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Effect of Humic Substance Applications on Mineral Nutrition and Yield of Granny Smith and Jersey Mac Apple Varieties

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ABSTRACT

This study was conducted to examine the effect of soil, leaf and soil+leaf applications of humic substance on fruit yield, some quality parameters and mineral nutrition of Granny Smith and Jersey Mac apple varieties grafted on MM106 rootstock. The study was carried out for two consecutive years. According to the results obtained from both years, humic substance applications had no significant effect on fruit yield and quality parameters generally, but relative increases were recorded in yields. Leaf N, K, Ca, Fe and Zn concentrations were significantly affected from the applications. At the first year, humic substance application significantly affected only N and K concentrations of Jersey Mac variety, but in the second year, humic substance applications led to increase in leaf N, K, Ca, Fe and Zn concentrations in Granny Smith and N concentration in Jersey Mac apple variety. According to the results obtained, it can be said that the effects of humic substances were higher than the first year's effects mostly.

Keywords: Fruit productivity; Fruit quality; Humic material; Nutrient concentration

Humik Madde Uygulamalarının Granny Smith ve Jersey Mac Elma Çeşitlerinin Mineral Beslenmesine ve Verimine Etkisi

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ÖZET

Bu araştırma, MM106 anacına aşılanmış Granny Smith ve Jersey Mac elma çeşitlerinin verimi, kalitesi ve mineral beslenmesi üzerine humik maddenin toprak, yaprak ve toprak+yaprak uygulamalarının etkisini incelemek amaçlanmıştır. Deneme ardışık iki yıl yürütülmüştür. Araştırma sonunda, humik madde uygulamalarının meyvenin verim ve kalite ölçütleri üzerine genellikle anlamlı bir etkisi olmazken, meyve verimlerinde nisbi artışlar kaydedilmiştir.Yaprağın N, K, Ca, Fe ve Zn konsantrasyonları hümik madde uygulamalarından olumlu etkilenmiştir. İlk yıl, humik madde uygulamaları sadece Jersey Mac çeşidinin N ve K konsantrasyonlarını etkilemiştir. Buna karşılık ikinci yıl humik madde uygulamaların Granny Smith çeşidinin N, K, Ca, Fe ve Zn konsantrasyonlarını, Jersey Mac çeşidinin ise N konsantrasyonunu artırdığı görülmüştür. Elde edilen sonuçlara göre, humik madde uygulamalarının ikinci yıldaki etkisinin, birinci yıla oranla daha fazla olduğu söylenebilir.

Anahtar Kelimeler: Meyve verimliliği; Meyve kalitesi; Humik madde; Besin elementi içeriği

1. Introduction

Turkey is one of the most important apple producing countries in the world. Apple production in Turkey was estimated as 3.1% of the world apple production. Although, Isparta is a very important apple growing region with the production nearly 26% of the country (TÜİK 2014), the yield and quality is not satisfactory. There might be several factors for this, but one of the main reasons of this is unfavorable soil condition due to low organic matter, some nutrient deficiencies and unavailability of nutrients (Erdal et al 2004).

Soil fertility is defined as condition or state which the soil can supply sufficient amount of nutrient for healthy plant growth. Soil organic matter is an important soil component that increases and keeps sustainability of soil fertility by means of many physical, chemical and biological effects. Soil organic matter increases water and heat holding capacity, improves drainage, aeration and aggregation, increases microbial activity by means of decomposition products, improves soil pH, lime content, cation exchange capacity etc. With these properties, organic matter has an indirect effect on soil fertility and plant growth. At the same time, in terms of nutrients that release with mineralization, organic matter has a direct effect on soil fertility and plant growth.

Humic acid (HA) and fulvic acid (FA) contain humic substances (HS), namely humus, which is an important component of the soil organic matter. Because of the different contribution ways on plant growth, HS are used in different areas of agriculture (Chen & Aviad 1990). Owing to chelating properties of HS with metallic cations, availability of many nutrients increase and thus plant growth is affected positively (Stevenson 1994). Additionally, HS increase root and root hair growth leading to expanded root surface area and thus nutrient uptake capacity increases (Marschner 1995; Pinton et al 1999; Cesco et al 2002). A small part of lower molecular weight components in HS can be taken up by plants. With the hormone-like function, HS may increase cell membrane permeability. Addition of organic material may increase plant growth due to the effect of HS on nutrient in the soils (Chen & Aviad 1990). Positive effects of HS on plant growth, yield and plant nutrient uptake can be supported by the previous findings of numerous researchers (Erdal et al 2000; Pilanalı & Kaplan 2003; Çelik et al 2008; Morard et al 2011; Tahir et al 2011; Çimrin et al 2013; Cunha et al 2015). Although there are many studies showing the positive effect of HS on plant growth and plant nutrient uptake, negative or no effects of HS have been reported (Tahir et al 2011; Leventoglu & Erdal 2014). Rauthan & Schnitzer (1981) indicated that more than 300 mg kg^{-1} of FA showed reducing effect on plant growth and nutrition uptake and these effects was below the control treatment at the levels of 1500 and 2000 mg kg^{-1} FA. Similarly, reduction of plant growth has been observed at the higher dose of HS applications (Chen & Aviad 1990). Nikbakht et al (2008) reported the non-significant effect of high levels of HS on fresh and dry weights of leaves. At the same study, nutrient concentrations increases with lower HA, but the higher levels of HA negatively affected some nutrient concentrations.

This study aimed to investigate the effects of HS applications on yield and mineral nutrition of Granny Smith and Jersey Mac apple varieties.

2. Material and Methods

The experiment was conducted as a field experiment for two consecutive years, 2012-

2013 at Horticultural Research Institute, Egirdir, Isparta-Turkey. The experimental soil was clayey loam (Bouyoucos 1951) having pH of 7.74 (1:2.5 soil to water ratio), 3% $CaCO_3$, 3.35% organic matter (Jackson 1962), 34 mg kg^{-1} $NaHCO_3$ extractable P (Olsen et al 1954), 565, 4811, 1235 mg kg^{-1} 1N NH_4OAC exchangeable K and Ca and Mg (Knudsen et al 1982). DTPA extractable Fe, Cu, Zn and Mn concentrations (Lindsay & Norwell 1978) were 14, 13, 5 and 14 mg kg^{-1}, respectively. As basal fertilization, 30 kg ha^{-1} N, 42.2 kg ha^{-1} P, 40 kg ha^{-1} K were applied using ammonium nitrate, mono ammonium phosphate and potassium nitrate. Thirteen year-old Granny Smith (GS) and Jersey Mac (JM) apple varieties grafted on MM106 which are planted as 3.0x3.5 m were used as plant materials. As humic substance, "TKİ HUMAS" containing 12% HA+FA (pH: 12) was used. The experiment was planned according to randomized blocks with 5 replications and each replicate consisted of one tree. For soil application (S) 4 levels of humic substances (-HS, S1, S2 and S3) corresponding to 0, 50, 100 and 200 kg ha^{-1} were given to each tree root zone around the tree canopy. As foliar application (L), 2% of HS was applied three times with one week intervals in June. Soil applications were made in early spring. Applications were repeated in the second years.

In order to determine leaf nutrient concentrations, samples were collected from the four sides of trees from the present year's shoots (Bergmann 1992). Then, samples were brought to laboratory and washed with water, dilute acid (0.2 N HCl) and distilled water. Later, samples were dried at 65±5 C° for 2 days. Afterwards, samples were dried, grounded and wet digested with microwave oven. Total N was determined according to Kjeldahl method. Leaf P concentration was measured spectrophotometrically (Shimadzu UV-1208, 430 nm), K, Ca, Mg, Fe, Cu, Zn, and Mn concentrations were determined using atomic absorption spectrophotometer (Kacar & İnal 2008). Harvest of fruits was performed three times for JM in July and once for GS in October. Fruit weight, height and width were measured by digital scale and caliper with 20 randomly selected fruit from each tree. Fruit flesh firmness was detected from the two equatorial points of the fruit using hand penetrometer with 11.1 mm probe. Soluble solids content was measured using a digital refractometer. Pomological characteristics of the Jersey Mac apple fruits were conducted on the second harvest. Data was subjected to statistical analysis using Co Stat statistical software and the means were grouped using DUNCAN test.

3. Results

Although application of humic substance had no significant effect on fruit yield for both years, slight increases in fruit yield were recorded (Table 1). While the lowest yield was obtained from the control treatments for both varieties and two years, yields showed increment up to 19% and 8% for JM and GS cultivars, respectively. In general, fruit yields, fruit weights, heights and widths of JM and GS varieties were not affected from HS applications for both years, but in the second year fruit heights were negatively affected from soil+leaf applications (Table 2). According to the first year results, HS application did not affect fruit flesh firmness, soluble solids and pH for both varieties. However, fruit flesh firmness and soluble solids in JM variety were affected

Table 1- Effects of HS applications on yield

Applications	*Yield (kg tree^{-1})*			
	First year		*Second year*	
	JM	*GS*	*JM*	*GS*
-HS	26.8	40.0	27.8	41.8
S1	28.0	42.0	29.0	44.0
S2	28.9	42.4	30.0	44.4
S3	30.3	43.0	31.4	45.0
L	30.5	42.4	31.6	44.4
S1+L	31.6	43.2	32.8	45.2
S2+L	31.1	42.0	33.0	44.0
S3+L	31.2	41.6	32.4	43.6

JM, Jersey Mac; GS, Granny Smith

Table 2- Effects of HS applications on fruit weight, height and width

Applications	*Weight (g)*		*Height (mm)*		*Width (mm)*	
	JM	*GS*	*JM*	*GS*	*JM*	*GS*
			First year			
-HS	111	220	65	81	54	73
S1	122	210	68	80	56	70
S2	127	196	69	78	57	68
S3	132	219	69	80	58	71
L	124	225	69	82	52	70
S1+L	120	190	68	70	56	61
S2+L	111	191	65	73	53	67
S3+L	134	196	69	77	58	67
			Second year			
-HS	130	211	67	79 a*	56	70
S1	115	194	64	77 a	57	79
S2	126	205	68	79 a	58	69
S3	130	205	69	78 a	59	71
L	119	217	68	81 a	59	82
S1+L	127	201	68	69 d	61	73
S2+L	138	180	70	74 b	62	67
S3+L	120	202	66	73 c	58	64

JM, Jersey Mac; GS, Granny Smith; *, no significant differences between the same letters (P>0.05) in the same column; for each column, the numbers without letters indicate non-significance

Table 3- Effects of HS applications on fruit flesh firmness, soluble solids and pH

Applications	*Firmness (lb)*		*Soluble solids (%)*		*pH*	
	JM	*GS*	*JM*	*GS*	*JM*	*GS*
			First year			
-HS	7.7	8.7	9.8	9.3	3.1	2.1
S1	7.2	8.7	9.5	11.7	3.1	2.2
S2	7.2	9.1	9.1	11.4	3.0	2.2
S3	6.6	8.5	10.1	11.6	3.0	2.2
L	7.3	8.6	9.6	11.5	3.0	2.6
S1+L	7.6	9.4	9.8	12.9	3.0	2.3
S2+L	7.3	9.4	9.2	12.7	3.0	2.3
S3+L	7.2	8.3	9.9	11.5	3.0	2.3
			Second year			
-HS	6.2 b*	7.4	10.8 a	14.0	3.2	2.1
S1	7.1a	8.8	9.5 c	14.5	3.2	2.2
S2	6.8 a	7.4	9.1 c	13.5	3.3	2.2
S3	6.8 a	8.7	10.1 b	14.0	3.3	2.2
L	7.2 a	8.1	10.7 a	13.4	3.1	2.5
S1+L	5.9 b	7.9	10.7 a	13.4	3.1	2.3
S2+L	5.3 c	7.9	11.0 a	13.8	3.2	2.3
S3+L	6.0 b	8.3	10.6 a	13.8	3.1	2.3

JM, Jersey Mac; GS, Granny Smith; *; no significant differences between the same letters in the same column (P>0.05); for each column, the numbers without letters indicate non-significance

significantly from the applications at the second year (P<0.05). While individual effect of soil and leaf applications had a positive effect on fruit flesh firmness, negative effect was observed by combine application of soil and leaf. Soil applications had a negative effect on soluble solids amount, but leaf and soil+leaf combinations were ineffective. In the second year, HS applications did not affect flesh firmness, soluble solids and pH of GS apples (Table 3).

Effects of HS application on leaf N, P, K, Ca and Mg concentrations are summarized in Table 4. As can be seen from the table, only leaf N and K concentrations of JM were affected from the applications at the first year. In this variety, leaf N concentrations increased with the leaf and soil+leaf applications. In the second year, leaf N concentration of both varieties were affected positively from HS applications and leaf N concentrations of JM and GS varieties increased about 34% and 25% respectively (P<0.05).

For both varieties, soil+leaf combinations gave the best results in terms of leaf N concentrations generally. Leaf K concentration was affected positively from HS applications (P<0.05). For first year, it was observed that S2 and S3 applications and their combinations with leaf application had the higher effects than the other applications in JM variety. Furthermore, K concentration of GS

Table 4- Effects of HS applications on N, P, K, Ca and Mg concentrations of leaves (%)

Applications	*N*		*P*		*K*		*Ca*		*Mg*	
	JM	*GS*	*JM*	*GS*	*JM*	*GS*	*JM*	*GS*	*JM*	*GS*
First year										
-HS	2.33 c*	2.36	0.27	0.25	1.33 b	1.35	1.28	0.73	0.35	0.27
S1	2.37 c	2.20	0.28	0.24	1.37 b	1.33	1.26	0.85	0.35	0.25
S2	2.38 c	2.27	0.28	0.25	1.50 a	1.30	1.38	0.89	0.33	0.26
S3	2.44 b	2.34	0.29	0.26	1.46 a	1.29	1.29	0.91	0.32	0.27
L	2.64 a	2.25	0.28	0.25	1.33 b	1.43	1.31	0.96	0.32	0.27
S1+L	2.55 a	2.03	0.27	0.23	1.40 b	1.21	1.09	0.74	0.32	0.24
S2+L	2.56 a	2.13	0.29	0.25	1.49 a	1.25	1.28	0.78	0.31	0.27
S3+L	2.52 a	2.29	0.29	0.24	1.51 a	1.30	1.29	0.81	0.29	0.26
Second year										
-HS	1.46 c	1.50 c	0.29	0.20	1.46	0.58 b	1.63 a	1.09 c	0.42 a	0.26
S1	1.47 c	1.55 c	0.31	0.21	1.48	0.68 b	1.35 c	1.10 c	0.30 d	0.25
S2	1.84 a	1.72 b	0.33	0.28	1.44	1.06 a	1.87 a	1.26 b	0.36 b	0.29
S3	1.76 b	1.53 c	0.33	0.29	1.51	0.95 a	1.64 a	1.29 b	0.35 b	0.29
L	1.72 b	1.71 b	0.32	0.26	1.48	0.96 a	1.70 a	1.29 b	0.38 a	0.27
S1+L	1.86 a	1.87 a	0.30	0.25	1.55	0.96 a	1.34 d	1.30 b	0.33 c	0.25
S2+L	1.91 a	1.82 a	0.29	0.28	1.58	1.06 a	1.45 b	1.33 b	0.34 b	0.27
S3+L	1.96 a	1.83 a	0.29	0.25	1.57	1.15 a	1.56 b	1.38 a	0.38 a	0.26

JM, Jersey Mac; GS, Granny Smith; *; no significant differences between the same letters in the same column (P>0.05); for each column, the numbers without letters indicate non-significance

variety was not influenced from applications at the first year. Second year, effect of HS on K nutrition of GS was quite noticeable. As seen from the table, leaf K concentration of GS increased up to 2 fold with HS applications (except S1). Potassium concentration in JM variety was not affected from HS in this year. Additionally, in the second year, leaf Ca concentrations showed considerable increase with HS applications in GS variety. For leaf Ca and Mg concentrations of JM, it can be said that whether the effects of HS were similar to control or the effects of them were negative mostly. Effects of HS applications on Fe concentration of both apple variety in the first and the second years were significant ($P<0.05$). As can be seen from the first year's results, leaf Fe concentrations were the lowest at control treatments (-HS). However, leaf Fe concentrations with HS, especially soil+leaf applications, increased remarkably for GS and JM varieties. Effects of HS on Cu, Zn, Mn and B concentrations of two apple varieties were not significant in the first year. In the second year, leaf Fe concentrations increased with the some of the HS applications. In this year, leaf and soil+leaf applications had higher effects than that of others on leaf Fe concentration. Another important finding in the second year is that Zn concentration of GS showed noteworthy increment with soil+leaf combinations. Leaf Cu, Mn and B concentrations were not influenced significantly in this year (Table 5).

Table 5- Effects of HS applications on Fe, Cu, Zn, Mn and B concentrations of leaves (mg kg^{-1})

Applications	*Fe*		*Cu*		*Zn*		*Mn*		*B*	
	JM	*GS*	*JM*	*GS*	*JM*	*GS*	*JM*	*GS*	*JM*	*GS*
First year										
-HS	73 c*	76 b	12	11	29	15	17	22	36	34
S1	75 c	79 b	10	10	28	14	15	25	36	31
S2	82 b	78 b	11	10	27	14	14	22	38	33
S3	83 b	82 b	11	10	26	13	15	23	37	32
L	83 b	81 b	11	10	26	13	14	23	37	31
S1+L	92 a	95 a	11	10	26	14	14	35	39	29
S2+L	93 a	89 a	11	10	25	13	14	25	40	33
S3+L	95 a	91 a	11	11	26	14	15	26	39	31
Second year										
-HS	77 c	105 b	9	8	25	20 b	19	20	43	30
S1	76 c	100 b	7	8	19	20 b	21	20	35	30
S2	81 b	130 a	8	7	24	20 b	23	20	39	31
S3	75 c	109 b	7	7	18	22 b	18	22	38	30
L	92 a	124 a	8	6	19	23 b	23	23	39	30
S1+L	91 a	134 a	8	7	20	27 a	18	27	40	28
S2+L	86 b	132 a	7	7	20	27 a	21	27	39	29
S3+L	93 a	134 a	8	8	25	30 a	20	30	41	30

JM, Jersey Mac; GS, Granny Smith; *; no significant differences between the same letters in the same column (P>0.05); for each column, the numbers without letters indicate non-significance

4. Discussion

Except for the second year's fruit height of GS, humic substance applications did not affect fruit yield and quality parameters statistically for both years (P>0.05). Although relative yield increases were recorded for both varieties for two years, these increases were not significant. The effect of HS applications on mineral nutrition of apple varieties varied with the years. While only N, K and Fe were affected positively from HS applications in the first year, Ca and Zn were added to these nutrients in the second year. From these results it can be said that HS applications were more efficient in the second year. These results may be related to increment of organic matter content and mineralization at the second year (Demir & Çimrin 2011). In addition chelating properties of HS on some metals can play a role in increasing of Zn and Fe in leaf (Fallahi et al 2006). One reason for increasing of leaf K concentrations in leaves can be due to K concentrations that come from the KOH used for HS production. Increasing of Ca concentration in the leaves of GS variety can be explained with the promotion of Ca uptake with increasing of K uptakes by plants (Özkan & Yaman 2009). Some nutrient concentrations in leaves did not change with the HS applications. Similar results were found with the study conducted by Leventoglu & Erdal (2014) and they explained the ineffectiveness of HS under some soil conditions. Focusing on the nutrient concentrations of trees, it is clear that both varieties showed different respons to HS applications. As explained before, different plant varieties or even different genotypes of same variety can vary in terms of nutrient uptake even they grow in the same environment (Tsipouridis & Thomidis 2005; Jimenez et al 2007; Küçükyumuk & Erdal 2009; Küçükyumuk et al 2015). Although some nutrient concentrations of plants did not increase, residual nutrients in the soil decreased. One of these results can be related to dilution of nutrient in plant tissues due to increased vegetative growth with HS applications (Kolsarıcı et al 2005). The other reason may be transforms of nutrient to the insoluble forms as organo-mineral complex due to soil HS applications (Strickland et al 1979; White & Chaney 1980; De Nobili et al 2002). Moreover, in some studies it is indicated that HS can compete with the nutrients for root uptake (Chen & Aviad 1990).

Humic materials are generally applied to the soil, and affect the some physical, chemical and microbiological properties of it. However as found in this study, foliar sprays of these substances under field conditions increased the concentrations of N, K, Fe and Zn in leaves (Fernandez-Escobar et al 1996). Additionally, Brownell et al (1987) and Katkat et al (2009) indicated that spraying of leonardite extracts promoted the growth of tomato, cotton, grape and wheat. This growth promoting functions of HS, may be due to plant hormone-like materials in the HS (O'Donnell 1973; Casenave de Sanfilippo et al 1990).

In conclusion, effect of HS showed different behaviors on nutrients availability thus nutrient concentrations in plants. Although HS applications did not have positive effect on leaf P, Mg, Mg, Cu, Mn and B concentrations, leaf N, K, Ca, Fe and Zn concentrations were affected positively from the HS applications. The shape and degree of influence of HS on mineral nutrition of apples showed variation depending on the variety. Even though there was no statistically effect; proportional yield increases were obtained from both varieties with HS applications.

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