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EFFECT OF POTASSIUM HUMATE APPLICTION AND IRRIGATION WATER LEVELS ON MAIZE YIELD, CROP WATER PRODUCTIVITY AND SOME SOIL PROPERTIES

Awwad, M.S.; K.S. El-Hedek, M.A. Bayoumi and T.A. Eid
Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt.

ABSTRACT

An experiment was conducted to study the response of Maize to irrigation levels with or without potassium humate on yield and yield components of maize (Zea. mays L., cv. single cross) and soil properties after harvesting. Maize was sown at Giza Agricultural Research Station, Agriculture Research Center, Giza Egypt, during summer season of 2013. The experiment was arranging spilt plot design with three replications. The experiment involved two factors, potassium humate (0, 5, 10 and 15 kg fed^{-1}) allotted to main plots and irrigation levels (100%, 75% and 50% of field capacity) allocated in sub plots. The results showed among irrigation levels treatments, W1 recorded the highest values of all studied traits of maize plants included plant height, shoot diameter (cm), Length of Ear (cm), No. of rows ear^{-1}, weight of 100 grain (g), dry shoot (kg/ fed.), grain yield (kg/fed.) and biological yield (kg/fed.) and harvest index (HI%). Likewise, N, P, K, Fe, Mn and Zn content and its uptake showed the same trend. On the other hand, water stress resulted in a significant decrease in these parameters. Concerning water use efficiency, the highest values were achieved with irrigation level (W1) compared to the other irrigation levels (W2 and W3). Results also illustrated that plants received 15 kg fed.$^{-1}$ potassium humate produced the highest values of the corresponding parameters than those in the control. In addition, plants received irrigation levels W2 or W3 combined with potassium humate registered the highest values of corresponding parameters compared to the irrigation without application potassium humate. Furthermore, potassium humate application were highly significant effect on improving soil characteristics, such as some available macro and micronutrients in soil, soil pH and EC, wet sieving stable aggregates and aggregation index, as compared to control treatment. The potassium humate at high level was superior on increasing abovementioned values. Potassium humate treatments under different irrigation levels were a more improving soil characteristics especially under W1 followed by W2 and W3 irrigation treatments. it can be concluded that irrigation level W1 and application of potassium humate with 15 kg fed^{-1} resulted in the highest yield and yield attributes, WUE and some soil properties. Also, application of potassium humate with deficiency in the amount of water irrigation led to gave the highest values of the former parameters compared to the transaction referred in the addition without.

keywords: irrigation levels, Potassium humate, properties' soils, Maize crop

INTRODUCTION

The production of crops depends on some factors for plants growth such as water, light and nutrients. Drought is one of the important stress factors, therefore, for global food security and agriculture production, many efforts are needed to develop strategies for improving plants resistance to drought. Humic acid is one generally characterized by relatively higher carbon contents, higher molecular and higher aromatic ring condensation. Also, humic acids contain relatively higher amounts of basic amino acids, but relatively lower amounts of acidic amino acids (Sowden *et al.,* 1979). Lab experiments on crop plants indicate that the use of humic substances as media amendments or foliar sprays can promote greater root and shoot growth; root branching; leaf chlorophyll content; rates of nutrient uptake, photosynthesis and respiration (Chen and Aviad, 1990). Humic acid is considered to increase the permeability of plant membranes and enhance the uptake of nutrients. Also, emphasize significant effect of humic acids on yield and yield components of wheat (Khan and Mir, 2002).

Drought is one of the most important factors to limit agriculture crops including maize in the world and especially in Egypt. Potassium humate increases the crop quality significantly and it increases stability of plant against alive and non-alive stresses (Gadimov *et al.,* 2007). Humates possess extremely high ion-exchange capacities, which allow them to hold cations in a way that makes them more easily available to plant roots and thus improve micronutrient transfer to the plant's circulation system. HA is particularly effective when added with banded fertilizer at the time of planting.

Maize (*Zea mays* L.) is the third most important cereal crop after wheat and rice all over the world as well as in Egypt. Maize grain is extensively used for the preparation of corn starch, corn syrup, corn oil dextrose, corn flakes, gluten, grain cake, lactic acid and acetone which are used by various industries such as textile, foundry, fermentation and food industries. With the development of poultry and livestock industry, its consumption in the feeds has also increased tremendously. Maize is one of the earning grain crops and in the world it is perhaps the most versatile. It is used in the human diet in both fresh and processed forms.

The current work aims to study the effect of different irrigation levels combined with potassium humate on some soil characteristics and maize yield and its components as well as water use efficiency.

MATERIALS AND METHODS

A field experiment was conducted on a clay soil at Agric. Res. Station at Giza, Governorate, Egypt, during the summer season of 2013. The soil sample at depth (0-30 cm) of the experimental area was taken to analysis and determine some physical and chemical properties according to the standard methods (Jackson, 1967). The data of analyses are presented in Table 1. The soil moisture constants (% per weight) and bulk density (Mg/cm^3) at depth of 0 -6 0 cm are shown in Table (2 a). Also, some chemical characteristics of potassium humate are found in Table (3).

Table1: Physical and chemical properties of soil under study

Properties	Value	Properties	Value
Sand (%)	**27.48**	**Available micronutrients (mg kg^{-1})**	
Silt (%)	34.22	Fe	6.71
Clay (%)	38.30	Mn	6.52
Texture	loamy Clay	Zn	4.68
$CaCO_3$ (%)	4.56	Soluble ions(me/L)	
EC (dS m^{-1})	2.96	Ca^{++}	13.8
pH (1:2.5)	7.88	Mg^{++}	10.2
Organic Matter (%)	2.29	Na^+	4.3
Available macronutrients (mg kg^{-1})		K^+	0.68
N	3.33	HCO_3^-	5.2
P	5.50	Cl^-	8.0
K	360	SO^{--}_4	15.78

Table 2a: Soil moisture characteristics

Depth	Field capacity (FC)		Wilting Point (WP)		Available water (AW)		Bulk density (BD) Mg/m^3
	% by weight	Cm	% by weight	cm	% by weight	cm	
0-15	37.9	6.99	18.6	3.43	19.3	3.56	1.23
15-30	35.8	6.39	17.8	3.18	18.0	3.21	1.19
30-45	32.1	6.12	16.1	3.07	16.0	3.05	1.27
45-60	31.7	7.32	15.9	3.67	15.8	3.65	1.54
Total		26.82		13.35		13.47	

The experimental design was arranged in a split plot design, where irrigation treatments were devoted to the main plots at rates of 100%, 75% and 50% of field capacity and the sub main plots were potassium humate at rates of 0, 5, 10 and 15 kg potassium humate /feddan. and some chemical properties of potassium humate are shown in Table 3. Application of calcium superphosphate (15% P_2O_5) and potassium sulfate (48 % K_2O) at rates of 30 kg $fed.^{-1}$ and 48 kg $fed.^{-1}$, respectively, for each plot before sowing with soil preparation. Ammonium nitrate (33.5% N) was added at rate of 120 kg N $fed.^{-1}$, at three equal doses, i.e., 15, 40 and 60 days from planting.

Climatic condition:

The meteorological data including T: air temperature (^oC), W.S: wind speed (m/ sec); R.H.: relative humidity (%); S.S: actual sun shine (hour); S.R: solar radiation (Mg^2/ cal / m). RF: rainfall (mm / month) during the two years of study had been daily recorded and their monthly mean values are presented in table (2b). *[Data were obtained from the agro meteorological Unit at SWERI, ARC]*

Table (2b): Meteorological data in 2013

Season							2013	Evaporation Pan	
	T. max	T. min.	W.S	R.H.	S.S	S.R	R.F	mm/ day	mm/month
May	35.5	18.0	4.1	32.1	10.5	585	0.1	6.31	195.6
Jun.	37.2	20.1	4.2	33.5	12.4	627	0.0	7.44	223.2
Jul.	37.2	20.3	4.0	39.0	11.9	613	0.0	8.16	252.9
Aug.	38.1	21.3	3.3	38.0	11.1	577	0.0	7.57	234.7
Sep.	35.2	19.8	3.8	44.5	10.3	512	0.0	5.95	178.5

The irrigation intervals for each treatment is the number of days in which the cumulative pan evaporation (CPE) should be approximately equal to the estimated water amount of the considered treatment. This depends on the weather conditions of the studied area. The irrigation treatments were imposed after the crop foliage nearly covered the ground (Jensen and Middleton 1965 and Eid *et al.,* 1982).

Water consumptive use (CU):

Water consumptive use or actual evapotranspiration (ETc) values were calculated for each irrigation using the following formula (Israelsen and Hansen 1962).

$$WCU = \sum_{i=1}^{i=4} \frac{(\theta_2 - \theta_1)}{100} \, X \, Bd \, X \, D$$

Where:

WCU= seasonal water consumptive use (cm),

Θ_2= soil moisture content after irrigation (on mass basis, %),

Θ_1= soil moisture content before irrigation (on mass basis, %),

Bd= soil bulk density (g/cm^3),

D= depth of soil layer (15cm each), and

i= number of soil layer.

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to 60 cm. Soil samples were collected just before each irrigation, 48 hours after irrigation and at harvest time.

Water Use Efficiency (WUE)

In the present trial, water use efficiency was estimated as kg grain yield per m^3 water consumed according to Jensen (1983) as follows:

$$WUE = \frac{\text{yield (kg)/feddan}}{\text{Water consumptive use (m}^3\text{/ fed.)}}$$

Table 3: Some chemical characteristics of potassium humate

EC dS m^{-1}	pH	OM%	Humic acid %	Macronutrients (%)			Micronutrients (mg kg^{-1})		
				N	P	K	Fe	Zn	Mn
0.26	7.30	63.00	85.00	2.14	0.12	12.00	550	147	198

At harvest time, the following data were recorded on 10 plants taken at random: plant height, shoot diameter (cm), length of ear (cm), no. of rows ear^{-1}, weight of 100 grain (g), dry shoot (kg/ fed.), grain yield (kg/fed.) and biological yield (kg/fed.) and harvest index (HI%). Suitable portion of the plant materials (shoot and grain) were oven dried 70 ^{0}C, thereafter chemically analyzed to determine their contents of macro and micronutrients according to Chapman and Pratt (1961). Surface soil samples (0 – 30 cm) were collected after harvesting air – dried, ground, good mixed, sieved through a 2m sieve and analyzed for some chemical properties and also its content of some macro-and micronutrients, pH, electrical conductivity (EC) and available N, P , K, Fe, Mn and Zn were determined as described by Black (1965); Jackson (1967) and Soltanpour (1985). The percent of soil in water-stable aggregates was assessed by a wet-sieving method (Cambardella and Elliott 1994). The differences between the means of the different treatments were compared by using L.S.D test at 5% probability according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Plant growth parameters:

The data regarding the plant height, shoot diameter, length of ear, diameter of ear and weight of 100 grains as influenced by different amounts water and potassium humate levels are presented in Table 4.

Among irrigation levels, the above mentioned parameters were increased significantly with the amount of irrigation water. In the case of W1, the plant height was maximum (195.00 cm) followed by 161.00 and 171.23 cm in W2 and W3, respectively. This was probably because healthy crop at higher moisture level as water is important for cell division and cell enlargement by increasing turgidity of cells. As regarding to potassium humate levels, longest plant height (219.00cm) was observed with potassium humate at rate of 15 kg $fed.^{-1}$ followed by 213.58 cm at rate of 10 kg $fed.^{-1}$, 195.42 cm at rate of 5 kg $fed.^{-1}$ and shortest plant height (175.91 cm) was obtained with application of potassium humate at rate of (control). The combined effect of W1 with 15 kg $fed.^{-1}$ potassium humate gave the highest value of plant height (260.00 cm). The data shown the shoot diameter (cm) as effected by application of irrigation water and potassium humate levels are presented in Table 4. Among the irrigation levels, maximum shoot diameter (5.89 cm) was obtained with treatment (W1) followed by 3.56 cm with treatment (W2) and (W3) (2.69 cm) respectively. These results are harmony with those of Nesmith and Ritchie (1992) who found that water deficit effects is reducing cell development by incomplete cell turgid and therefore water stress caused diameter reduction.

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The application of potassium humate at rate of 15 kg $fed.^{-1}$ produced the maximum shoot diameter (6.84 cm) followed by potassium humate at rate of 10 and 5 kg fed (6.52 and 6.02 cm), respectively. The interactive effect of (W1 with potassium humate at rate of 15 kg $fed.^{-1}$) also achieved the highest value of shoot diameter (8.18 cm). These results are quite in line with those of Mohammadipour *et al.,* (2012) who showed that the application of humic acid enhanced the plant growth parameters.

The importance of ear length is evident from the fact that it influences directly the final grain yield. The data exhibit the ear length as influenced by irrigation water levels and potassium humate rates is represented in Table 4. Among irrigation levels, maximum ear length (15.00 cm) was recorded under W1 treatment followed by 10.59 cm with W2 treatment and W3 (10.00 cm). The application of potassium humate at rate of 15 kg $fed.^{-1}$ produced the maximum value of ear length (19.17 cm) followed by 10 kg $fed.^{-1}$ (18.51 cm) and 5 kg $fed.^{-1}$ (16.58 cm) which were significantly compared to the control treatment which produced the minimum ear length (11.86 cm). The interactive effect of (W1 with potassium humate at rate of 15 kg $fed.^{-1}$) also gave the highest ear length (22.23 cm). Data concerning the number of rows per ear is presented in Table 4. In case of treatment W1, the number of rows per ear (13.00) were maximum followed by number of rows per ear (10.48) and (10.02) for W2 and W3, respectively. In the case of potassium humate application, the application of 15 kg fed^{-1} produced the highest number of rows (11.44) per ear followed by 10 kg $fed.^{-1}$ and control which having the lowest number of rows per ear. Maximum rows per ear 14.00 were attainted in relation to (W1 x potassium humate at rate of 15 kg fed.-1). The enhancing effect of increasing irrigation water levels on plant growth can be explained by the fact that water is a major constituent of growing plant tissues and many biochemical processes. Water has a crucial role in the process of photosynthesis and acts as a translocation agent of organic and mineral constituents. Hence, the size and turgor of the cells increase, resulting in increases of vegetative growth. On the other hand, the restriction of growth under water deficits was reported by Sharp (1996). Generally, growth is cell division and cell enlargement with water absorption, which is limited under the lowest irrigation rate (50% of field capacity). Growth reduction is the result of decrease of photosynthesis, where inhibition of net photosynthesis is closely correlated with leaf water potential and stomatal closure. Metabolic inhibition of photosynthesis under water stress may also result in part from lower diffusion of CO_2 across the leaf mesophyll (Flexas and Medrano, 2002).

Data on 100- grain weight as influenced by irrigation and potassium humate are shown in Table 4. Among irrigation levels, 100 grain weight was the highest 30.23 g in the case of W1 which followed by 25.38 g and 22.34 g for treatment W2 and W3, respectively. 100-grain weight increased with the increasing level of potassium humate. The highest value of 100 grain weight (33.50 g) was achieved by application of 15 kg $fed.^{-1}$ potassium humate followed by 31.90 g in case of treatment 10 kg $fed.^{-1}$ potassium humate and 29.09 g in case of 5 kg $fed.^{-1}$ potassium humate, respectively. These findings are in conformity with those of Navigeh *et al.* (2012) who stated that application of 2% potassium humate at the vegetative and reproductive stages under drought conditions increased 100 seed weight. The interaction showed that a maximum 100 grain weight (38.58g) obtained by application W1 with potassium humate at rate of 15 kg fed.$^{-1}$. Data in Table 4, depicted that the effect of irrigation level and potassium humate application at different rates on shoots and grain yields of maize plants, concerning to irrigation water levels the results indicated that the highest values of shoot and grain yields (4752.19 and 3353.56 kg), respectively were achieved with W1 treatment. However, the lowest values (3597.60 kg and1185.05 kg) were obtained by W3. Reduction of yield over 50 percent as a result to stress in corn reported by Wydianatha and Tandon (2001).

In the case of potassium humate, the highest values of shoot and grain yields (5448.26 kg and 4163.93) were obtained by application of potassium humate at rate of 15 kg fed.$^{-1}$. The combination between W1x15 kg potassium humate per fed.$^{-1}$ caused the maximum values of shoot and grain (6635.37 kg and 5344.47 kg), respectively, compared with other treatments.

The data regarding the biological yield as influenced by irrigation water and potassium humate levels are shown in Table 4. The data indicated that irrigation water levels individually or combined with potassium humate was increased the biological yield of maize plants. Individually, the highest biological yield (8105.75 kg fed.$^{-1}$) was obtained by W1 treatment followed by 6432.20 kg fed.-1 in the case of W2 treatment while, the lowest value of biological yield (4782.65 kg) was recorded W3 by treatment, for the application of potassium humate, maximum value of biological yield 10537.52 kg fed.$^{-1}$ was obtained by application of potassium humate at rate of 15 kg fed.$^{-1}$, which was followed by (8940.71 kg and 8157.54 kg) for 10 and 5 kg fed-1 potassium humate, respectively, while the lowest value of biological yield (6440.20 kg) was obtained in control. Ayas and Gulser (2005) reported that humic acid caused to increase growth and height and subsequently increase biological yield through increasing nitrogen content of the plant. Smith (2004) reported that water stress decreased dry weight as 28 to 32% in growth period.

The mean data regarding harvest index (HI) is mentioned in Table 4. There were significant differences for different levels of irrigation water and potassium humate as well as its interaction. The means regarding HI revealed that the highest value (41.37%) was obtained with application of W1 while the lowest one (24.77 %) with W3. The maximum value of HI (42.94%) was observed with the application of 15 kg fed.$^{-1}$ potassium humate, while minimum value (35.41%) was observed at control treatment. In the case of interaction, maximum value of HI (44.61%) was obtained from the application of 15 kg fed.$^{-1}$ potassium humate and W1, while the minimum value (39.73%) was recorded in soil treated with potassium humate and W3. These results are harmony with Navigeh *et al.* (2012) who showed that the water deficiency decreased grain yield and harvest index compared to control, but the rate of decrease was lower with the application of potassium humate. Shahryari and Shamsi (2009) reported that potassium humate increased the rate of biological yield of wheat from 3.26 to 3.72g/plant; but it had not effect on harvest index. Also, they found that uses of potassium humate increased grain yield. It worth to mention that, the highest values of plant height, shoot diameter, length of ear, diameter of ear, weight of 100 grains, dry shoot, grain yield, biological yield and harvest index (200, 8.18, 22.23, 14.00, 38.58, 6635.37, 5344.42, 11979.84 and 44.61) were obtained under irrigation after W1 and 15 kg fed.$^{-1}$ potassium humate application. While, at the irrigation water level W3 without application of potassium humate, 34% reduction was observed in grain yield, but with application of potassium humate only 14 percent reduction was observed.

Macronutrients (N, P and K) concentration and uptake by shoots and grain of maize plants

Data of N, P and K concentration in shoots and grains are shown in Table 5. It is clear from the Table that N, P and K concentration in shoots and grains was affected by the irrigation levels individually or combined with potassium humate application. Concerning the irrigation levels, the maximum values of N, P and K concentration were (0.81, 0.14 & 1.60 %) and (1.79, 0.24 & 0.42) for shoots and grains, respectively were noted in W1, where, the minimum concentration were recorded in W3. These reduction in the contents of these elements in both shoots and grains may be attributed to primarily to soil water deficit which markedly reduces the flow rates of elements in soil, their absorption by stressed roots cell and also its ability to translocate through the different organs and tissues (Khalil, 2012).

This could be attributed to the strengthening of rooting system, which was reflected in increasing nutrients uptake by plants (Cooper and Chunhua, 1998).Regarding the effect of potassium humate on N, P and K concentration in shoots and grains, the highest mean values were observed with application of potassium humate at rate of 15 kg fed.$^{-1}$ with (1.05, 0.23& 1.98%) and (1.83, 0.29 & 0.47%) followed by potassium humate at rate of 10 kg fed.$^{-1}$ having (0.95, 0.22 & 1.53%) and (1.72, 0.26 & 0.44%), respectively and then (0.80, 0.17 & 1.45%) and (1.59, 0.24& 0.41%) with application of potassium humate at rate of 5 kg fed.$^{-1}$. Zaghloul et al. (2009) found that application of potassium humate led to increase nitrogen, phosphorus and potassium in the plant due to increasing absorption and transfer of nutrients in plants by enhancing metabolism. So, humate with its positive effects on physiological processes including photosynthesis and facilitating the transfer of materials within the plant can improve the grain growth. Concerning the interaction of irrigation water levels with application of potassium humate, the data in Table 5 showed that combination between irrigation water and potassium humate application gave the highest values of N, P and K concentration in shoots and grain of maize plants compared with irrigation levels solely. Maximum N, P and K concentration (1.23, 0.25& 2.25%) and (2.35, 0.32& 0.52%) in shoots and grain, respectively were found in W1+potassium humate at rate of 15 kg fed.$^{-1}$.

It was interesting to see that, at the irrigation level W2 without application of potassium humate, (9.87%, 7.14% & 9.37%) and (15.08%, 4.16% & 4.76%) reduction was observed in N, P and K concentration in shoots and grain, respectively but with application of 15 kg fed-1 potassium humate only (38.27%, 35.71% & 25.00%) and (10.05%, 25% & 11.90 %)

percent of increasing was higher. MacCarthy *et al.* (2001) concluded that humates enhance nutrient uptake, improve soil structure, and increase the yield and quality of various oilseed crops.

Concerning the effect of irrigation water levels individually or combined with potassium humate application on N, P and K uptake by maize plants (shoot and grains), the results are shown in Table 5. As regard to irrigation water levels, it was observed that irrigation water level had a significant effect on N, P and K uptake by both shoot and grain of maize plants. However, the highest values of N, P and K uptake (38.49, 6.65 &76.03 kg fed.-1) and (60.03, 8.04 &14.00 kg fed.$^{-1}$) for shoots and grains, respectively were noted at W1. Patel and Singh (1998) observed that water stress reduced the uptake of nutrients in plants, and the most of N and P were accumulated in grains, while most of K in stem and leaves. Ibrahim and Kandil (2007) found that irrigation treatment of 10 days interval gave the highest significant increase of all the chemical constituents of corn grains, i.e. total P mg/g, total N mg/g, crude protein % ,carbohydrate % ,T .S.S.%, starch % and oil% followed by irrigation intervals of 14 and 18 days in descending order.

In case of the application of potassium humate at rates of 5, 10 and 15 kg fed.$^{-1}$ the mean values of N, P and K uptake were (39.63, 51.13 & 58.54 kg fed.$^{-1}$), (8.49, 11.66 & 11.48 kg fed.$^{-1}$), and (71.43, 82.02 & 106.90 kg fed.$^{-1}$), respectively for shoots, (54.38, 65.68 & 83.62 kg fed.$^{-1}$), (8.36, 9.95 & 12.15 kg fed^{-1}) and (13.99, 16.39 & 19.87 kg fed^{-1}), respectively for grains. However, the interaction between the irrigation levels and potassium humate application indicated that the highest values of N, P and K uptake by shoots and grains (81.61, 16.58 & 149.29 kg fed^{-1}) and (125.59, 17.10 & 27.79 kg fed.$^{-1}$), respectively were obtained when W1 combined with potassium humate at rate of 15 kg fed.$^{-1}$. Muhammadn *et al*. (2013) showed that nutrients (N, P and K) contents were significantly increased by the application of humic acid and PSB inoculation.

Micronutrients (Fe, Mn and Zn) concentration and uptake by shoots and grains of maize plants:

Data in Table 6 revealed that Fe, Mn and Zn concentration in shoots and grains and its uptake were affected by the irrigation levels individually or combined with potassium humate application. Generally, data show that the highest values of the previous parameters were obtained under W1 irrigation level followed by W2 and W3 irrigation levels in descending order. It might be concluded that maize plants showed significant reduction in micronutrients constituents by decreasing the soil moisture content by using irrigation level W3. Data presented in Table 6 show that the all levels of potassium humate significantly increased the concentration and uptake of micronutrients (Fe, Mn and Zn) in both shoots and grains of maize plants as compared with control. The highest values of micronutrients content in both shoots and grains (136.00, 60.66 &39.33 mg kg^{-1}) and (56.00, 60.66 & 30.66 mg kg^{-1}), respectively were obtained by application of 15 kg potassium humate/fed., the corresponding values of uptake were (0.77, 0.34 & 0.22 kg fed.$^{-1}$) and (0.25, 0.17 & 0.13 kg fed.$^{-1}$), respectively.

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The interaction between irrigation levels and potassium humate rates significantly affected the concentration and uptake of micronutrients by both shoots and grains of maize plants. The highest values of the Fe, Mn and Zn concentration in both shoots and grains (191.00, 80.00 &47.00 mg kg^{-1}) and (62.00, 46.00 & 35.00 mg kg^{-1}), the corresponding values of uptake were (1.04, 0.53 & 0.31kg $fed.^{-1}$) and (0.27, 0.25 & 0.19 kg $fed.^{-1}$), respectively were attainted under irrigation level W1 combined with potassium humate at rate of 15 kg $fed.^{-1}$. These results may be due to the effect of both direct and indirect effects on plant growth, indirect effects involve improvements of soil properties such as aggregation, aeration, permeability, water holding capacity, micronutrient transport and availability. Direct effects, which require uptake of humic substances into the plant tissue resulting in various biochemical's, and physiological effects, (Chen and Aviad, 1990 and Eyheraguibel *et al.,*2008). Bohme and Thi Lua (1997) reported that humic acid had beneficial effects on nutrient uptake by plants, and was particularly important for the transport and availability of micronutrients due to the better developed root systems.

Water consumptive use (CU):

Seasonal rates of water consumption by maize plants under various treatments are presented in Table 7. Results showed that seasonal water use values were 565.9, 517.9 and 454.0 mm for irrigated plants at W1, W2 and W3. respectively. These results demonstrate that water consumption increased as soil moisture was maintained high by frequent irrigations. The probable explanation of these results is that higher frequent irrigations provide chance for more consumption of water which ultimately result in increasing transpiration and evaporation from the soil surface. These results are confirmed with data reported by Abd El-Hafez (2001) and Abdel Mawly and Zanouny (2005.

Table 7 :Monthly and seasonal water consumptive use (mm) as affected by irrigation treatments .

Level of irrigation	Rate of K-humate (kg/fed.	Water consumptive use (mm)				
		Monthly rates (mm)				Seasonal water consumption (mm)
		June	July	Augu.	Sept.	
W1	5 kg m	32.5	221.0	179.8	131.0	564.3
	10 kg m	32.5	221.1	179.9	133.0	566.5
	15 kg m	32.5	221.4	180.2	135.2	569.3
	control	32.5	220.6	179.4	130.8	563.3
		32.5	221	180	132.5	565.9
W2	5 kg m	32.5	196.5	161.3	127.6	517.9
	10 kg m	32.5	196.5	161.3	127.6	517.9
	15 kg m	32.5	196.8	161.7	128.3	519.3
	control		196.3	160.9	126.9	516.6
		32.5	196.5	161	127.6	517.9
W3	5 kg m	32.5	176.3	140.8	103.9	453.6
	10 kg m	32.5	176.6	142.3	104.7	456.2
	15 kg m	32.5	176.2	141	104.2	454.0
	control	32.5	175.6	139.9	104.1	452.2
Mean		32.5	176.2	141	104.3	454.0

Water Use Efficiency

Data regarding the effect of irrigation water levels and potassium humate application on water use efficiency are given in Fig 1, which revealed that irrigation water levels and potassium humate had significant effect on water use efficiency of maize crop. As regard to irrigation water levels, the mean maximum value of water use efficiency 1.36 kg m^{-3} was achieved with W1 treatment and minimum value (0.59 kg m^{-3}) was found with W3 treatment.

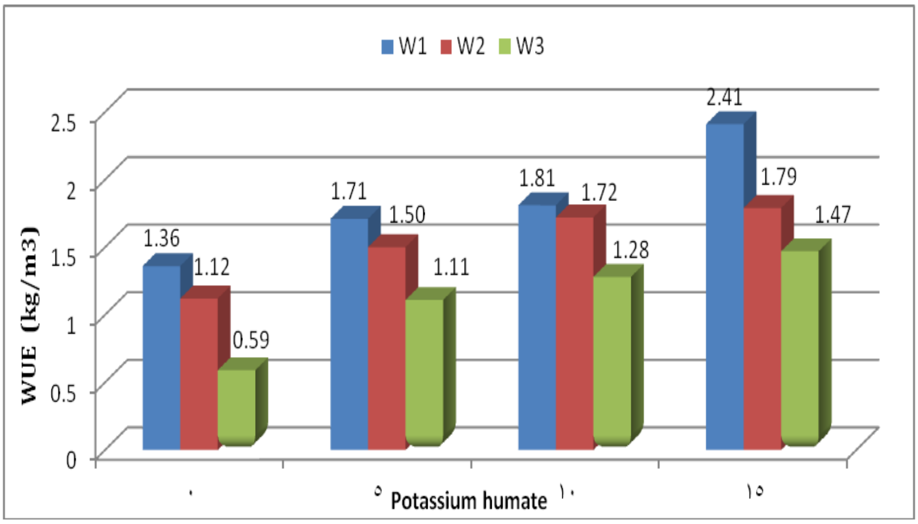

Fig. 1: Effect of irrigation water levels and potassium humate on water use efficiency (WUE kg m^{-3})

Respecting to the potassium humate application at high rates, the maximum value of water use efficiency 1.89 kg m^{-3} was measured in case of treatment of potassium humate at rate of 15 kg per fed., and minimum of 1.02 kg m^{-3} water use efficiency was with cotrol treatment without application potassium humate. Potassium humate reduced the improved WUE. It is revealed from the data presented in Fig. 1 that the interaction between irrigation water levels and potassium humate had significant effect on WUE and the combination betweenW1 x potassium humate at rate of 15 kg fed-1 achieved maximum value of water use efficiency (2.41 kg m^{-3}). Results show that WUE was increased due to increasing potassium rates, these due to the enhancement of water stored in the effective root zone with high potassium rates and these observations indicated that addition potassium humus-fertilizer mitigated the harmful effect of water stress, because the trudged cells of the stomata that are rich in K keep the stomata closed most of time, so transpiration rate decreased, however there is no need for more water to be absorbed by plant roots which in turn reduce the amount of absorbed water. These results are harmony with Ebtisam *et al*. (2012) who found that the maximum value of water use efficiency (WUE) for grains maize was (2.18 kg grain yield m^{-3}) for humic acid in combination with irrigation level at 75 % of ET_0.

Effect on soil EC and pH

Table (8) revealed the effect of irrigation levels and potassium humate on Soil EC and pH. Data indicated that the irrigation treatments had great effect on soil EC, since it could be arranged in descending order as follows, W1, W2 and W3. On the other hand, potassium humate application caused an increasing in soil EC compared to the check treatment (without application potassium humate). Likewise, the highest value of soil EC was recorded by application of potassium humate at high level combined with W3.

A general increase in EC of normal soil was observed by application of potassium humate. Although EC of the soil increased with different treatments but the actual values did not reach the critical limit of 4.0 dS m^{-1}. Such similar results have been reported in the literature Selvakumari et al. (2000), Niklasch and Joergensen (2001) and (Sarwar *et al.* (2003), which indicated that EC increased when organic materials of different nature were applied to the soil. The decomposition of organic materials released acids or acid forming compounds that reacted with the sparingly soluble salts already present in the soil and either converted them into soluble salts or at least increased their solubility.

The change in soil pH due to addition of different levels of potassium humate are presented in Table (8). Initial the pH value was 7.88. Due to potassium humate addition, the pH was reduced under all levels. Data indicated that at the end of experiment the mean value of pH was reduced to 7.72 in soil with application of potassium humate at the rate of 15 kg $fed.^{-1}$.

The available macronutrients

Data presented in Table 8 reveals that the available of N, P and K content of soil increased significantly with increasing levels of irrigation. The maximum available N (30.74 mg kg^{-1}), P (14.30 mg kg^{-1}) and K (337.50mg kg^{-1}) were observed under irrigation W1 and the minimum value were under W3. The application of potassium humate at rate of 5, 10 and 15 kg fed^{-1} increased mean values of available N, P and K content of soil to extent of (29.68, 31.82 and 33.52 mg kg^{-1}), (13.60, 14.63 and 15.53 mg kg^{-1}) and (351.66, 364.83 and 372.66 mg kg^{-1}), respectively as compared to control. The significant increase in available nutrients content of the soil after harvesting of the crop may ascribe to the humic acid is a commercial product of organic fertilizers containing most elements that improve soil fertility and increase nutrients availability, thus enhances plant growth and yield as well as decreases the harmful effect of water. Similar results were also reported by Doran *et al.* (2003). Also, Selim *et al.,* (2010) showed that addition of humic substances jointly with N, P and K either single or combined fertilizer form improving the soil fertility status at different soil layers. Mesut *et al.,* (2010) who reported that humic acid released the fix K.

The available micronutrients (Fe, Mn and Zn)

Results illustrated in Table 8 showed that the application of different levels of irrigation water individually or combined with potassium humate at different rates had significant effect on Fe, Zn and Mn content of soil.

8

The availability of micronutrients in soil was higher due to potassium humate application than control. Potassium humate application at rate of 15 kg fed.$^{-1}$ resulted in higher availability of Fe (8.35 mg kg^{-1}) , Mn (7.00 mg kg^{-1}) and Zn (6.20 mg kg^{-1}). The positive effect of humic substances in increasing the availability of micronutrients may be due to the its priming effect to increase water soluble amounts of micronutrients after addition of humic substances, which led to chelating and subsequent release of micronutrients. Pandey *et al*. (2000) determined the stability constant of complexes formed between humic acid and metal salts solution using the ion exchange equilibrium method and concluded that the stability of HA-metals complexes in soil was in the order: Cu > Fe > Pb > Ni > Co > Ca > Cd > Zn > Mn > Mg. For this reason, some micronutrients bound more easily than the other metals by the humic substances. Sushanta and Kumar (2007) found that the application of 0.2% humic acid compared with 0.1% resulted in greater increase in DTPA-Zn concentration in soil application.

Wet sieving stable aggregates:

Regarding to the distribution of aggregates size fractions and water stable aggregates (WSA) as affected by irrigation treatments and potassium humate (KH) as a soil application (Fig. 2), results showed that wet stable aggregates which having diameters from 1 to 0.5 mm were found to be the largest size in the different treatments under study, followed by diameter 0.5-0.25 mm. Data showed that the highest values of wet aggregate diameter and water stable aggregates were obtained with plots receiving irrigation level W1.

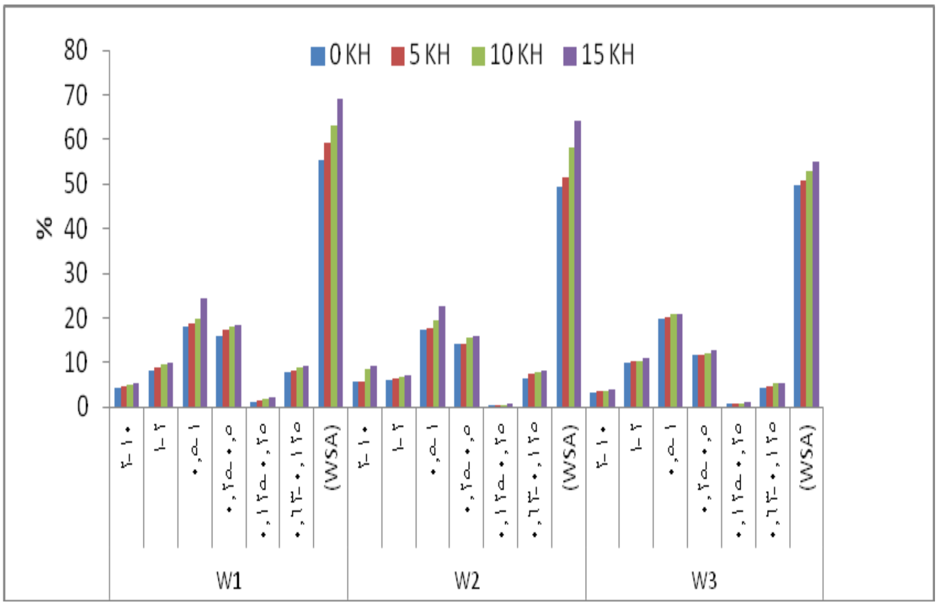

Fig. 2:Effect of irrigation water levels (W1, W2 and W3) combined with potassium humat (KH) on water stable aggregates and distribution of aggregates size fractions

Data also, indicated that the maximum values of the aggregation size at different diameters were obtained as a result of potassium humate application. Concerning the WSA the highest values was recorded for plots receiving potassium humate at different rates compared to the control treatment, however, irrigation level under potassium humate treatments were more pronounced effect on enhanced water stable aggregation, increase in percentage of WSA were (6.65%, 14.05% and 24.80 %), (4.18%, 17.84% and 30.14%) and (2.02%, 5.91% and 10.41%) for (5, 10 and 15 kg fed.-1) potassium humate compared to control at irrigation level W1, W2 and W3, respectively. These results are in agreement with obtained by Tayel *et al* (2010) who found that HA has a great effect on the formation of the aggregate that decrease soil runoff and erosion by wind.

Aggregation index

Aggregation index of the soil aggregate was significantly improved by increasing concentration of potassium humate applied from 5 to 15 kg fed-1 compared to without potassium humate application. Also, the result showed that the highest values of aggregation index was obtained due to application of W1 combined with 15 kg fed.-1 potassium humate. This could be due to the role of humic acid in forming and stabilizing soil aggregates. Aggregate stability increased by 2.59 %, 24.67% and 25.97 %, respectively for 5, 10,and 15 kg fed^{-1} compared to control. These results may be due to when brought into contact with the soil aggregates, carboxylate groups from the K-humate reacted quickly with the polyvalent cations present on the clay surfaces forming bridges, which resulted in organo-metal–clay complexes. As these reactive acid groups are distributed throughout the heterogeneous humic acid macromolecules, simultaneous chelation of the polyvalent cations may occur on the various clay particles in the soil, thereby enhancing the soil aggregate stability.

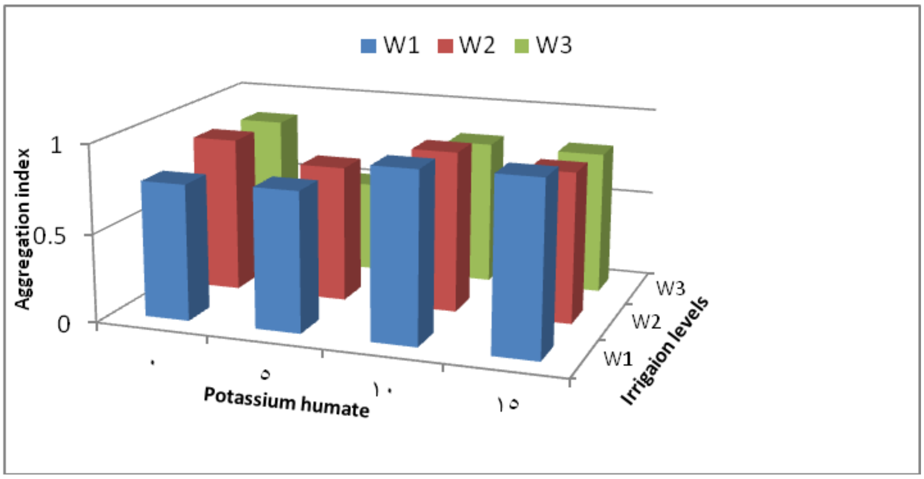

Fig. (2) Effect of irrigation levels with potassium humate on Aggregation index

Chaney and Swift (1986) stated that humic substances were capable of stabilization of aggregates for a long term in which the humic substances are mainly involved in the micro-aggregate formation.

Thus it can be concluded that irrigation level W1 and application of potassium humate with 15 kg fed^{-1} resulted in the highest yield and yield attributes, WUE and some soil properties. Also, application of potassium humate with deficiency in the amount of water irrigation led to gave the highest values of the former parameters compared to the transaction referred in the addition without.

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أثر اضافة هيومات البوتاسيوم مع مستويات من مياه الري على محصول الذرة وانتاجية وحدة المياه و بعض خواص التربة

محمد سعيد عواد ، خالد شعبان الحدق ، محمد عبد العزيز بيومى و طارق احمد عيد
معهد بحوث الاراضى و المياه و البيئة، مركز البحوث الزراعية ، مصر

أجريت تجربة لدراسة استجابة نباتات الذرة لمستويات من الري مع او بدون اضافه هيومات البوتاسيوم على محصول الذرة و مكوناته (صنف هجين فردي عشره) ، و خصائص التربه بعد الحصاد. زرعت الذره فى مزرعه محطه البحوث الزراعيه بالجيزه ، مركز البحوث الزراعيه الجيزه ، مصر فى موسم الصيف لعام 2013. تم تصميم التجربه الى قطع منشقه وثلاث مكرارات، وشملت عاملين الاول وهو اضافة هيومات البوتاسيوم بالمعدلات الاتيه (0 ، 5 ، 10 ، 15 كجم للفدان) و العامل الثانى و هو الرى بمستويات مختلفه من السعه الحقليه (100% ، 75% ، 50%) .

أوضحت النتائج المتحصل عليها الاتي:

ان مستوى الري عند 100% من السعه الحقليه قد سجل اعلى القيم للصفات المدروسه وهى ارتفاع النبات ، قطر الساق ، طول الكوز ، عدد الصفوف فى الكوز ، ووزن ال100 حبه ، ومحصول كلا من السيقان الجافة و الحبوب والمحصول البيولوجى وايضا دليل الحصاد. و بالمثل فأن هذه المعامله ايضا قد ادت الى زياده التركيز و الممتص من عناصر النيتروجين و الفوسفور و البوتاسيوم و الحديد و المنجنيز و الزنك . ومن الجهة الاخرى فقد ادى نقص مياه الرى الى انخفاض فى قيم التقديرات السابقه المشار اليها.

أما فيما يتعلق بكفاءة استخدام المياه فقد تحقق اعلى قيمه مع مستوى الري عند 100% مقارنه بالمستويين السابقيين. و فيما يختص باضافة هيومات البوتاسيوم فقد ادى اضافة المعدل العالى منها (15كجم للفدان) الى تسجيل قيم عاليه من التقديرات السابقة مقارنه بالمعدلين الاخريين و الكنترول. أيضا اضافة هيومات البوتاسيوم مع معدلات الري(50 % و 75%) قد سجل اعلى القيم من نفس التقديرات مقارنه بنفس المعدلين بدون اضافة البوتاسيوم هيومات.

وعلاوه على ذلك فأن اضافة البوتاسيوم هيومات كان لها اثر على تحسين فى خواص التربه، مثل زياده تيسر بعض العناصر فى التربه مثل النيتروجين و الفوسفور و البوتاسيوم والحديد و المنجنيز و الزنك و تحسن فى التوصيل الكهربى و ايضا رقم الحموضه وزياده التجمعات الثابته المبتله و ايضا دليل التجمعات مقارنه بالكنترول وزياده القيم قد زادت مع زياده الكميه المضافة من البوتاسيوم هيومات.

ايضا اضافة البوتاسيوم هيومات مع معدلات مختلفه من مياه الرى فقد ادى الى تحسن فى خواص التربه مع مستوى الري 100% يليها المعدل الثانى 75% و اخيرا الثالث 50%. و من هذا يمكننا ان نستنتج الاتى ان المستوى من الرى 100% مع البوتاسيوم هيومات بالمعدل 15 كجم للفدان قد اعطت اعلى القيم للمحصول و صفاته و كفاءة استخدام المياه وبعض خواص التربه. ايضا ادى اضافة البوتاسيوم هيومات مع نقص فى كميات المياه المضافه قد ادى الى اعطاء اعلى القيم السابق الاشاره اليها مقارنه بالمعاملات البدون اضافة.

Table 4: The combined effect of different irrigation levels and potassium humate on yield and yield components of maize plants.

Level of irrigation	Rate of K-humate (kg/fed.)	Plant height (cm)	Shoot diameter (cm)	Ear Length (cm)	No. of rows ear^{-1}	Weight of 100 grain (g)	Dry shoot (kg/ fed.)	Grain yield (kg/fed.)	Biological yield (kg/fed.)	Harvest Index (%)
W1	0	195.00	5.89	16.00	13.00	30.23	4752.19	3353.56	8105.75	41.37
	5	230.00	7.49	20.00	13.33	31.41	5869.24	4251.35	10120.59	42.00
	10	252.00	7.82	21.00	13.45	36.78	6370.84	4510.29	10880.29	41.45
	15	260.00	8.18	22.23	14.00	38.58	6635.37	5344.47	11979.84	44.61
W2	0	161.50	3.56	10.59	10.48	25.38	3852.49	2579.71	6432.20	40.10
	5	181.05	5.60	15.30	11.05	28.47	4614.55	3456.23	8070.78	42.82
	10	199.75	6.46	18.28	11.08	30.15	5031.94	4015.42	9047.36	44.38
	15	207.00	6.80	18.58	11.33	32.47	5248.03	4205.28	9453.31	44.48
W3	0	171.23	2.69	10.00	10.20	22.34	3597.60	1185.05	4782.65	24.77
	5	175.00	4.97	14.45	10.65	27.41	4045.95	2235.32	6281.27	35.58
	10	189.00	5.30	15.26	10.20	28.78	4326.21	2568.28	6894.49	37.25
	15	190.00	5.56	15.72	10.49	29.45	4461.38	2942.05	7403.43	39.73
L.S.D. 0.05	W	8.00	0.230	0.123	5.731	2.482	3.284	8.979	9.562	1.212
	KH	8.63	0.750	1.529	0.183	1.611	5.387	5.829	7.867	1.909
	W*KH	9.46	1.000	2.032	0.244	2.141	7.160	7.747	10.455	2.538

W1=100% FC, W2=75% FC W3=50% FC W-Irrigation KH-Potassium humate

Table5: The combined effect of different irrigation levels and potassium humate on macronutrients(N, P and K) content and uptake by maize plants.

Level of irrigation	Rate of K-humate (kg/fed.)	Shoots						Grains					
		Content %			Uptake kg fed.$^{-1}$			Content %			Uptake kg fed.$^{-1}$		
		N	P	K	N	P	K	N	P	K	N	P	K
W1	0	0.81	0.14	1.60	38.49	6.65	76.03	1.79	0.24	0.42	60.03	8.04	14.00
	5	0.89	0.21	1.65	52.23	12.32	96.84	1.83	0.28	0.46	77.79	11.90	19.55
	10	1.12	0.24	1.75	71.35	15.29	111.48	2.11	0.30	0.48	95.16	13.53	21.64
	15	1.23	0.25	2.25	81.61	16.58	149.29	2.35	0.32	0.52	125.59	17.10	27.79
W2	0	0.73	0.13	1.45	28.12	5.00	55.86	1.52	0.23	0.40	39.21	5.93	10.31
	5	0.84	0.18	1.54	38.76	8.30	70.14	1.59	0.24	0.41	54.95	8.29	14.17
	10	0.96	0.22	1.54	48.30	11.07	77.48	1.63	0.26	0.43	65.45	10.44	17.26
	15	1.12	0.23	2.00	58.77	12.07	104.96	1.97	0.30	0.47	82.04	12.61	19.76
W3	0	0.61	0.11	1.16	21.94	3.95	41.73	1.22	0.18	0.34	14.45	2.13	4.02
	5	0.69	0.12	1.17	27.91	4.85	47.33	1.36	0.22	0.37	30.40	4.91	8.27
	10	0.78	0.13	1.32	33.74	5.62	57.10	1.42	0.23	0.40	36.45	5.90	10.27
	15	0.79	0.13	1.49	35.24	5.79	66.47	1.47	0.23	0.41	43.24	6.76	12.06
L.S.D. 0.05	W	N.S	N.S	0.111	2.872	1292	1.432	0.046	0.116	0.255	1.312	0.906	0.113
	KH	N.S	N.S	0.129	1.726	1.387	1.499	0.037	0.009	0.007	1.048	0.981	1.438
	W*KH	N.S	N.S	0.173	2.294	1.843	1.992	0.056	0.019	0.115	2.267	1.059	2.052

W1=100%FC, W2=75% FC W3=50% FC W-Irrigation KH-Potassium humate

Table 6:The combined effect of different irrigation water levels and potassium humate on micronutrients (Fe, Mn and Zn) content and uptake by maize plant.

Level of irrigation	Rate of K-humate (kg/fed.)	Shoots						Grains					
		Content mg kg^{-1}			Uptake kg fed^{-1}			Content mg kg^{-1}			Uptake kg fed^{-1}		
		Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn	Zn
W1	0	109.0	52.0	33.0	0.53	0.24	0.15	42.0	32.0	24.0	0.14	0.11	0.08
	5	119.0	58.0	39.0	0.70	0.34	0.22	48.0	35.0	28.0	0.20	0.15	0.12
	10	163.0	72.0	40.0	1.04	0.45	0.25	59.0	37.0	31.0	0.27	0.16	0.14
	15	191.0	80.0	47.0	1.26	0.53	0.31	62.0	46.0	35.0	0.33	0.25	0.19
W2	0	79.0	42.0	31.0	0.30	0.16	0.11	53.0	30.0	21.0	0.13	0.08	0.05
	5	82.0	46.0	33.0	0.38	0.21	0.15	48.0	35.0	25.0	0.16	0.12	0.09
	10	108.0	51.0	37.0	0.54	0.25	0.18	53.0	38.0	27.0	0.21	0.15	0.10
	15	123.0	56.0	40.0	0.64	0.29	0.21	55.0	41.0	30.0	0.28	0.17	0.13
W3	0	66.0	36.0	23.0	0.23	0.12	0.08	51.0	28.0	20.0	0.06	0.03	0.02
	5	73.0	38.0	25.0	0.29	0.15	0.10	47.0	31.0	22.0	0.11	0.07	0.05
	10	85.0	41.0	27.0	0.36	0.17	0.12	50.0	32.0	24.0	0.12	0.08	0.06
	15	95.0	46.0	31.0	0.42	0.21	0.14	51.0	35.0	27.0	0.15	0.10	0.08
L.S.D. 0.05	W	1.895	1.432	2.482	0.078	N.S	N.S	3.123	1.432	1.324	NS	NS	NS
	KH	1.959	1.059	1.935	0.082	N.S	N.S	1.467	2.011	2.001	NS	NS	NS
	W*KH	2.604	2.697	2.571	0.109	N.S	N.S	1.950	2.672	2.672	NS	NS	NS

Table 8:The combined effect of different irrigation levels and potassium humate on EC, pH available N, P, K, Fe, Mn and Zn in soil after harvesting of maize plants.

Level of irrigation	Rate of K-humate (kg/fed.)	EC (dSm^{-1})	pH (1:2.5)	Available Macronutrients mg kg^{-1}			Available Micronutrients mg kg^{-1}		
				N	P	K	Fe	Mn	Zn
W1	0	1.10	7.85	30.74	14.30	337.50	5.30	4.94	3.50
	5	1.21	7.70	31.61	14.50	375.00	8.58	7.22	5.58
	10	1.28	7.68	35.47	16.50	387.50	8.66	7.63	6.14
	15	1.31	7.63	38.15	17.50	400.00	9.36	7.89	6.84
W2	0	1.63	7.82	26.87	12.50	328.50	5.42	4.74	3.34
	5	1.61	7.80	30.08	13.80	340.00	7.72	5.99	4.58
	10	1.58	7.77	31.97	14.60	360.00	7.98	6.25	5.42
	15	1.53	7.76	34.38	15.70	367.50	8.22	6.69	5.84
W3	0	1.82	7.84	24.86	11.30	300.00	4.66	4.63	3.13
	5	1.81	7.82	27.37	12.50	340.00	6.86	5.15	4.60
	10	1.78	7.78	28.03	12.80	347.00	7.00	5.92	4.66
	15	1.70	7.79	29.21	13.40	351.00	7.48	6.42	5.92
L.S.D. 0.05	W	0.007	0.007	1.228	0.078	3.791	1.827	0.706	1.261
	KH	0.082	0.082	1.925	1.760	4.239	0.725	0.781	0.927
	W*KH	0.006	0.008	2.559	2.339	5.634	0.963	1.038	1.232