The Influence of Humic Acid Treatment on The Performance and Water Requirements of Plum Trees Planted in Calcareous Soil

S. El-Shall[1];W.M.Abd El-Messeih[2]; Nagwa.A. Abd El Megeed[2]and Okalebo J.[3]

ABSTRACT

Research was conducted at the Nubaria Horticultural Research Station, El-Bohira Governorate in Egypt's calcareous soil to determine the effect of humic acid amendments and flood irrigation scheduling on the development and growth of *Prunus domestica* L. (Kelsy plum). The research was conducted over a four year period beginning in 2005 when the plum fruit trees had developed for 2 years having budded on a *Mariana* rootstock. Tests were conducted during 2006- 2009 growing seasons.

The main and interacting effects of flood irrigation frequency and humic acid amendments were tested using a split-plot design experimental set-up. Kelsey plum was planted at a spacing of 4 x 5 m under a flood irrigation system in calcareous soils. The trees were irrigated under three regimes, which were: 5-day (I_1), 10-day (I_2) and 15-day (I_3) interval. The humic acid treatments (*thereafter referred to as* HA) included: humic acid soil application around tree's trunk (T_1), foliar application (T_2), soil and foliar application (T_3) and a control (T_4) whereby no humic acid treatment was made. HA treatments were applied on the months of April, May, June and July during each of the years (2006-2009). During 2006 and 2007 vegetative growth measurements and leaf mineral contents were measured. In 2008 and 2009 when the plum trees had attained maturation and had reached their reproductive stage, the fruit quality and yield were determined.

Each of the humic acid additions in either soil or foliar application method increased the physical attributes (vegetative) of the trees during the first and second seasons of growth relative to the control. The combined foliar and soil applications of humic acid (T_3) increased tree height and Trunk Cross-sectional Area (TCA); shoot number, length and diameter during 2006 and 2007 seasons compared to all other treatments. The largest combined effect of irrigation and humic acid treatments during the vegetative seasons (2006 and 2007)on the plum trees was observed for the T_3 I_2 treatment, followed by the T_3 I_1 and T_1 I_2 in that order. The vegetative growth parameters highlighted the importance of humic acid and its usefulness in increasing water use efficiency for the 10-day irrigation interval as compared to the 5-day interval. Foliar and soil humic acid treatment significantly induced high leaf contents of both macro- and micro- minerals (N, P, K, Fe, Mn and Zn). The soil mode of application T_1 was inferior to the foliar mode of humic acid application (T_2) during the growing seasons of 2006 and 2007.

In the two studied years 2008 and 2009, the highest yield with good fruit quality was obtained from trees under T_3, so it recommended.

INTRODUCTION

Prunus domestica (Kelsey plum) is a very popular deciduous fruit tree in Egypt. *Prunus* species with many varieties and do well in Egypt's Mediterranean climate. The plum trees have shown a lot of promise in Egypt's calcareous soils and other areas in Egypt that have been newly reclaimed. Calcareous soils are soils of high pH and essential nutrients to plants are trapped or unavailable to plants due to the excessiveness of $CaCO_3$. Calcareous soils are commonly found in mediterreanean, arid, semi-arid climates such as in Egypt. Over one half of a billion ha of soils in the world are calcerous (Laytem and Mikkelsen, 2005). Field crops as well as fruits are cultivated on these soils but producers are faced with the challenge of plant stress induced by the lack of micro-nutrients (Katkat *et al*., 2009). The soil fertility of these calcareous soils is limited by losses of nitrogen through ammonification and insolubility of phosphorus (Katkat *et al*., 2009).

In order to improve the quality and quantity of fruit from these plum trees, various varieties have been introduced that withstand drought and that are highly productive such as Kelsey plum. This variety is grown for its high market value and, attractiveness and its resistance to Plum pox virus (PPV). It has a high content of Vitamins A & C. There have been several studies conducted to increase the production of Kelsey plums. For example, Eissa, (2003) utilized biostimulants to improve the vegetative growth, yield, and fruit quality of Kelsey plums. The Total Soluble Content, fruit firmness and TSS content increased and the shelf-life of the fruit increased (Eissa, 2003).

Humic acid is a constituent of organic matter (Asik *et al*., 2009; Katkat *et al*., 2009). It is the most active fraction of humus coupled with fluvic acid. As early as 1930's, work was conducted on humic acid and its ability to stimulate plant growth. For example, Burk *et al*., (1931) conducted experiments whereby they

[1]Horticultural Research Institute ,Horticultural Research Center, Egypt.
[2]Nubaria Research station,Horticultural research Institute, Horticultural Center, Egypt.
[3]NaturaL Resource Dep. Nebrasca Univ. Lincolen (USA).
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concluded that "*The use of humic acid might permit satisfactory or improved growth under substantially neutral or alkaline conditions*." De Kock (1955) focused on iron deficient crops and reported that humic acid influences plant growth and development through its interaction with iron promoting increased plant uptake.

Later in the 20th century, increased work on humic acid shows that it promotes soil aggregation, water holding capacity of soils, nutrient availability to plant roots and helps in root development and growth (Lobartini, *et al.*,1997; Tan, 1998 and 2003; Nardi, *et al.*,2002, Chen *et al*., 2004)[a] . Humic substances have also been documented to improve micronutrient uptake of zinc and iron by plants (Chen *et al*., 2004a, 2004b; Elena *et al*., 2009). Additionally, humic acid forms complexes with some metals enhancing the availability of these micronutrients to root plants and improving their uptake (Chen *et al*., 2004a; Garcia-Mina *et al*., 2004). It improves water infiltration in soils that are clayey (Tan, 2003; Katkat *et al*., 2009).

Humic acids have been reported to improve the physical structure of soils, increase the cation exchange capacity, soil microbial activity and reduced losses of nutrients through leaching (Tan, 2003; Katkat *et al*., 2009). Additionally, humic acid has been utilized to remediate soils that are polluted (Kulikova et al., 2005) and reduce the effect of soil salinity on plant growth and development (Masciandaro et al., 2002). Several researchers have determined the positive impacts of humic acid on calcerous soils. For example(Katkat et al., 2009). reported that humic acid increased nitrogen, phosphorus, potassium, iron, manganese and zinc uptake. Additionally, humic acid stimulated an increase in wheat dry weight.

The main objective of this study was to evaluate the increased water use efficiency of plum trees subjected to different flood irrigation regimes and modes of humic acid application using vegetative growth and fruit quality parameters. The research attempts to determine whether humic acid can reduce irrigation frequencies while at the same time maintain and/or improving fruit quality and yield through deficit irrigation and humic acid soil amendments.

MATERIALS AND METHODS

Study Site:

The study was conducted at Nubaria Horticultural Research Station, El-Bohira Governorate, over four consecutive growth seasons beginning in 2006 to 2009**.**

Plant Description:

Prunus domestica L. (Kelsy plum) trees that had been grafted on *Mariana* rootstock were 2-years-old when they were transplanted to a field at a spacing of 4 x 5 meters apart. The trees were disease-free and have similar vigor. Normal agricultural practices recommended for Kelsy plum were applied throughout the experimental duration. The trees were treated with actosol®. a fertilizer whose NPK ratio is 10-10-10 and a Humic acid concentration of 2.9%. Humic acid is manufactured by ARCTECH Inc. in USA.

Experimental Design:

A total of 48 trees were planted to determine the main effects and interaction of two growth variables, namely, humic acid addition and irrigation frequency. Four modes of humic acid additions and three flood irrigation regimes were tested within a split plot experimental design replicated 4 times. Flood irrigation is commonly employed for horticultural field crops and fruit trees. Three watering regimes were tested and included: 5-, 10- and 15- day intervals between flood irrigation.

The modes of humic acid amendment application included:1) Direct soil application of the humic product at the rate of 40 ml per tree (T_1) 2) Foliar application of solution (250ml/100 liters of water) (T_2) 3) Direct soil and foliar application (40 ml per tree and application of 250 ml/100 liters of water) (T_3)and 4) Control (T_4).

Vegetative Growth:

Four uniform branches were selected and tagged at their cardinal points. The average number of new shoots in each of the branches was counted. The length and diameters of each of the shoots was measured in mid-November. Tree height and canopy diameter was measured late in November for the first and second seasons of the experimental duration (2006 and 2007). The trunk cross-sectional area (TCA) was calculated based on the two aforementioned seasons following the method described by Westwood (1988). The trunk diameter for each tree was measured 10 cm above the scion and rootstock union, on the first of March and late November during the two vegetative seasons.

Fruit quality and Yield:

During the month of July when the fruits matured, they were harvested. Harvesting was conducted during the first week of July (2008 and 2009).

Table A. Physical and Chemical Properties of the Experimental Calcareous soil*

Texture	pH	Total $CaCO_3$ (%)	EC (dS/m)	Organic Matter (%)
Sandy loam	8.5	32.55	2.12	0.52

*None saline soil (2.12ds/m) of low organic matter(0.52%) and high $CaCo_3$ content(32.55%).

Twenty mature fruits were picked at random from each tree to determine fruit quality. The average fruit weight was recorded (gm),firmness was determined according to Magness &Taylor.1925 pressure tester using a 5/16" plunger. Additionally flesh thickness, %Total Soluble Solids (TSS) content was measured using a hand-held refractometer. Titratable acidity (TA) was determined as a percent of malic acid using the method outlined in AOAC, (1980).

Leaf Mineral Composition:

The effects of flood irrigation intervals and humic acid application on leaf mineral status were tested during the first and second seasons of the experiment when vegetative development was occurring. Tmenty mature leaves were collected at random from each tree at the beginning of June during the 2006 and 2007 growing seasons. The leaves were rinsed thoroughly with tap water, thereafter with distilled water and dried under a constant temperature range of 70-80˚C in an electric air-drying oven. Each sample of dried leaves was ground to powder using a porcelain mortar to avoid contamination. A smaller sample of ground leaves of 0.3 gm was digested using H_2O_2 and H_2SO_4 following Evenhuis and Dewaard (1980). Aliquots were then taken for mineral determination. Total nitrogen(N) and phosphorus (P) were determined colorimetrically following Evenhuis(1976) and Murphy and Riley (1962), respectively. Potassium (K) was determined against a standard using air propane flame photometer following Chapman and Pratt, (1961). Iron (Fe), Manganese (Mn) and Zinc (Zn) were measured using a Perkin-Elmer Analyst Atomic Absorption Spectrophotometer Model 305_B. The concentrations of N, P and K were expressed as a percentage while those of Fe, Mn and Zn were expressed in parts per million (ppm) on a dry weight basis.

Statistical Analysis:

Data collected from each season were analyzed separately, the Least Significant Difference tests were conducted at 0.05 probability level to compare treatments averages (according to Snedecor &Cochran, 1990).

RESULTS AND DISCUSSIONS

Vegetative Growth:

The results reported here increase the evidence that points to the positive effects of humic acid on vegetative growth of plants (Table1). Each of the humic acid additions in either soil or foliar application method increased the physical attributes (vegetative) of the trees during the first and second seasons of growth relative to the control. The combined foliar and soil applications of humic acid (T_3) increased tree height and Trunk Cross-sectional Area (TCA); shoot number, length and diameter during the 2005 and 2006 seasons compared to all the other treatments. Noticeable tree diameter increment was recorded during the second year of study (2007). The soil application of humic acid (T_1) outperformed the foliar application (T_2).

Trees grown under the 10-day flood irrigation regime (I_2) were significantly superior to those of the 5-day (I_1) and 15-day (I_3) irrigation regimes. Superiority was based on the vegetative growth parameters during the two seasons of study. The largest combined effect of irrigation and humic acid treatments during the vegetative seasons (2006 and 2007)on the plum tree height was observed for the T_3 I_2 treatment, followed by the T_3 I_1 and T_1 I_2 in that order (Table 2). Rapid tree height (cm) increase was limited by water availability in all of the treatments. The highest shoot count, diameter and length were recorded for trees that received soil and foliar HA application together with a 10-day flood irrigation interval (Table 3). The shoot count for the T_3x I_2 treatment was almost twice that of the control. These results are similar to those of Fern?ndez-Escobar et al. (1996) who reported that olive trees growing in the field and treated with a foliar application of humic substances exhibited increased Fe content and increased shoot growth.

Leaf Macro and Micro Nutrients:

Several studies have been conducted to evaluate the effect of humic acid on plant nutrient uptake, have shown the positive benefits of humic acid. For example, Asik *et al*., (2009) in their study working with wheat, showed that the uptake of N increased with soil application. Foliar application increased, P, K, Mg, Na, Cu and Zn in saline soils. In this study, the leaf content of N, P, K, Mn, Zn and Fe increased when compared to the control and this had a direct effect on the fruit size and quality.

Leaf Macro Mineral Contents :

Nitrogen (%):

The effect of foliar application of HA (T_2) was more noticeable on the nitrogen content of fruit tree leaves than trees subjected to a soil application of HA (T_1). A combined application of HA to soil and foliage (T_3) produced results which were not significantly different than those of similar to that of (T_2) for both growing seasons. Foliage nutrient uptake was more pronounced for the trees with a rise as high as 0.11% in the (T_3) treatment that received flood irrigation water every 15 days (I_3).

Table 1. Effect of Humic acid and irrigation treatments on the vegetative growth of plum trees during 2006 and 2007 growing season

First season (2006)	Tree Height (cm)				Tree Diameter (cm)				TCA increase (cm^2)				Shoot Number				Shoot length (cm)				Shoot diameter (cm)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application																								
Soil	125.000	129.000	120.000	124.667	99.400	100.400	90.400	96.733	4.145	6.029	3.297	4.490	6.500	6.000	5.500	6.000	71.250	73.400	70.300	71.650	0.620	0.640	0.590	0.617
Foliar	122.000	127.000	118.800	122.600	92.300	95.300	91.400	93.000	2.763	3.297	2.355	2.805	5.500	6.500	4.500	5.500	65.130	67.130	64.130	65.463	0.610	0.630	0.590	0.610
Soil and Foliar	130.000	140.000	122.000	130.667	100.100	110.300	95.300	101.900	8.164	9.067	3.540	6.924	7.000	8.500	5.750	7.083	78.130	80.130	75.130	77.797	0.650	0.680	0.610	0.647
Control	115.000	119.000	112.000	115.333	88.400	90.400	85.000	87.933	1.601	1.789	0.879	1.423	4.500	4.500	4.000	4.333	50.130	52.300	49.130	50.520	0.550	0.550	0.530	0.543
Mean	123.000	128.750	118.200		95.050	99.100	90.525		4.168	5.046	2.518		5.875	6.375	4.938		66.160	68.240	64.673		0.608	0.625	0.580	
L.S.D.(0.05)																								
Irrigation		2.909				2.998				0.07 8				0.800				0.7 03				0.012		
HA		2.303				4.458				0.459				0.913				0.505				0.014		
Irrigation×HA		4.400				4.583				2.142				1.047				0.981				0.018		

Second season (2007)	Tree Height (cm)				Tree Diameter (cm)				TCA increase (cm^2)				Shoot Number				Shoot length (cm)				Shoot diameter (cm)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application																								
Soil	215.000	219.000	195.000	209.667	125.500	127.300	118.000	123.600	11.632	10.048	7.253	9.774	7.500	7.500	6.500	7.167	72.130	75.250	72.400	73.260	0.630	0.650	0.580	0.620
Foliar	212.000	217.000	193.000	207.333	122.600	124.400	117.500	121.500	11.882	12.779	7.034	10.565	6.500	8.500	4.500	6.500	67.170	69.250	65.250	67.223	0.620	0.640	0.600	0.620
Soil and Foliar	220.000	225.000	199.000	214.667	129.300	133.100	102.500	121.633	12.717	13.287	8.409	11.471	8.000	9.000	5.750	7.583	80.130	82.130	75.250	79.170	0.650	0.680	0.620	0.650
Control	190.000	191.000	159.000	180.000	115.000	116.500	99.000	110.167	5.935	13.287	2.512	4825	4.500	5.500	4.500	4.833	52.400	54.130	50.250	52.260	0.560	0.550	0.550	0.533
Mean	209.250	213.000	186.500		123.100	125.325	109.250		10.617	10.536	6.302		6.625	7.625	5.313		67.958	70.190	65.788		0.615	0.630	0.588	
L.S.D.(0.05)																								
Irrigation		2.079				5.891				0.638				1.124				1.200				0.014		
HA		1.994				4.000				0.539				0.685				0.621				0.011		
Irrigation×HA		4.936				6.107				1.362				1.433				1.966				0.025		

Table 2. Effect of Humic acid and irrigation treatments on the leaf macro-mineral content of plum trees during 2006 and 2007 growing seasons

First season (2006)	N (%)				P (%)				K (%)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application												
Soil	2.220	2.210	2.180	2.203	0.210	0.220	0.200	0.210	1.310	1.330	1.280	1.307
Foliar	2.100	2.100	2.000	2.067	0.190	0.190	0.180	0.187	1.290	1.320	1.240	1.283
Soil and Foliar	2.240	2.250	2.190	2.227	0.240	0.260	0.220	0.240	1.490	1.550	1.390	1.477
Control	1.770	1.800	1.750	1.773	0.160	0.170	0.170	0.167	1.240	1.210	1.210	1.220
Mean	2.083	2.090	2.030		0.200	0.210	0.193		1.333	1.353	1.280	
L.S.D.(0.05)												
Irrigation		0.022				0.014				0.024		
HA		0.024				0.016				0.015		
Irrigation×HA		0.042				0.016				0.059		

Second season (2007)	N (%)				P (%)				K (%)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application												
Soil	2.240	2.220	2.190	2.217	0.210	0.230	0.210	0.217	1.330	1.340	1.270	1.313
Foliar	2.140	2.150	2.110	2.133	0.200	0.200	0.180	0.193	1.310	1.320	1.250	1.293
Soil and Foliar	2.270	2.260	2.210	2.247	0.250	0.270	0.210	0.243	1.520	1.560	1.420	1.500
Control	1.820	1.840	1.780	1.813	0.160	0.180	0.160	0.167	1.250	1.210	1.200	1.220
Mean	2.118	2.118	2.073		0.205	0.220	0.190		1.353	1.358	1.285	
L.S.D.(0.05)												
Irrigation		0.027				0.009				0.023		
HA		0.024				0.012				0.016		
Irrigation×HA		0.120				0.020				0.047		

Table 3. Effect of Humic acid and irrigation treatments on the leaf macro-mineral content of plum trees during 2006 and 2007 growing seasons

First season (2006)	Fe (ppm)				Mn (ppm)				Zn (ppm)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application												
Soil	161.000	162.000	158.000	160.333	51.000	52.000	50.000	51.000	29.000	31.000	28.000	29.333
Foliar	153.000	155.000	149.000	152.333	47.000	49.000	44.000	46.667	27.000	29.000	25.000	27.000
Soil and Foliar	168.000	170.000	160.000	166.000	58.000	61.000	52.000	57.000	31.000	33.000	30.000	31.333
Control	145.000	144.000	139.000	142.667	42.000	42.000	40.000	41.333	21.000	22.000	19.000	20.667
Mean	156.750	157.750	151.500		49.500	51.000	46.500		27.000	28.750	25.500	
L.S.D.(0.05)												
Irrigation		2.109				1.929				2.069		
HA		3.132				1.482				1.249		
Irrigation×HA		2.627				2.941				1.645		

Second season (2007)	Fe (ppm)				Mn (ppm)				Zn (ppm)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application												
Soil	162.000	164.000	159.000	161.667	52.000	53.000	51.000	52.000	30.000	32.000	29.000	30.333
Foliar	154.000	156.000	150.000	153.333	48.000	50.000	45.000	47.667	28.000	31.000	27.000	28.667
Soil and Foliar	169.000	171.000	161.000	167.000	60.000	62.000	53.000	58.333	33.000	36.000	32.000	33.667
Control	144.000	145.000	137.000	142.000	43.000	41.000	39.000	41.000	21.000	21.000	19.000	20.333
Mean	157.250	159.000	151.750		50.750	51.500	47.000		28.000	30.000	26.750	
L.S.D.(0.05)												
Irrigation		0.594				1.009				0.912		
HA		1.875				0.994				1.269		
Irrigation×HA		2.518				3.224				1.257		

Phosphorus (P %):

Whenever P fertilizer is applied to calcareous soil, it results in the precipitation of Ca phosphates which inhibits plants from acquiring the nutrient (Sample et al., 1980). However, the results of the experiment show that treatment of plum Kelsey trees and soils increased P uptake. The phosphorus content of fruit tree leaves (%) that were treated with HA applied in the soil (T_1) was higher than that applied to the foliage. A combined application of HA to soil and foliage (T_3) produced the highest phosphorus content in both the growing seasons (2006 and 2007). Root nutrient uptake of phosphorus is higher for fruit trees. As shown below, the reduced rate of irrigation impacted the leaf phosphorus content especially for irrigation treatment I_3. This positive impact of humic acid on calcareous soils in increasing P availability has also been documented by Delgado et al., (2002) who expounded that organic matter "*slows the precipitation of poorly soluble Ca phosphates*" and a mixture of Humic-Fulvic Acid increases the efficiency of P fertilizers. Additionally, Fixen et al., (1983) and Havlin and Westfall (1984) noted that fluvic and humic organic amendments increased the efficiency of P fertilizers and the availability of soluble Ca phosphates.

Potassium (K%):

The effect of HA treatments on the potassium content of leaves was very similar to that in Nitrogen (discussed above). T_1 and T_2 were not significantly different in terms of the K% in leaves. The combined effect of HA on both foliage and soils, increased the K% content compared to the rest of the treatments for the 2006 and 2007 growing seasons. Water availability decreased the K content in leaves especially for the I_3 flood irrigation frequency.

Leaf Micro Mineral Contents:

Soil application (T_1) proved to be beneficial for root uptake of Iron, Manganese and Zinc during the 2 growing seasons. The combined application (T_3) induced the highest micro-nutrient content in leaves. It was evident also that the best irrigation rate for micro-mineral uptake as evidenced in micro-nutrient leaf content was I_2 (10-day interval) for all HA treatments. The leaf iron content increase can be explained by the fact that humic acid decreases the pH of soils thereby releasing inorganic and organic iron compounds which would otherwise have precipitated with high pH (Burk *et al*, 1931). Humic-metal complexes are very instrumental in increasing availability of micronutrients to plants (Pinto *et al*., 1999; Chen *et al*. 2004a, Chen *et al*. 2004b; Garcia-Mina, 2006; Elena *et al*. 2009). According to Burk *et al*. (1931), natural humic acid increases growth through the iron it contains. Burk *et al*, (1931) reported that humic acid may be classified as a stimulant that provides iron for nutrient and growth such that iron is more available when compared to other media. Adani *et al*., (1998) studying tomatoes, attributed stimulated growth and uptake of iron to the possibility of humic acid playing a major role in the reduction of Fe^{3+} to Fe^{2+} . Iron contained in humic acid may promote plant cell processes such as "respiration, nitrification, catalase activity" (Burk *et al*, 1931).

Additionally, Ozaki *et al*., (2003) conducting experiments with rice to determine how humic acid affects the uptake of radionuclides by rice plants. They determined that the humic acid that was adsorbed on the rice root surface attracted Mn and Zn such as that there were increased micro-nutrient amounts readily available for uptake by rice plants. They also discovered that the pH of the culture medium and the addition of humic acid, had an influence of Mn and Zn uptake such that uptake increased at pH 4.3 while uptake decreased at pH 5.3 (Ozaki *et al*., 2003). This is in agreement with results in this study where the Mn and Zn leaf contents were always lower for the control (no amendment) whose soils had high pH.

Tree Yield (kg):

During the first harvest season (2008), the average fruit tree yield values, were similar in the treatments where HA was applied to the soil (T_1) (2.224 kg) and when HA was applied to the foliage (T_2) (2.220 kg) (Table 4). The combined application of HA to both foliage and soil (T_3) resulted in the highest yield of 2.48 kg. In the following year, (2009), the yields for either soil or foliar HA application had increased by a factor of 1.9 while that of the combined application (T_3) had increased by a factor of 2.28. The tree yield of the control (no HA application) increased by a factor of 1.52. Several researchers have also determined the positive impact on HA on crop yield. Sangeetha et al., (2006) reported an increase in onion yields. Additionally Adani et al., (1998) and David et al., (1994), noted higher yields for tomatoes and nutrient uptake respectively. Govindasmy and Chandrasekaran, (1992) likewise determined that humic acid increased the growth rate, yields and sugar content of sugarcane.

Fruit weight (gm):

Data in (Table 4) indicates that (T_3) treatments recorded the highest mean fruit weight of 90.6 and 103.7 gm during the 2008 and 2009 harvest seasons respectively. Fruits grown under one mode of HA application (T_1) and (T_2), weighed 4.2 and 5.3 gm less than fruits grown under the combined treatment (T_3) in 2008. The difference in weight was more pronounced in 2009, when the fruits grown under (T_1) and (T_2)

weighed an average of 12.1 and 13.0 gm less than those of (T_3) in 2009.

Table 4. Effect of Humic acid and irrigation treatments on the yield and physical fruit quality of plum trees during 2008 and 2009 growing season

Third season (2008)	Tree yield (kg)				Fruit weight (gm)				Fruit polar diameter (cm)				Fruit equatorial diameter (cm)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application																
Soil	2.228	2.225	2.218	2.224	88.600	86.200	84.400	86.400	4.780	4.650	4.550	4.660	4.540	4.390	4.300	4.410
Foliar	2.224	2.221	2.216	2.22	87.200	85.100	83.600	85.300	4.710	4.590	4.510	4.603	4.450	4.340	4.260	4.350
Soil and Foliar	2.620	2.614	2.207	2.480	95.400	89.600	86.800	90.600	5.150	4.840	4.690	4.893	4.870	4.560	4.430	4.620
Control	1.970	1.965	1.960	1.965	80.300	77.000	75.200	77.500	4.330	4.160	4.060	4.183	4.100	3.930	3.840	3.957
Mean	2.261	2.256	2.150		87.875	84.475	82.500		4.743	4.560	4.453		4.490	4.305	4.208	
L.S.D.(0.05)																
Irrigation	0.106				0.509				0.118				0.115			
HA	0.131				0.627				0.146				0.142			
Irrigation×HA	0.357				1.706				0.396				0.385			

Fourth season (2009)	Tree yield (kg)				Fruit weight (gm)				Fruit polar diameter (cm)				Fruit equatorial diameter (cm)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application																
Soil	4.265	4.240	4.128	4.241	92.800	91.600	90.400	91.600	5.010	4.950	4.880	4.947	4.730	4.670	4.610	4.670
Foliar	4.255	4.221	4.209	4.228	91.400	90.800	90.000	90.733	4.940	4.900	4.860	4.900	4.650	4.630	4.530	4.603
Soil and Foliar	5.690	5.645	5.633	5.656	105.600	103.700	101.800	103.700	5.700	5.600	5.500	5.600	5.390	5.290	5.190	5.290
Control	2.995	2.985	2.965	2.982	85.600	84.700	82.900	84.400	4.620	4.570	4.080	4.423	4.370	4.330	4.230	4.310
Mean	4.301	4.273	4.256		93.850	92.700	91.275		5.068	5.005	4.830		4.785	4.730	4.640	
L.S.D.(0.05)																
Irrigation	0.215				0.588				0.146				0.133			
HA	0.265				0.724				0.180				0.163			
Irrigation×HA	0.721				1.971				0.491				0.445			

Table 5. Effect of Humic acid and irrigation treatments on the physical and chemical fruit quality of plum trees during 2008 and 2009growing season

Third season (2008)	Flesh Thickness (cm)				Fruit firmness (Ib/ I^2)				TSS (%)				Acidity (%)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application																
Soil	2.000	1.950	1.950	1.967	13.800	13.870	13.990	13.887	14.900	14.800	14.500	14.733	0.640	0.660	0.690	0.663
Foliar	1.980	1.930	1.890	1.933	13.770	13.850	13.950	13.857	14.900	14.700	14.300	14.633	0.640	0.650	0.680	0.657
Soil and Foliar	2.160	2.030	1.970	2.053	13.870	13.950	14.110	13.977	15.400	15.200	14.900	15.167	0.650	0.690	0.720	0.687
Control	1.820	1.750	1.710	1.760	13.990	14.120	14.330	14.147	13.300	12.900	12.200	12.800	0.600	0.630	0.650	0.627
Mean	1.990	1.915	1.880		13.858	13.948	14.095		14.625	14.400	13.975		0.633	0.658	0.685	
L.S.D.(0.05)																
Irrigation		0.076				0.086				0.216				0.039		
HA		0.094				0.106				0.266				0.048		
Irrigation×HA		0.255				0.289				0.724				0.130		

Fourth season (2009)	Flesh Thickness (cm)				Fruit firmness (Ib/ I^2)				TSS (%)				Acidity (%)			
Irrigation	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean	I_1	I_2	I_3	Mean
Mode of Humic Application																
Soil	2.100	2.080	2.050	2.077	13.820	13.880	14.000	13.900	14.800	14.800	14.600	14.733	0.650	0.670	0.690	0.670
Foliar	2.070	2.060	2.040	2.057	13.780	13.860	13.980	13.873	14.700	14.800	14.500	14.667	0.640	0.660	0.690	0.663
Soil and Foliar	2.390	2.350	2.310	2.350	13.890	13.980	14.160	14.010	15.500	15.300	15.200	15.333	0.660	0.680	0.730	0.690
Control	1.940	1.920	1.720	1.860	13.980	14.150	14.360	14.163	13.200	12.900	12.300	12.800	0.610	0.620	0.650	0.627
Mean	2.125	2.103	2.030		13.868	13.968	14.125		14.550	14.450	14.150		0.640	0.658	0.690	
L.S.D.(0.05)																
Irrigation		0.094				0.088				0.218				0.039		
HA		0.116				0.109				0.269				0.048		
Irrigation×HA		0.317				0.296				0.732				0.131		

Fruits grown under (T_4) were consistently smaller and weighed 14.5% and 18.6% less than those of (T_3) in the 2008 and 2009 harvest seasons, respectively.

Fruit polar and equatorial diameters (cm):

A soil and foliar application of HA (T_3) was superior to either the foliage application of HA (T_2) or the soil application (T_1) resulting in both longer fruit polar and equatorial diameter. The fruits grown under control treatment (no HA application) were always shorter by as much as 0.7 to 1.2 cm during the 2008 and 2009harvest seasons, when compared to those treated with HA.

Acidity %:

Acidity increases with decreased water availability (Table 5). There was a negligible increase in fruit acidity over the two harvest seasons, which was not significant (0.01%). Fruit acidity decreased slightly (0.01%) for the combined HA application irrigated at a 10-day interval. Additionally, fruits grown without any HA addition (the control), had a slight decrease in % acidity (0.01%).

Total Soluble Solutes (%):

The % of TSS of the fruit decreased with reduced flood irrigation water availability. It was noticeable that during the 2009 harvest season, the more frequent flood irrigation (5-day interval) resulted in a decrease in %TSS relative to that of the 2008 harvest season.

Flesh Thickness (cm):

Fruits that are irrigated every 15 days were generally less fleshy than those that were irrigated every 5 days. A HA application to both tree foliage and soil produced fruits that were more fleshy. During the 2009 harvest season, the flesh thickness of the fruits growing under combined tree foliage and soil HA application, increased between 10.65 – 17.26% when compared to those grown under a control that exhibited an increase ranging from 0.58-9.71% of that of the previous harvest season.

Fruit Firmness (Ib/I^2):

Reduced irrigation frequency yielded the highest fruit firmness for all the treatments. Control treatments exhibited the highest fruit firmness with each irrigation regime. However, HA application (T_3) and least water application (I_3) induced the highest increase in fruit firmness for 2008 and 2009 harvests as compared to the other treatments.

CONCLUSION

Vegetative Growth:

The results of this study indicate that soil application of HA (T_1) and foliar application (T_2) modes of HA increased the vegetative growth of the trees. However, the soil application was superior to the foliar application. The combined amendments, T_3 (soil and foliar application of humic acid) significantly increased the height and TCA of the trees and the number, length and diameter of the shoots during the 2006 and 2007 vegetative seasons. The effect of T_3 on tree diameter was observable during the second season.

Irrigation:

It was noticeable from the results that flood irrigation after 10 days was more effective than both the 5- (I_1) and 15-day (I_3) interval. The 15-day interval was detrimental to vegetative growth than the 5-day interval as shown by the results during the two tested seasons. The differences between treatments were significant.

Fruit Quality and Yield:

Fruit yield per tree reveals that the highest significant average fruit yield (kg) was obtained from trees grown under T_3 followed by those trees grown under T_1, T_2 and the control in that order. The differences between T_1 and T_2 were not significant. The data also clearly show that trees grown under I_1 and I_2 produced yields that were significantly higher than those grown under I_3 in 2008. In 2009, the differences between the irrigation regimes (I_1, I_2 and I_3) were not significant.

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الملخص العربي

تأثير معاملة حمض الهيوميك(HA)على السلوك والاحتياجات المائية لأشجار البرقوق المنزرعة فى الأرض الجيرية

سعد الشال، وصفى ماهر عبد المسيح، نجوى أبو المجد عبد المجيد، جان أوكاليبو

أجرى هذا البحث فى محطة بحوث بساتين النوبارية محافظة البحيرة لدراسة تأثير معاملةحمض الهيوميك (HA) وجدولة الرى بالغمر على نمو أشجار البرقوق صنف"كلزى". أجرى البحث على فترة أربع سنوات بدأت فى عام ٢٠٠٦ عندما كانت أشجار البرقوق فى عمر سنتان ومطعومة على أصل برقوق الماريانا وحتى عام ٢٠٠٩.

وكان نظام التصميم الإحصائى المستخدم هو نظام القطع المنشقة split-plot design

زرعت الأشجار على مسافة ٤×٥ متر فى أرض جيرية تحت نظام الرى بالغمر. كانت الأشجار تروى على ثلاث فترات هى: I_1 كل ٥ يوم، I_2 كل١٠يوم، I_3 كل ١٥يوم. وكانت معاملات الـ HA كما يلى:

T_1 إضافة أرضية من حمض الهيوميك للأشجار حول جذع الشجرة.

T_2 إضافة رشا على الأشجار.

T_3 عبارة عن T_1 + T_2 بالإضافة الى معاملة المقارنه Control (بدون إضافة حمض هيوميكHA).

أجريت معاملات ال HA خلال أشهر أبريل ومايو ويونيو ويوليو فى الفترة من ٢٠٠٦– ٢٠٠٩.

تم اخذ قياسات النمو الخضرى فى عامى ٢٠٠٦و ٢٠٠٧ وكذلك المحتوى المعدنى للأوراق بينما تم دراسة محصول الأشجار وصفات جودة الثمار فى عامى ٢٠٠٨ و ٢٠٠٩. أدت معاملات الHA سواء الأرضية أو رشا على الاوراق الى تحسين للنمو الخضرى مقارنة بالكنترول. المعاملة T_3 أدت الى زيادة مساحة مقطع الجذعTCA وعدد النموات الحديثة وطولها وقطرها خلال عامى ٢٠٠٦ و ٢٠٠٧ مقارنة ببقية المعاملات. وهذا أدى الى وضوح وفائدة الHA فى زيادة كفاءة استخدام المياه لفترة الرى كل ١٠يوم عند مقارنتها بفترة الرى كل ٥ يوم. T_3 أيضا أعطت محتوى عالى معنويا من N ، P، K، Fe ، Mn، Zn. وفى عامى الدراسة ٢٠٠٨ و ٢٠٠٩ أدت المعاملة T_3 الى الحصول على أعلى محصول وصفات جودة ثمار لذلك تمت التوصية بها.