academicJournals

Vol. 9(12), pp. 586-590, 30 June, 2014
DOI: 10.5897/SRE2014.5819
Article Number: 35E902C45701
ISSN 1992-2248 © 2014

http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

The effects of humic acid application upon the phosphorus uptake of the tomato plant (*Lycopersicum esculentum L.*)

Sezer Şahin[1]*, M.Rustu Karaman[1] and Naif Gebologlu[2]

[1]Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Gaziosmanpaşa University, Tokat, Turkey.
[2]Department of Horticulture, Faculty of Agriculture, Gaziosmanpaşa University, Tokat, Turkey.

Received 24 January, 2014; Accepted 4 June, 2014

Humic acid can transform mineral nutrients into available forms for the plants. High lime content, low organic matter content, high pH, low moisture content and insufficient profile characteristics all higher plant phosphorus uptakes and consequently regress plant growth and development. The present research was conducted to investigate the effects of humic acid treatments (H.A.) (0, 60, 120 mg/kg) on phosphorus use efficiency (PUE) (0, 50, 100 mg/kg P) of grape and pole tomato (*Lycopersicum esculentum L.*) varieties. Pot experiments were carried out in a glasshouse in randomized block design with three replications. As basic fertilization, 250 mg/kg N and 200 mg/kg K was applied to the pots. Plants were harvested when they had their 5th raceme. Dry matter yields, N, P and K contents were analyzed. Dry matter yields increased with humic acid and phosphorus treatments. Phosphorus contents also increased with increasing phosphorus doses. While humic acid and phosphorus treatments affected the potassium contents, Ca contents increased through only the humic acid application.

Key words: Humic acid, phosphorus use efficiency, tomato plant.

INTRODUCTION

Phosphorus is a macro-element that plays an important role upon the development of higher plants. Phosphorus has several functions in plants. It is a component of key molecules such as nucleic acids, phospholipids and ATP, and, consequently, plants cannot grow without a reliable supply of this nutrient (Daniel et al., 1998). P is also involved in controlling key enzyme reactions and in regulation of metabolic pathways (Theodorou and Plaxton, 1993).

Lime dissolves in neutral or acidic soils, but does not readily dissolve in alkaline soils and instead serves as a sink for surface-adsorbed calcium phosphate precipitation (Hopkins and Ellsworth, 2005). Moreover, high pH decreases the availability of phosphorus administered as low organic matter chemical fertilizer. Phosphorus is an efficient mineral upon the root development of the plant and poor root development is observed in case of insufficient supply of phosphorus.

*Corresponding author. E-mail: sezer.sahin@gop.edu.tr, Tel: +90 356 2521616, Fax: +90 356 252 14 8.

Significant yield losses are also experienced in plants which are not nourished with sufficient phosphorus, and the quality of crop is affected negatively, as well. Efficiency and beneficialness of phosphorus fertilizers can increase the solubility of phosphorus in soil solution.

Chemical formula of the soil organic matter is not specific due to its dynamic structure (Khaled and Fawy, 2011). Soil organic matter mainly includes humic and fulvic acid (Andriesse, 1988). Humic substances are deterioration-resistant heterogeneous natural resources that have high molecular weight and varying in colors from yellow to black (Akıncı, 2011). Humic substances in interaction with phosphorus in the soil can decrease the phosphorus fixation and increase the phosphorus uptake of plants (Hua et al., 2008).

Cation exchange capacity and soil productivity are increased through administering humic acid into soils and having positive impacts on mineral matter uptake of plant (Stevenson, 1994). Humic acid serves as a buffer at a broad pH interval and several micro-elements can be taken by the plants since the soil is neutralized (Yılmaz, 2007). The studies carried out on humic acids have revealed the necessity of using these substances in vegetative production. Commercial humic-fulvic acid treatments improve the phosphorus fertilizer use efficiencies (Delgado et al., 2002). Besides increasing the plant growth of squash, humic acid application also increased fruit yield and quality (Hafez, 2004). Humic acid treatments increased the total yield of watermelon hybrids (Salman et al., 2005). Together with increased root dry matter yields and plant heights, humic acid also increased the N. P, K, Ca, Cu, Mn, Zn and Fe uptake of maize plants (Eyheraguibel et al., 2008).

The present study was conducted to investigate the effects of humic acid applications upon phosphorus uptake of tomato plant in soils with high lime content under greenhouse conditions.

MATERIALS AND METHODS

This study was carried out in a greenhouse over experimental fields Gaziosmanpasa University in the year 2011. A pot experiment was conducted in completely randomized block design with three replications. Pots were filled with four kg of calcareous soil.Bandita and Bestona tomato varieties (*Lycopersicum esculentum L.*) were grown in pots. Each pot had a single plant.

Commercial liquid humic substance (TKI Humas; total organic matter 5%, total humic and fulvic acid 12% and potassium oxide 2%) was administered at 0.60, 120 mg/kg doses as the humic substance of the experiments. Phosphorus fertilizer was administered at 0, 50, 100 and 150 mg/kg P doses as phosphoric acid (H_3PO_4). As basic fertilization, 250 mg/kg N as ammonium nitrate and 200 mg/kg K as potassium nitrate were administered to the pots. For plant development, other nutrients were administered to each pot equally as they needed. When the leaves of the plants reached up to 5th raceme, they were harvested, dried to a constant weight at 68°C and their dry weights were determined.

The leaves of plant were combusted according to dry combustion method (Kacar and Inal, 2008). Plant N content was analyzed according to distillation method (Bremner, 1965) and P, K, Ca, Mg, and S contents were analyzed using ICP-AES (Perkinelmer 2100DV). In the experimental soil, texture (Gee and Bouder, 1986), soil $CaCO_3$ (Chapman and Pratt, 1961), soil pH (McLean, 1986), exchangeable potassium (Richards, 1954) and available P (Olsen et al., 1954), organic matter (Jackson, 1956) and available Fe, Zn, Cu and Mn contents in DTPA were determined (Lindsay and Norwell, 1978). Experimental soil has a clay-loam texture and has clay, silt and sand contents respectively of 31%, 33% and 36%. Lime content was 18.90%, pH (soil:H_2O = 1:2.5) was 8.15, organic matter content was 1.20%, available P content was 1.45 kg/da, CEC = 36.90 me/100 g and exchangeable K content was 200 mg/kg. DTPA soluble Fe, Cu, Zn, and Mn contents were 2.05, 1.02, 0.11 and 3.65 µg/g, respectively.

Variance analysis of the obtained data was performed using the MSTAT-C statistical software and the differences between the means were determined by Duncan's multiple range test (Düzgüneş et al., 1978).

RESULTS

Dry matter yields and P contents

The effects of different doses of humic acid and phosphorus treatments on dry matter yields of Bandita and Bestona tomato species and variance analysis results are presented in Tables 1 and 2. Humic acid treatments had significant impacts *($p<0.05$)* on dry matter yields of Bandita and Bestona tomato species. Through the humic substance treatments, dry matter yield of Bandita tomato species increased from 25.8 g pot^{-1} to 34.3 g pot^{-1}. Compared to control treatment, humic substance treatments also significantly increased the dry matter yields of Bestona tomato species (from 18.3 to 26.3 g pot^{-1}).

Phosphorus treatments also resulted in significant increases in dry matter yields of tomato species ($p<0.01$). The highest dry matter yield of Bandita and Bestona tomato species in 150 ppm P application was respectively observed as 49.5 g pot^{-1} and 43.6 g pot^{-1}. The effects of humic substance x phosphorus interaction on dry matter yields of tomato species were also found to be significant ($p < 0.01$).

The effects of humic acid treatments on phosphorus contents of tomato species were not found to be significant (Tables 1 and 2). In both tomato species, foliar P contents did not significantly change with humic acid treatments. However, phosphorus doses had significant ($p<0.01$) impacts on P contents of the leaves (Tables 1 and 2) and increasing P contents were observed with increasing phosphorus doses. The highest P content in Bandita tomato species was 1.69% in 100 mg/kg P and 120 mg/kg H.A treatment and the highest P content in Bestona tomato species was 1.65% in 150 ppm P and 60 mg/kg H.A treatment. Exploited phosphorus amounts showed parallelism with phosphorus contents of the plant for both tomato species (Tables 1 and 2).

N, K, Ca, S, and Mg contents of tomato plants

Humic substance and phosphorus treatments did not

Table 1. The effects of humic acid and phosphorus treatments on dry matter yield and macro nutrient contents of Bandita tomato species.

H.A ppm		Bandita phosphorus treatment (mg/kg)				Average
		0	50	100	150	
	0	14.3	29.4	23.3	31.1	25.8
Dry matter yield (gr/pot)	60	19.4	28.1	38.2	49.5	36.1
	120	28.3	35.8	43.2	44.1	34.3
	0	0.36	0.85	1.09	1.21	0.87
P (%)	60	0.48	1.10	1.26	1.23	1.01
	120	0.39	1.25	1.69	1.47	1.20
	0	51.4	250.1	254.1	375.1	232.3
Total P, mg/pot	60	93.1	306.3	475.1	607.6	370.1
	120	110.3	457.6	733.9	648.2	487.1
	0	3.00	2.91	3.19	2.83	2.98
N (%)	60	3.17	3.20	3.16	2.87	3.07
	120	2.75	3.33	3.26	3.06	3.10
	0	2.60	3.60	3.72	3.28	3.30
K (%)	60	3.66	4.32	4.36	3.54	3.97
	120	3.46	3.91	4.20	3.99	3.89
	0	1.72	1.51	1.42	1.85	1.62
Ca (%)	60	1.96	2.30	2.24	2.14	2.16
	120	2.48	2.06	2.43	2.12	2.27
	0	0.20	0.13	0.14	0.13	0.15
S (%)	60	0.12	0.21	0.13	0.21	0.17
	120	0.21	0.20	0.24	0.17	0.20
	0	0.90	0.80	0.61	0.85	0.79
Mg (%)	60	0.79	0.95	0.80	0.86	0.85
	120	0.92	0.87	0.91	0.83	0.88

Dry matter yield: H.A.:*, P.A.:**, HA x PA:*; P content: H.A.: N.I.,P.A.:**, HA x P.A:N.I.; Total P: H.A.:*, P.A.:**, HA x PA:*; K content: H.A.:**, P.A.:**, H.A x P.A.: ** Ca content: H.A.:**, P.A.:N.I, HA x P.A.:N.I.; NI: Not Important; * $P<0,05$ and ** $P<0,01$, $P<0,001$ possibility are important.

have significant effects on nitrogen contents of tomato species (Tables 1 and 2). On the other hand, H.A. and treatments had significant impacts on K contents of tomato plants at 1% level (Tables 1 and 2). Considering the averages, potassium content of Bendita tomato species increased from 3.30% to 3.97% through the humic acid treatments. In Bestona species, potassium content increased from 3.59 to 3.98% with the humic acid treatments. Similarly, it was also noticed that K contents of both species increased with phosphorus applications. According to research results, it was seen that as a result of the increase at vegetative development the plant produced at low phosphorus, the plant benefited more from the administered potassium.

While the humic acid treatments had significant ($p<0.01$) effects on calcium contents of the plants, phosphorus treatments did not result in any significant impacts on calcium contents. Ca content of Bandita tomato species was observed as 1.62% in H 0 mg/kg treatment, 2.16% in H 60 mg/kg and 2.27% in H 120 mg/kg treatment. Ca contents of Bestona tomato species were, respectively observed as 2.08, 2.31, and 2.11%.

Table 2. The effects of humic acid and phosphorus treatments on dry matter yield and macro nutrient contents of Bestona tomato species.

H.A ppm		Bestona phosphorus treatments (mg/kg)				Average
		0	50	100	150	
	0	11.8	16.3	20.1	24.9	18.3
Dry matter yield (gr/pot)	60	13.2	19.2	19.4	33.0	21.2
	120	16.6	17.9	27.0	43.6	26.3
	0	0.36	1.22	1.23	1.64	1.11
P (%)	60	0.32	1.30	1.65	1.51	1.19
	120	0.36	1.13	1.41	1.30	1.05
	0	42.8	198.2	333.2	408.3	245.8
Total P (mg/pot)	60	42.8	253.6	327.2	500.5	281.1
	120	59.7	202.2	283.4	566.8	227.2
	0	3.11	2.88	2.98	3.25	3.05
N (%)	60	2.94	2.87	3.10	3.28	3.05
	120	3.02	3.52	3.27	3.12	3.23
	0	3.33	4.02	3.54	3.49	3.59
K (%)	60	3.67	3.92	3.98	3.42	3.75
	120	3.86	4.08	4.14	3.86	3.98
	0	2.23	2.39	1.81	1.90	2.08
Ca (%)	60	2.97	2.10	2.16	2.01	2.31
	120	2.25	1.92	2.09	2.18	2.11
	0	0.22	0.19	0.23	0.16	0.20
S (%)	60	0.23	0.23	0.24	0.27	0.24
	120	0.26	0.21	0.21	0.23	0.23
	0	0.76	0.78	0.81	0.84	0.79
Mg (%)	60	0.76	0.88	0.90	0.89	0.86
	120	0.88	0.88	0.87	0.91	0.88

Dry matter yield: H.A.:*, P.A.:**, HA x PA:*; P content: H.A.: N.I.,P.A.:**, HA x P.A:N.I.; Total P: H.A.:*, P.A.:**, HA x PA:*; K content: H.A.:**, P.A.:**, H.A x P.A.: ** Ca content: H.A.:**, P.A.:N.I, HA x P.A.:N.I.; NI: Not Important; * P<0,05 and **P<0,01, P<0,001 possibility are important.

Finally, humic acid and phosphorus treatments did not have any significant effects on sulfur and magnesium contents of tomato plants.

DISCUSSION

Compared to the control treatment, humic acid treatments resulted in significant increases in dry matter yields of tomato plants. Previous studies also reported significant positive impacts of humic substance treatments on dry matter yields of different plants (Hafez, 2004; Salman et al., 2005; Eyheraguibel et al., 2008). Functional groups of humic molecules form complexes with metals through various means (Livens, 1991). These functional groups provide percolation of cations in soils and serve as natural chelate in soils. Stable complexes of humic substances with metal ions are related to these functional groups. Humic substances have high cation exchange capacity, thus metals in soils can form chelates with humic acids. Humic substances may hold the existing and externally applied soil minerals and consequently enrich plant growth and development. The increases in dry matter yields of the present study may also be related to these functions of humic substances. Increasing foliar phosphorus concentrations were observed in this study with increasing phosphorus doses. Plant phosphorus uptake from the soil is directly related to dry matter yields of the plants. Exploited amount of phosphorus was higher in Bestona than Bandita tomato species. Effects of humic acid were more distinctive in this case.

Conclusions

The present results revealed that tomato dry matter yields significantly increased with humic substance treatments and such results comply with the findings of the previous studies (Hafez, 2004; Türkmen et al., 2004; Akıncı, 2011). P treatments also significantly increased P contents of the leaves and dry matter yields of the plants at 1% level. High pH, high lime and low organic matter content of experimental soil might have restricted the phosphorus uptake and the effects of these characteristics could clearly be inferred from the results of the study.

K and Ca contents of the plants also increased through the humic acid treatments, but significant effects were not observed on other minerals. These findings comply with the results of previous studies (Eyheraguibel et al., 2008; Mohamed, 2012). It was concluded in this study that the organic sedimentary compounds such as humic acids administered to the rhizosphere part of the plant roots after plantation increased the nutrient uptakes of the plants. Moreover, phosphorus treatments also enriched root development and growth.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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