth parameters and nutrients concentration of pistachio seedlings in a complete randomized design with six replications for two years (2011–2013). Results showed that cow manure decreased the leakage percent and maximum leaf number and leaf surface area were obtained in MSWC with foliar application of humic acid and cow manure without humic acid, respectively. The highest chlorophyll b and carotenoid were observed in the second year with cow manure treatment whereas foliar application of humic acid increased total chlorophyll. Calcium (Ca) and iron (Fe) decreased in the second year. At the first year Cow manure application increased phosphorus (P) and manganese (Mn) but in the second year increased magnesium (Mg) concentration. MSWC at the first year increased copper (Cu) and zinc (Zn) concentration. Cow manure and foliar application of humic acid increased the Nitrogen (N) concentration in the first year. These results may have implications for pistachio production in arid and semi-arid soils.

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Introduction

Pistachio (*Pistacia vera* L.), which belongs to the Anacardaceae family, is an important and exportable nut crop cultivated in arid and semi-arid regions of Iran since ancient times. Enhancement of organic matter (OM) in sufficient quantity and quality plays an important role in agricultural production and soil sustainable management. The application of OM in soil to improve and increase soil aggregate stability, productivity, and fertility is essential, particularly in the arid and semi-arid regions of Iran, with very low soil organic matter content. MSWC is mostly made-up of kitchen and yard wastes, and its composting has been adopted by many municipalities (Otten 2001). MSWC production will decrease chemical fertilizers economically and environmentally (Zhang, Ervin, and Schmidt 2003). MSWC can be used as an alternative in sustainable agriculture and organic farming (Hargreaves, Adl, and Warman 2008). Additionally, cow manure only increases the OM content and biological activity in soil, but also acts as a nutrient pool, improves nutrient cycling, increases cation exchange capacity (CEC), buffering capacity, reduces soil compaction, and also improves other soil physical properties including aggregation, friability, density, root penetration, water-holding capacity and water infiltration (Walker, Clemente, and Bernal 2004). Humic acids are important soil components that can ameliorate nutrient availability, stimulate cell division, increase root development and can influence other

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important chemical, biological, and physical properties of soil. With applications of humic acids, plants become more resistant to diseases, by improving plant growth and nutrient uptake (Khaled and Fawy 2011). Humic materials are naturally occurring polymeric and organic compounds produced by the decay of OM found in soil (Sharif, Khattak, and Sarir 2002). Humic and fulvic acids can produce various morphological, physiological and biochemical effects on higher plants (Eyheraguibel, Silvestre, and Morard 2008). In many studies, humic and fulvic acids were reported to enhance mineral uptake (Mackowiak, Grossl, and Bugbee 2001), promote root growth (Canellas et al. 2002), and increase the fresh and dry weights of crops (Chen, De Nobili, and Aviad 2004).

However, little is known about the effectiveness of MSWC, cow manure and humic acid application on the growth of pistachio seedlings in the arid climate of Iran, particularly in field conditions. Therefore, the present study investigated the effects of two OM sources (MSWC and cow manure) and different methods of humic acid applications (soil and foliar) on growth properties and nutrient uptake ability of one-year-old, 10–15 cm long pistachio seedlings by analyzing nutrient (mineral) uptake of pistachio leaves for two years.

Material and methods

Orchard management

To assess the effect of cow manure, MSWC, and humic acid application on the growth and chemical composition of pistachio seedlings, the experiment was conducted in 2012 and 2013 at the Research Station of Izadyaran Company, 30 km south of Sirjan (55°40′ 0′ E and 29° 27′ 0′ N), Kerman province, Iran. The area climate was hot and dry with desert characteristics. The absolute annual maximum and minimum temperatures were 40 and −8 (°C), respectively. The annual rainfall average was 150 mm, which was concentrated in the Winter. Cow manure and MSWC were collected from Izadyaran field and Kerman municipal, respectively (Table 1). After tillage, the plots with dimensions of 3 × 7 m were prepared. Treatments (cow manure and MSWC) were applied to the plots with six rows, consisting of six adjacent pistachio seedlings on each row. For each seedling, one hole was dug up (55 cm length and 40 cm diameter).

Treatments

A field experiment in a randomized complete block design (split plot) with six replications was conducted under field conditions for two years. Two treatments were applied as follows: two organic wastes, MSWC and cow manure as the major factor, methods of humic acid applications (without humic acid (control), soil application (using 40 liters per hectare) and foliar application (spray) using 2.5 liters per hectare) as the subplot. A total of 36 treatments were performed. Liquid humic acid with the trademark HUMAX (humic acid: 12%, fulvic acid: 3% and potassium oxide: 3%) was obtained and used for two experimental years (36 × 2 = 72). Soil of some holes was mixed well with cow manure and others with MSWC as assigned for treatment combinations and one pistachio seedling (var. Badami-e-Sirjan, one-year-old) was planted at the beginning of March 2011and irrigated near field capacity level via drip irrigation. During the growth period, three months after planting, at first June days (2011), humic acid treatments were applied (for some seedlings soil application and others foliar application) and this treatment was repeated the following year (2012) in as determined upon the experimental plan.

Table 1. Some properties of soil, MSWC, and cow manure.

	N	OC	P	K	Fe	Mn	Zn	Cu
	g $100g^{-1}$		mg kg^{-1}					
soil	0.02	0.35	25	276	1.00	0.53	0.17	0.63
MSW	1.73	12.15	200	4200	4253	325	407	11.7
Cow	1.06	19.60	1240	25200	793	626	192	65.2

Measurements

Near the end of July, five months after planting, several plant growth parameters including stem height, leaf number, leaf area index, number and length of lateral branches, stem diameter, internodes distance, leaf area index were determined using five youngest, fully expanded leaves from the terminal shoots with a portable leaf area meter (model 3000, Li-Cor, Lincoln, NE, USA) in the field and leaf sampling was performed randomly, and transported to a laboratory. Leakage percent (Lutts, Kinet, and Bouharmont 1996), leaf total chlorophyll, chlorophyll a, chlorophyll b, and carotenoid contents were measured on an exponential basis, using the equations proposed by Arnon (Arnon 1949).

Nutrients analysis

Leaves were dried at 60°C for 72 h. The dried leaves were grinned and pass through a 40-mesh screen. One gram of plant materials was dry ashed at 550°C and extracted with 2 N hydrochloric acid (HCl) for macro and microelement analyses. The N % was determined by the Kjeldahl method (Bremner and Mulvaney 1965), P % was determined by the vanadomolybdophosphoric method (Kacar and Inal 2008), K % was determined by flame emission (Horneck and Hanson 1998), and Ca, Mg, Fe, Mn, Zn, and Cu nutrients were measured by atomic absorption spectrometry (Hanlon 1998).

Statistics

Statistical analysis was performed (SAS Inc., Cary, NC). The effect of treatments on plant growth and nutrient uptake were evaluated by ANOVA and mean separation procedure and Duncan's multiple range test (DMRT), at 0.05 levels of significance by using MS Excel (Microsoft Corp. Pullman WA).

Results and discussion

Growth parameters

Results indicated that the effect of cow manure on the leakage was different from those of MSWC. Cow manure decreased leakage by 10 more than MSWC (Figure 1). Foliar application of humic acid significantly improved total chlorophyll by 29% compared with the control (Figure 2); however, soil application of humic acid did not significantly influence the total chlorophyll and other parameters. Leaf number and leaf surface area significantly increased 53% and 28%, respectively, after one year (Table 2).

The effect of interaction between organic waste and humic acid application methods was significant on leaf number, and leaf surface area. The most number of leaves were determined in MSWC and foliar application of humic acid treatments. The highest value of leaf surface area was found in cow manure treatment without humic acid application (Table 3). The effect of interaction between time and humic acid application methods was significant on stem diameter, leakage, and chlorophyll a (Table 4). The highest value of stem diameter was found in the second year without humic acid application, and the lowest amount of leakage percent was measured in the first year without any significant differences between methods of humic acid application; however, the highest amount of chlorophyll a was obtained in the first year along with foliar applications of humic acid. Time and organic waste interaction was significant for total chlorophyll, chlorophyll a, chlorophyll b, and carotenoid contents of leaves (Table 5). In the second year, total chlorophyll and chlorophyll a had the lowest values under cow manure and MSWC treatments, respectively. By contrast, the highest levels of chlorophyll b and carotenoids were found in the second year with cow manure treatment. MSWC stimulates plant growth, indirectly and with a long-term effect, by improving the soil organic matter. Some studies have been conducted on Tunisian semi-arid climates showing improvement of soil morphological and chemical properties by MSWC treatment (Ouédraogo, Mando, and Zombré 2001). Apart from supplying nutrients, the application of organic substances, including cow manure, also provides growth-regulating substances (Sharma and Mittra 1988) and

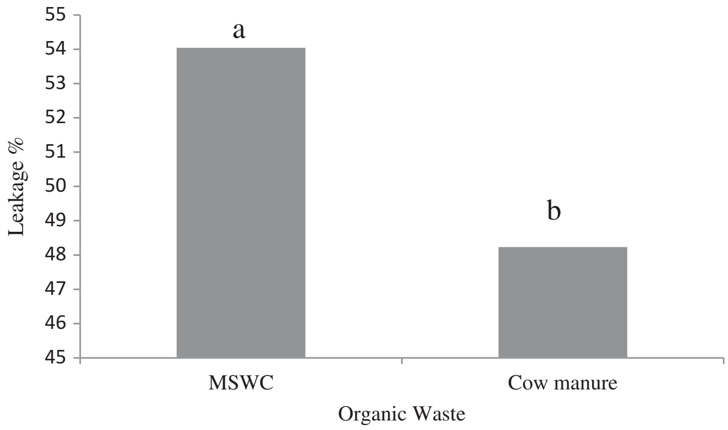

Figure 1. Effect of organic waste on the leakage.
Column with the same letters is not significantly different at P < 0.05 with Duncan's multiple range tests.

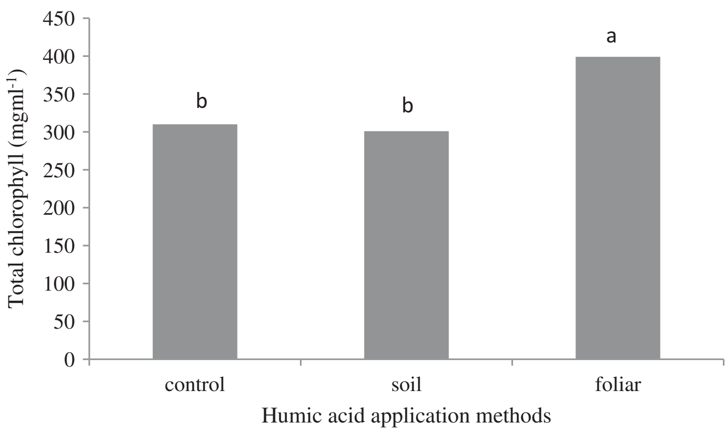

Figure 2. Effect of humic acid application methods on total chlorophyll content.
Column with the same letters is not significantly different at P < 0.05 with Duncan's multiple range tests.

Table 2. Effect of time on leaf number, leaf area, and Fe concentration.

year	Leaf number	Leaf area index (cm^2)	Fe ($mg\ kg^{-1}$)
1st	198^b	26.3^b	77.12^a
2nd	303^a	33.8^a	59.20^b

Values followed by the same letters within a column are not significantly different at the 5% level according to Duncan's multiple range tests (Each mean is an average of 36 seedlings).

improves the physical (El-Shakweer, El-Sayad, and Ewees 1998), chemical (Schjønning, Christensen, and Carstensen 1994), and microbial (Belay et al. 2001) properties of the soil. Researchers have shown that yield enhancement with cow manure application is attributed to the addition of NPK and other essential nutrients, as well as its desirable effect on the physical, chemical, and microbial properties of the soil (Prasad et al. 2002). The enhancement in some morphological properties may be attributed to increasing nutrient levels in MSWC and cow manure. This phenomenon continuously provides available nutrients in usable forms to the plants, consequently increasing growth and

Table 3. Interaction effect of organic waste and humic acid application methods on some growth parameters and nutrient concentration.

organic waste	humic acid	Leaf number	Leaf surface(cm^2)	P (g $100g^{-1}$)	N (g $100g^{-1}$)
MSWC	control	244^{b}	28.00^{cd}	0.12^{bc}	2.22^{b}
	soil	171^{b}	33.43^{ab}	0.12^{bc}	2.07^{b}
	foliar	420^{a}	30.62^{bc}	0.11^{cd}	2.25^{b}
cow manure	control	182^{b}	35.80^{a}	0.14^{a}	2.14^{b}
	soil	244^{b}	25.13^{d}	0.10^{d}	2.16^{b}
	foliar	246^{b}	27.29^{cd}	0.10^{d}	2.61^{a}

Values followed by the same letters within a column are not significantly different at the 5% level according to Duncan΄s multiple range tests (Each mean is an average of 12 seedlings).

Table 4. Interaction effect of time and humic acid application on some nutrient concentration.

year	humic acid	Stem diameter (cm)	Leakage (%)	Chlorophyll a (mg ml^{-1})	Ca ($g100g^{-1}$)	N ($g100g^{-1}$)	P ($g100g^{-1}$)
first	Control	2.39^{c}	28.23^{c}	196^{bc}	1.32^{a}	2.29^{bc}	0.13^{a}
	Soil	2.85^{b}	26.01^{c}	203^{ab}	1.34^{a}	2.33^{b}	0.10^{c}
	Foliar	2.06^{c}	18.93^{c}	300^{a}	1.11^{b}	2.73^{a}	0.09^{d}
second	Control	3.41^{a}	81.09^{a}	246^{ab}	0.90^{c}	2.08^{cd}	0.12^{ab}
	Soil	3.18^{ab}	70.10^{b}	142^{c}	0.99^{bc}	1.90^{d}	0.12^{b}
	foliar	3.11^{ab}	82.44^{a}	216^{bc}	0.96^{c}	2.13^{bcd}	0.12^{b}

Values followed by the same letters within a column are not significantly different at the 5% level according to Duncan΄s multiple range tests (Each mean is an average of 12 seedlings).

Table 5. Interaction effects of time and organic waste on physiological parameters and Mn concentration.

year	Organic waste	Total Chlorophyll	Chlorophyll a (mg ml^{-1})	Chlorophyll b	Cartenoied	Mn ($mgkg^{-1}$)
first	MSWC	395^{a}	245^{a}	137^{ab}	6.23^{c}	25.82^{b}
	Cow manure	362^{a}	239^{a}	121^{ab}	3.70^{c}	31.66^{a}
second	MSWC	236^{b}	146^{b}	103^{b}	44.06^{b}	20.92^{c}
	Cow manure	353^{a}	256^{a}	151^{a}	66.29^{a}	17.81^{d}

improving morphological parameters. These results may be illustrated by the postulated slow release and contiguous storage of nutrients from organic wastes, causing increased cell elongation, cell division, and leaf-area duration and thus promoting increased rates of chlorophyll content after a year. Some differences between our results and those of other studies may be ascribed to differences in the quality of MSWC and cow manure, as well as their level of decomposition, soil initial conditions, study duration and most importantly, pistachio physiology and morphology and its response to treatment, particularly in field conditions. Humic acid can produce various morphological, physiological and biochemical effects on higher plants and is made up of heterogeneous and complex molecules that are, ubiquitous in the environment (Chen and Aviad 1990). Numerous studies have shown that humic substances do not only increase root, leaf, and shoot growth but also stimulate the germination of diverse crop species (Piccolo, Nardi, and Concheri 1992). The explanation of these positive effects is related to the direct interaction of humic acid with physiological and metabolic processes (Nardi et al. 2002). Nutrient uptake was increased with the addition of humic acid (Linehan 1978), cell permeability and modified mechanisms involved in stimulation of plant growth (Vaughan and Malcolm 1985). Humic acid application has increased water consumption, confirming a significantly enhanced global plant growth and moreover humic acid seems to accelerate plant development (Eyheraguibel, Silvestre, and Morard 2008). Tahir (Tahir et al. 2011) indicated that application of humic acid at 60 mg kg^{-1} in both soils (calcareous and non-calcareous) affected plant height, shoot fresh weight, and shoot dry weight positively. However, the highest humic acid level (90 mg kg^{-1}) had a negative effect on the growth of wheat in both soils.

Our results suggest that humic acid improves the growth and development of the plant through increasing height, leaf number, and lateral branch number of the plant and generally improving its biomass synthesis efficiency. In the first year, foliar application of humic acid stimulated growth and increased the number of lateral branches, followed by the increase in leaf number and chlorophyll contents. The highest stem diameter was achieved in the second year. Soil application of humic acid was more effective than foliar application on lateral branch length. Investigation about the effects on plant development indicated a potential interaction (direct or indirect) with plant growth regulators. To illustrate these phenomena, humic molecules have been reported for their auxin-like activities (Muscolo et al. 1999). Our findings showed that humic acid increased the amount of chlorophyll a, and total chlorophyll. These results may be associated with the effect of humic acid in decreasing stress and promoting growth and leaf number. Researchers have also discovered a significant correlation between humic acid and leakage percent, which was used to indicate membrane permeability, and suggested that humic acid affect plant growth at the cellular level by influencing cell permeability (David, Nelson, and Sanders 1994). However, our study indicated that humic acid application did not significantly affect the leakage percent. Few studies exist on the use of humic substances for foliar application. In a field experiment, Govindasmy and Chandrasekaran (1992) sprayed humic acids extracted from lignite on sugarcane and found that the addition of humic acid improved sugar yield and nutrient concentration in leaf blades and sheaths. On the other hand, the yields of the cultivated crops were not significantly affected by the application of potassium humate because of the high amounts of humic substances (Khaled and Fawy 2011).

Leaf nutrients

MSWC and cow manure did not have significant direct effects on the nutrient concentrations. The interaction between time and organic waste was only significant for Mn concentration. The highest concentration of Mn was obtained in the first year with cow manure application (Table 5). However, previous studies have shown that MSWC is often reported to be less effective in supplying available N in the first year of application to the soil–plant system than inorganic mineral fertilizers (Eriksen, Coale, and Bollero 1999). Organic N mineralization in compost is dependent on many factors, such as C/N ratio of raw material, composting conditions, compost maturity, time of application, and compost quality (i.e., C/N ratio and C- and N-fractions) (Amlinger et al. 2003). Some scientists observed that soil P availability increased with the addition of MSWC; however, soil P retention decreased with increasing compost application because of the competition between organic ligands and P for sites on metallic oxides, as well as the formation of phosphohumic complexes, which can improve P mobility (Jimenez et al. 1993).

Several studies have shown 36% to 48% of total K in MSWC was available in plants (Soumare, Tack, and Verloo 2003). In blueberry leaves, Mg concentrations were also observed to increase with MSWC and proportionate to the application rate (Warman et al. 2004). Researchers found barley Mg concentrations appeared to decline with increased compost addition, and wheat Mg concentrations also increased with compost application rate but declined at the highest application rate (Rodd et al. 2002). Studies showed that plant Cu uptake, however, has been enhanced in corn, potato, squash, clover, basil, and Swiss chard, in which plants were grown in soils ameliorated with MSWC. The uptake of Zn by potatoes, Swiss chard, and basil grown in soil amended with MSWC has been reported (Zheljazkov and Warman 2004). MSWC application did not tend to enhance soil and plant Fe concentrations. MSWC compost applied at 100 Mg ha^{-1} and 35 to 140 Mg ha^{-1} did not increase available soil Fe concentrations, or clover and blueberry leaves compared with the control (Warman 2001). Iron concentrations in basil decreased when MSWC was applied at rates of 200 Mg ha^{-1} to 600 Mg ha^{-1}. Iron concentrations of lettuce were reduced when 20 Mg ha^{-1} MSWC was applied to a calcareous soil but increased when 80 Mg ha^{-1} was added. The largest portion of Mn in soil treated with MSWC was reported to be bound in the iron-manganese fraction, which is not available to plants (Zheljazkov and Warman 2004). Reduced plant availability of Mn usually exists as a result of MSWC addition because of the increase in soil pH associated with MSWC application (Warman et al. 2004). Our findings did not show any significant decrease or increase in nutrient uptake with MSWC and cow manure application. Many reasons were possible, such as the amount of MSWC and cow manure consumption, original source, step of maturity, and production of MSWC and cow manure. The shelf-life and physical and chemical properties of soil may have affected the availability of elements. The most important factors, however, included the properties of pistachio roots, elongation, and chemical root exudates, which influenced the nutrient uptake.

Results showed Fe (23%) concentration decreased in the second year (Figure 3, Table 2). With increasing plant growth and development after a year, the decrease in nutrient uptake may be attributed to the dilution effect (RazaviNasab, Tajabadi Pour, and Shirani 2014). Effect of time and humic acid interaction was similar to Ca, and P concentration. Maximum concentration was found in the first year when humic acid was not applied. The highest N accumulation was obtained in the first year along with the foliar application of humic acid (Table 4).

The effect of Interaction between organic waste and humic acid application methods was only significant on P and N concentration, but their trend was inconsistent (Table 3). The results showed that the highest P concentration was observed in cow manure and no humic acid treatment. However, cow manure and foliar application of humic acid caused the highest N concentration.

Triple effects of time, organic waste and humic acid application method were significant on the Mg, Cu, and Zn concentrations (Figure 3). The highest concentration of Mg was observed in the second year with cow manure without humic acid application, but it was not significant compared with other means. Maximum concentration of Cu and Zn were obtained in the first year with MSWC without humic acid application.

Cow manure stimulated root development and increased P and N concentration. Cow manure may cause partial decline of pH and lead to enhance P concentration. Cow manure also increased N accumulation because of residual ammonium compounds in manure, leading to enhanced root elongation and N concentration. Therefore, foliar application of humic acid caused increase in leaf number, more efficient photosynthesis, and consequently, more nitrogen concentration because of the synergic interaction between cow manure and foliar application of humic acid to N concentration. It seems that MSWC with two mechanisms avoid Cu precipitation and then increase Cu concentration; 1) complex Cu and 2) reduce pH. As previously mentioned, humic acid application resulted in high water consumption and increased water efficiency, leading to improved efficiency of biomass synthesis. According to Pinton (Pinton et al. 1999), the beneficial effects of humic substances on plant nutrition may be ascribed to the promotion of root development and simplifying nutrient absorption. Humic acid can also function as a chelating agent (David, Nelson, and Sanders 1994). Researchers (Demirkiran and Cengiz 2010) observed that humic acid positively affected P concentration. The probable reasons for these positive influences may be direct and indirect effects of organic materials in the soils such as an increase in P content of pistachio leaves, and a decrease in Cu content. High levels of P may be attributed to the low uptake of some micro-elements including Cu. Some scientists found that the increased nutrient uptake by the plants is affected by humic acid, can be partially ascribed to the enhancement in root growth. Humic acid increased the concentration of N, P, K, Mg, and Ca compared with the control (Nikbakht et al. 2008). Some scientists (David, Nelson, and Sanders 1994) concluded that humic acid may enhance the concentration of P indirectly by complex with Fe. Some researchers reported that humic acid application improves the uptake of most elements including N, P, K, Mg, Ca, Fe, and Zn (Fagbenro and Agboola 1993). These findings can be mainly attributed to the ability of humic acid to increase the permeability of cell membranes through its hormone-like activities (Zhang, Ervin, and Schmidt 2003). The high uptake of Fe and Zn is similar to findings by Sánchez-Sánchez et al. (2002). Scientists observed the simultaneous increases in Fe and P accumulation in tomato shoots, suggesting that humic acid may enhance the uptake of P indirectly by complexion with Fe. Researchers (Celik et al. 2010) found the highest uptake of N, P, Mg and Mn were found after the lower doses of

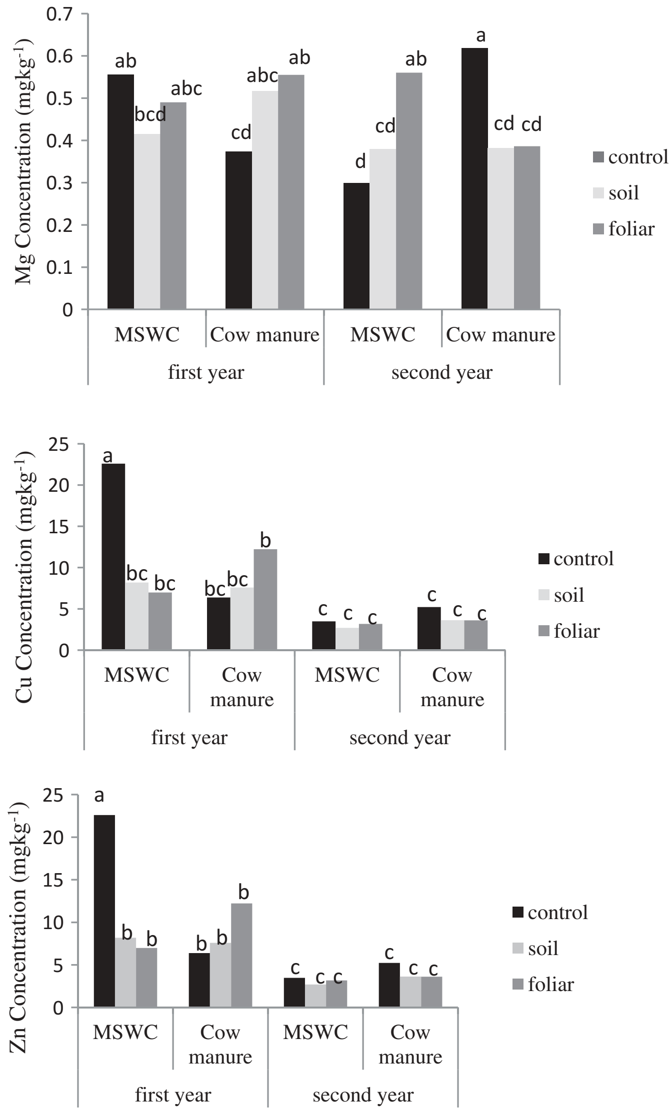

Figure 3. Triple effect of time, organic waste and humic acid application on some nutrient concentration.

Column with the same letters is not significantly different at P < 0.05 with Duncan ́s multiple range tests.

humus (1 g kg^{-1}) and the highest uptake of K and Ca were measured at higher doses of humus (2 g kg^{-1}) and Zn and Cu uptake were not affected by the higher doses of humus. Numerous hypotheses were proposed for the stimulatory effects of humic acid with the ability of chelating micronutrients and increasing their availability (Khaled and Fawy 2011). Few studies exist on the foliar application of humic substances. Scientists (Fernandez-Escobar et al. 1996) found that foliar application of leonardite extracts stimulated the shoot growth and promoted the accumulation of K, B, Mg, Ca, and Fe in olive leaves under field conditions. Several studies reported conflicting results on the effect of humic substances on plant nutrition. These conflicts may be partially related to the differences in soil, growing media, origin of humic acid and species treated by humic acid (Arancon et al. 2005). Fernandez (Fernandez-Escobar et al. 1996) indicated that when leaf N and K values were below the sufficiency range, the foliar application of humic substances did not enhance the accumulation of these nutrients in leaves. Katkat (Katkat et al. 2009) showed the soil application of humus had a statistically significant effect on the dry weight and mineral elements uptake of wheat, except Zn and Na. The highest dry weight and nutrient (N, P, K, Ca, Mg, Fe, Mn, Cu) uptake were obtained from 1 g kg^{-1} of humus treatment and the amounts decreased on 2 g kg^{-1} of humus application. Foliar application of the humic acid had a statistically significant effect on Mg, Fe and Mn uptake ($p < 0.01$). Although the dry weight and other nutrients were also affected, they were not found statistically significant. In our research, humic acid application did not significantly influence the nutrient concentration. These results may be caused by several reasons, such as doses of humic acid application (high and low concentrations of humic acid did not achieve desirable results). In addition, the physical, chemical and biological properties of soil and the climate condition affected the efficiency of humic acid application (soil or foliar), especially at the field condition. The decrease of P, Cu, and Zn concentration probably caused by the dilution effect accompanied with growth. Pilanali and Kaplan (Pilanal and Kaplan 2003) reported that calcareous soil declines the positive effect of the solid and liquid form of humic acid to uptake nutrient in the strawberry plant.

Conclusion

Pistachio is an important crop in the semi-arid areas of Iran. However, production regions are not only lacking in soil organic matter content, soil fertility, and productivity, but they also lack proper management of organic residues and maintenance of soil fertility, which are essential for optimum and sustained productivity. Thus, the optimal combination of OM, such as soil conditioning and humic acid application, as well as growth stimulators with direct and indirect effects, is necessary. Notably, humic acids are not fertilizers, but they are effective agents to complement with synthetic or organic fertilizers.

More importantly, the combination of MSWC and cow manure can increase the growth parameters and nutrient uptake if used in suitable amounts. The age, origin, quality, and maturity stage of MSWC and cow manure should also be considered. Foliar application of humic acid was more effective than soil application on growth parameters and nutrient uptake in the duration of this study. To enhance the efficiency of soil application, particularly at field conditions in semi-arid regions, humic acid doses should be increased. In Iran’s arid climate, a few preliminary studies have been conducted to assess the combined effects of MSWC and cow manure as an organic amendment. As such, humic acid as a growth stimulator and regulator can represent the most feasible fertilizer mixture specifically under field condition, which is also economical and agree with the aims of sustainable agriculture.

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