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EFFECT OF ADDING POTASSIUM HUMATE AT DIFFERENT LEVELS OF MOISTURE TENSION IN SOME PHYSICAL PROPERTIES OF SOIL AND IN GROWTH OF ZEA MAIZE

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Abstract: The need to determine the ideal moisture tension for maize growth is significant, because the plant's response to water is more related to moisture tension compared to any other single factor and studying the effect of theinteraction with the optimal level of potassium humate, considering it a rapid organic intervention that improves the physical and hydrodynamic properties of the soil and increases the nutrients use efficiency Accordingly, A pot experiment was conducted on a clay silty soil to study the effect of different levels of potassium humate (POWHUMUS WSG 85) (0.6-1.8-3.6 kg/d) at different levels of moisture tension (400-600-800 millibar) on the physical properties of clay silty soil growing maize. The results show that soil bulk density was significantly decreased at 400 millibar in all levels of potassium humate added by 0.05-0.1-0.17 g/cm^3 respectively. Increasing moisture tension to 600 and 800 millibar and not receiving humate, bulk density decreased by 0.08 -0.13 g/cm^3 compared to the moisture tension 400 millibar treatment. The experimental constants (a) and (b) in $\psi=a\theta^b$ increased as the level of humate addition was increased at all levels of moisture tension. Moreover, leaf area of maize plant at the same moisture tension increases with the increase of humate addition reaching the highest value of 2476 cm^2 at 600 millibar and 1.8 kg/d. This study suggests that potassium humate has the potential to increase, nutrient uptake by improving soil physical properties. However, it recommends the application of this material for corn at the rate of 1.8 kg/d on a clay silty soil.

Keywords: *Available water; bulk density; clay soil; Potassium humate; moisture tension; moisture content; Zea*

INTRODUCTION

Physical and water properties of the soil occupy an important place in the overall agricultural operations aimed to improve soil fertility and productivity, and the physical properties related to soil productivity can be divided into two parts**:**
1) Directly related to plant development (water, oxygen, soil resistance to penetration, heat)
2) Indirectly related (texture, porosity, structure, bulk density) [1].
In this context, organic matter plays the main role in improving the physical and fertility properties of the soil. The addition of organic matter to the soil relieves the most of problems associated with dry areas, and results in a good soil structure, which facilitates agricultural operations, and improves the transport of nutrients and water for crops [2], organic matter application (from various sources) improves soil porosity, soil moisture, and reduces soil compaction [3] In addition, Soil structure also affects the transfer of fluids, gases, and heat, as well as physical processes such as seepage and aeration [4]. However، Plant growth and development do not occur unless the soil is adequately aerated [5]. The effects of organic manure on physical properties vary depending on the type and quantity of used materials and according to the type of

soil and its management [6]. Humic compounds constitute 50-80% of soil organic carbon [7] and humic acids are among the most prevalent organic compounds on Earth, as they are found not only in soil but in cow dung, sewage, compost, algae, brown coal (lignite) and other miscellaneous sediments [8]. They are compounds that are resistant to microbial degradation due to their complex and highly random structure [9] and it has high ability to form complexes with soil minerals 10]. It acts as a cushion and interface between the nutrients in the soil and the plants' roots, as these substances increase the growth of plants directly and indirectly. Plants can absorb elements faster from humic substances such as nitrogen, phosphorous, potassium, calcium and magnesium, or encourage changes in the availability of these elements in the soil, which increases soil productivity from the crop yield of the cultivated plant [11]. Humic compounds improve structure stability at low addition rates; therefore, it has better performance than animal manure [12]. According to Tahir et al. [13], adding 1 kg of humic acids (HA) has a benefit equivalent to 1 ton of manure (for example, cow dung), which needs a long time to dehumidify. The improvement in soil structureresulting from the addition of humic materials, including humic acids, affects the movement of water and airthrough the soil, and thus the ability of the soil to maintain life and perform its other vital functions. As it well-known it impacts the interactions between soil and atmosphere within multiple temporal and spatial scales [14].

The main problem in dryland soils management is the low availability of soil moisture so that the soil is no longer able to support the growth and productivity of crops [15]. Studies have shown the advantages of using moisture tension in soil moisture management [16], which allows determining the moisture content to be maintained for a particular crop in soils with different physical properties. Rawls and others [17] found that the relationship between moisture tension and organic carbon content was affected by soil texture and this effect is greater at moisture tension -kpa33, where the percentage of available water increased by an average of 22% when adding 10 kg/dunum of potassium humate 18].The plant is directly affected by the moisture tension in the soil, according to the prevailing climatic conditions affecting evapotranspiration, as the actual evapotranspiration decreases with the increase in moisture tension, and the water deficit appearsin the plant (Ibrahim and Barakat, 2013) [19].

The relationship between soil structure, moisture tension and evapotranspiration in the soil has great importance, especially for drought-sensitive crops with high water needs, including maize [20]. In any case, water requirements in crops, including corn, differ according to the stage of growth, maize requires less water in the early and late stages of growth, while the peak water requirement is during a period of two weeks before and after the expulsion of the flowering inflorescence [21]. Rivera-Hemandez and others [22] have shown that the appropriate moisture tension for sweet maize is about 30 kpa.

On the other hand, the proportion of these materials in the soil decreases with the passage of time due to the prevailing climatic conditions and the intensive investment of the soil [23]. Furthermore, studies recommend a careful and sustainable use of organic matter sources. For this reason, it was thought to use potassium humate, because it constitutes the largest part of the organic matter in the soil and provides an easy source to use and transport due to its application in very small quantities. It has proven its worth in improving the soil and reducing the impact of drought on plants [24]

In addition to provide a suitable medium for nutrients absorption within the soil-roots-plant system, and compensating the deficiency and deterioration of the soil. In contrast, moisture tension and soil moisture content play a prominent role in improving the efficiency of using organic materials through its effect on the structure stability through wetting and drying cycles, and thus affecting the absorption of water andnutrients. To confirm the uncertainty regarding the best application rate of potassium humate to the soil and the role of moisture tension, the current study was conducted using different rates of humate (from very low to very high) at gradual levels of moisture tension (above the permanent wilting point) on the growth of maize plant. However. This study would shed some light on the effect of potassium humate application rates at different levels of moisture tension on the physical and hydrodynamic properties of soil, and their effect on the growth of maize plant. Moreover, determination the hydrodynamical constants of the studied soil at different levels of potassium humate and moisture tension.

MATERIALS AND METHODS

Experiment materials

Soil: The soil was collected from the Scientific Research Center (Stkhers) from the topsoil (10 cm), which is a transferred clay soil.

Table 1. Main physical and chemical characteristics of clay silty soil

Analysis	Result	Used method
(0.002 < mm) clay)%(	45.79%	pipette (Bernharat,1967) [25]
(0.002–-0.05 mm) silt)%(	50.61%	
(0.05– 2 mm) sand)%(	3.6%	
Soil type	clay silty	German texture triangle (TGL,1985) [26]
Organic matter	0.72%	Wet Digestion, Ryan et al)2003([27]
Calcium carbonate	39.5%	Calibration Ryan et al)2003(
Effective lime	15 %	Doreno, Ryan et al)2003(
Cation exchange capacity	35.6 me/100g soil	Sodium acetate Ryan et al)2003(
Field capacity % volume	35	Membrane pressure device (Eijkelkamp Agrisearch Equipment 6987 ZG Giesbeek)
wilting point % volume	22	
True density	2.6	The pycnometer (Ibrahim and Barakat, 2013)
Inorganic nitrogen	24 ppm	Keldahl, Ryan et al)2003(
Available phosphor	12 ppm	Olsen, Ryan et al)2003(
Available potassium	422 ppm	Ammonium Acetate Ryan et al)2003(
pH	7.53	

Plant material: American yellow corn cultivar F1 Taxon hybrid.
Potasium humate: available under the trade name POWHUMUS WSG 85 was used, which consists of 65% organic matter, of which 80-85% potassium humate, 10-12% potassium oxide K_2O, 1% organic nitrogen, and 1% iron, according to the manufacturer on the packaging cover.

Determination of moisture tension levels in soil

The following moisture tension levels (ψ) are set using a hygrometer LUTRON –PMS-714 :

20. Ψ1 :at 400 milli bar (90% of field capacity)
21. Ψ2: at 600 milli bar (85% of field capacity)
22. Ψ3: at 800 milli bar (78% of field capacity)

Where the device is calibrated at different levels of moisture and moisture tension and the equation was as follows:

$Y=1.1736x-11.872$ y: device's reading, x: moisture content $R^2=0.9986$

The moisture content was calculated by the device's reading and the amount of water to be added to the pot was calculated to raise the moisture to reach the level corresponding to the appropriate moisture tension (Figure 1).

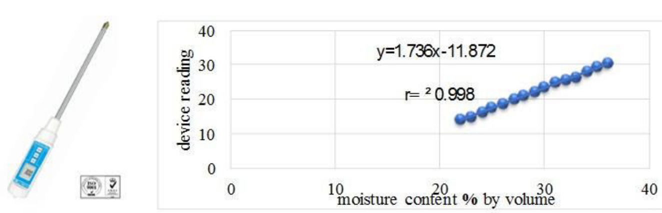

Figure 1. Calibration curve for hygrometer

The device is placed vertically within the soil, taking into account complete contact with the soil at a depth of 10 cm, to determine the soil moisture after knowing the reading of the device. After that, the amount of water to be added to reach the required moisture tension was calculated according to the following equation:

$$\Delta H2O = (\frac{M2+100}{M1+100} - 1) . Mm$$ (Ibrahim and Barakat, 2013)

ΔH_2O: The amount of water to be added to raise soil moisture from one specific moisture to another required one

$M2$: required moisture $M1$:current moisture Mm: Soil weight with current moisture

Experiment design

The Experiment design included studying the effect of 4 rates of potassium humate (0-0.6-1.8-3.6 kg/dunum), and three levels of moisture tension (400-600-800 millibars) and thus there were 12 treatments, four treatments of humate at each level of moisture tension, and each treatment has three replicates, according to the following Table 2.:

Table 2. The treatments

Moisture tension level (Milli bar)	Potassium humate rate kg/dunum	Replicates
400	M0 = 0	X 3 = **36** pots
600	x M1 = 0.6	
800	M2 =1.8	
	M3 =3.6	

Humate application was after dissolving it with irrigation water. The application rates were distributed in two batches:
First: 50% of the application rate a month before planting
Second :50% of the application rate after month and a half of planting
The allocated amount for each pot was calculated based on the weight of the soil in 1 dunum at a depth of 10 cm after knowing the bulk density of the soil as follows:
MS=$\delta d. 1000. B. F$
MS: Totally dry soil weight for 1 dunum at a depth of 10 cm ،
δd : bulk density 1000: conversion number B: depth (m.) F: area
Thus, the weight of the soil per square meter can be calculated as follows
0.8*1000*0.1*1000 =80000 kg/d/10 cm depth=80 kg/m2
Thus, humate treatments at the studied moisture tension treatments in 6 kg soil pots are as follows:
M0 pots have not received any humate
M1 (0.6 kg humate/d) pots received 0.045 g of humates distributed in two batches
M2 (1.8 kg humate/d) pots received 0.135 g of humates distributed in two batches
M3 (3.6 kg humate/d) pots received 0.27 g of humates distributed in two batches

Experiment preparation for cultivation

In the experiment, pots with a capacity of 8 kg, a diameter of 23 cm and a depth of 23.5 cm were used, so that the surface area was 0.0415 cm 2 and 6 kg of completely dry soil was placed in each pot. Phosphorous and potassium fertilizers were added in the full fertilizing dose after mixing with the soil, calculated according to the fertilizer formula: 40_80_120 (Roqaia et al., 2005) [28]
Each pot received 0.723 g/pot potassium sulfate and 2.98 g/pot triple superphosphate. Pots were distributed to the experiment square according to the randomized complete block method. They were watered with normal water until they reached the field capacity and left for a month until planting time .The planting was done by placing corn seeds at a depth of 2-2.5 cm on 26/7/2017 at a rate of 5 seeds per pot, where the first nitrogen fertilization dose was added in the form of urea 46% N (one third of the quantity at a rate of 0.65 g/pot) from the basic amount of 1.95 g /pot

Germination began after a week and was completed after 11 days, and germination percentage was 85%, and it was separated into 3 plants in the pot. After about half a month of germination, a plant was left in each pot.

Experiment Care

The second nitrogen fertilizer dose was carried out (Urea 0.65 g/pot after 15 days of planting) and the third dose (Urea 0.65 g/pot when the male inflorescence began to be expelled) and irrigation operations were carried out periodically. And that According to the needs of the moisture tension treatments under study, using ordinary water (sourced from the Tishreen 16 Dam).

Harvest Procedures

It was harvested 63 days after planting (the appearance of silk on the cones), where the growth parameters were recorded by cutting the plants from the soil level and the following measurements were taken**:**

Leaf area (Sakalova,1997) [29]

S = L.W.N.0.6

S: plant's leaf area cm^2 L: maximum leaf length W: maximum leaf diameter

N **:**leaves number Correction 0.6: coefficient for leaf area

After harvesting, samples of undamaged structure were taken using metal cylinders from all treatments with three replicates from each treatment to determine**:**

1**-** Bulk density**.**

2 **-**Available water:

We can determine the size of pores with a diameter of (0.2-10) µm as they contain the water available to the plant and play an important role in the transport and storage processes in the soil profile and play a prominent role in delaying the emergence of water deficit periods in plants during drought periods, which were identified in the membrane pressure device according to the law:

Pm=4σW/d (Ibrahim and Barakat, 2013)

σw: surface tension of water, d: pore diameter After that, the size of pores containing the available water (0.2-10) µm is determined:

PV% (0.2-10) µm=Wvol.pF2.5-Wvol.pF4.2

WvolPF2.5 the volumetric moisture at the end of the applicable pressure equivalent to the moisture tension pF2.5

WvolPF4.2 the volumetric moisture at the end of the applicable pressure equivalent to the moisture tension pF4.2.

Soil moisture characteristic curves by pressure membrane at (pF=1.8-2.5-3-3.5-4-4.2)

Soil moisture characteristic curves show the relationship between moisture tension (i.e., water holding force) and volumetric moisture in the soil. Soil moisture characteristic curves were determined using a membrane pressure device by applying increasing pressures starting from the pressure (pF1.8 - pF2 - pF2.5- pF3 -pF3.5 - pF4.2) using soil cylinders with a height of 4 cm, where the moisture content is calculated at different moisture tension levels and the corresponding averages of moisture are determined and these values are processed by computer The relationship between ψ and θ was of the form: $\psi=a\theta^b$(Gardner et al.,1970) [30] .After determining the moisture content at different levels of pressure, the following relationships are reached at all levels of potassium humate addition and moisture tension levels .

Saturated hydraulic conductivity:

Saturated hydraulic conductivity is considered one of the most important hydraulic properties of soil which is the ratio of flow to hydraulic stress gradient. This parameter is greatly affected by the size of the total porosity, especially the size of the pores with a diameter greater than 10 microns, and the degree of straightness of these pores (Suleiman and Ritchie,2001) [31]. It is also affected by the carbon content in the soil (Wang et al.,2009) [32].

Determining this parameter is very difficult due to the manifold of the pore system in the soil in addition to the variations in the shape and length of the tubes, where the amount of water flowing in the soil section is proportional to the fourth power of the pore radius described in the relationship:

$$q=\pi r^{(4)}(\Delta P/8\eta L)$$

L: Pore length (cm)   r: Pore radius (cm), ΔP: height (H1-H2)*g*δw δw: water density g/cm^3 g:earth's gravitational acceleration cm/sec^2
(H1-H2): hydraulic height η:g/cm*sec water viscosity ,q: the amount of water flowing (cm^3/sec)
Thus, a small increase in the diameter of the pores is accompanied by a large exponential increase in the amount of water flowing, which is important to know the radii of the poresinvolved in the transfer processes. Sohnberg (1965) [33] determined Laboratory conductivity coefficient based on Darcy's law: Kf=q/Grad φH
q: the amount of water flowing through the soil section (m/d), Grad Φ: hydraulic gradient. Where the measurements were carried out for all samples at one hydraulic gradient and in the case of continuous flow). Also, samples of damaged structure were cut out to calculate the structure stability that were determined by the immersion method (Hartge and Horn, 1991) [34]. The average change in diameter of the secondary particles before and after immersion in water is determined according to the following equation:

$$\Delta GM = \frac{\sum ni.di - \sum na.di}{\sum ni} \text{(Hartge and Horn, 1991)}$$

ni: the weight of dry granules with diameter of di before wet sieving
na: the weight of completely dry grains with diameter of di after wet sieving
∑ ni: Weight the completely dry soil before wet sieving.

RESULTS AND DISCUSSION

The effect of potassium humate and moisture tension on bulk density

Bulk density is one of the most important physical properties of soil and it is a compound physicalcharacteristic through which it is possible to give ideas of water and air movement in the soil profile (Kunze and Petelkau, 1980) [35], which will have a reflection on plant growth and productivity (Petelkau, 1984)[36].
The table below gives a breakdown of soil's bulk density values under the effect of potassium humate and moisture tension. Overall, it can be seen that bulk density values decreased gradually with the increase in application rates of humates under all applicable moisture tension levels in the soil and the same figure was witnessed when moisture tension rose. Starting at 1.15 g/cm^3 bulk density value in the control treatment (400 milli bar, without humate), bulk density dropped significantly by (0.05 g/cm^3, 0.1 g/cm^3,0.17 g/cm^3) respectively. With the increments in application rates of potassium humate. Similarly, under both 600 millibar and 800 milli bar moisture tension, bulk density declined with the highest amendment of potassium humate (3.6 kg/dunum) by (0.1 g/cm^3) and (0.07 g/cm^3) compared to control (without humate). However, in treatments without adding potassium humate, moisturetension has a crystal-clear effect on reducing bulk density, this figure was by 0.13 g/cm^3 under 800 milli bar comparedto 400 milli bar moisture tension. This is due to the wetting and drying cycles of the soil, which positively affected the soil structure.

Table 3. Soil bulk density changes with humate levels and moisture tension

	M0	M1	M2	M3	$LSD_{0.05}$
Ψ1 400 milli bar	1.15	1.1	1.05	0.98	0.046
Ψ2 600 milli bar	1.07	1.04	1.02	0.97	0.05
Ψ3 800 milli bar	1.02	0.99	0.96	0.95	0.026
$LSD_{0.05}$	0.035	0.024	0.042	0.05	

These results are consistent with Mousa (2017) [37] which indicated a decrease in the bulk density with a steady increase in the application rate of potassium humate, and long and short-term studies indicate a remarkable linear relationship between the decrease in bulk density and the increase in organic carbon in the soil, which may be attributed to the additions of extracted humic acids (Bresson et al., 2001) [38].

Effect of potassium humate and moisture tension on the available water pore size (0.2-10 µm) in soil
Table (4) illustrates changes in pores size holding available water in soil under different levels of potassium humate and moisture tension. In general, the highest moisture tension distinguished with the highest values of pores size (0.2-10 µm) whatever potassium humate rate was. At 400 milli bar, pores size (0.2-10 µm) rises with the increasing of potassium humate rate under the same moisture tension until the first significant difference appeared by (5.47%) under 3.6 kg/dunum potassium humate application. In contrast, 600 mill bar moisture tension showed significant differences at (1.8 and 3.6 kg/dunum) by 2.75% and 5.32% respectively while the highest moisture tension started to response significantly at the first amendment rate by (2.9%, 3.98%,5.14%) respectively. Available water increases by 10.2% when humate is added by 250 g/dunum (Abdel-Razek,2011) [39]. Cristensen (1996) [40] clarified that potassium humate application for soil postponed plants wilt by6-9 days. This was explained on the basis of organic carbon ability to modify water adsorption sites on clay minerals.

Table 4. The pores size containing available water in soil under different rates of potassium humate and moisture tension

Pores size (0.2-10µm)	Application rate	Moisture tension
11.88	M0	Ψ1 400 milli bar
14.09	M1	
14.01	M2	
17.35	M3	
12.75	M0	Ψ2 600 milli bar
14.72	M1	
15.50	M2	
18.07	M3	
12.99	M0	Ψ3 800 milli bar
15.89	M1	
16.97	M2	
18.13	M3	
2.46	$LSD_{0.05}$	

The effect of potassium humate and moisture tension in Soil moisture characteristic curves and the empirical constants

Table 5. Soil moisture characteristic curves equations and empirical and selection coefficients constants

selection coefficients	Equation	treatment	Empirical coefficients	
			a	b
Ψ1M0	$\Psi=0.00088.\theta^{-11.1288}$	r2=0.96	0.00088	11.1288-
Ψ1M1	$\Psi=0.109.\theta^{-6.788}$	r2=0.74	0.109	6.788-
Ψ1M2	$\Psi=0.0458.\theta^{-8.028}$	$r^2=0.97$	0.0458	8.028-
Ψ1M3	$\Psi=0.13.\theta^{-7.119}$	$r^2=0.96$	0.13	7.119-
Ψ2M0	$\Psi=0.00916.\theta^{-8.994}$	$r^2=0.97$	0.00916	8.994-
Ψ2M1	$\Psi=0.0369.\theta^{-8.164}$	$r^2=0.98$	0.0369	8.164-
Ψ2M2	$\Psi=0.1016.\theta^{-7.141}$	$r^2=0.98$	0.1016	7.141-
Ψ2M3	$\Psi=0.719.\theta^{-6.09}$	$r^2=0.98$	0.719	6.09-
Ψ3M0	$\Psi=0.028.\theta^{-8.227}$	$r^2=0.96$	0.028	8.227-
Ψ3M1	$\Psi=0.213\theta^{-6.851}$	$r^2=0.99$	0.213	6.851-
Ψ3M2	$\Psi=0.206\theta^{-6.793}$	$r^2=0.98$	0.206	6.793-
Ψ3M3	$\Psi=0.371\ \theta^{-6.441}$	$r^2=0.97$	0.371	6.441-

Ψ :moisture tension (water column cm) ، θ :moisture content as part from one, Soil moisture characteristic curves were also illustrated according to graphic lines as shown in Figures (2-3-4).

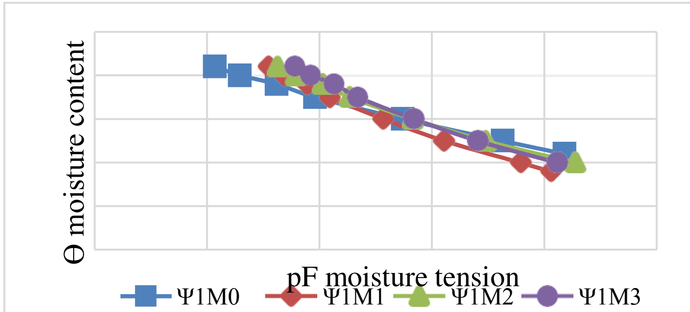

Figure 2. Soil moisture characteristic curves under different levels of potassium humate and moisture tension 400 milli bar

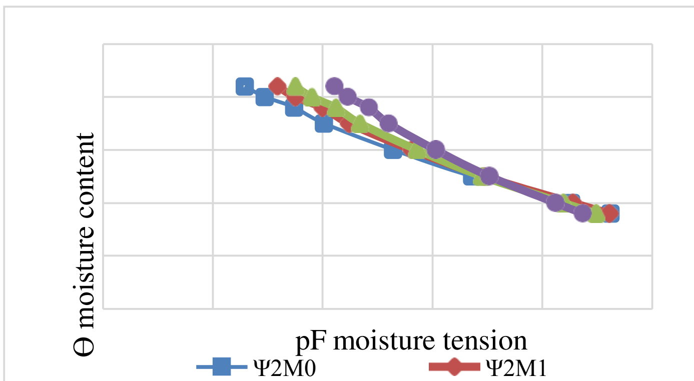

Figure 3. Soil moisture characteristic curves under different levels of potassium humate and moisture tension 600 milli b

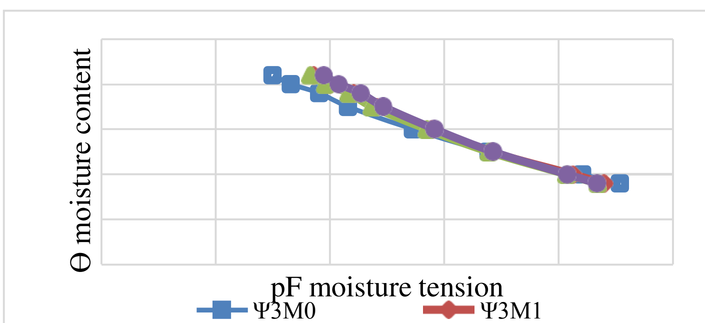

Figure 4. Soil moisture characteristic curves under different levels of potassium humate and moisture tension 800 milli bar

The soil's moisture content decreases with the increase of the moisture tension in all the studied treatments. It is also noted that with the increase in the potassium humate application rate at the same moisture tension, the moisture content in the soil increases as the humate increases the water holding capacity of the soil (Mackowiak et al., 2001) [41]. This rise is greater at low moisture tension levels. In conclusion, this indicates an increase in the soil's efficiency in water-holding capacity, especially the part called available

water table (5).
Equations in Table (5) indicate that empirical constants of soil (a) and (b) rise with the increase in the potassium humate application rate and the increase in moisture tension and this has a significant and positive effect during the movement of water by capillary action to the root system area. Usually, the water moving towards the surface of the roots is loaded with nutrients by the Darcy flow mechanism, which will positively reflect on the growth and productivity of the plant. (Mengle and Kirkby, 2001) [42]. The capillary channels also form the water column towards the surface of the roots, which forms a medium for the diffusion of the lowest concentration nutrients in the soil, and both mechanisms together increase the volume of the soil from which the plant benefits in absorbing nutrients (Marschner, 1995) [43].

Effect of potassium humate and moisture tension on saturated hydraulic conductivity
The table below states saturated hydraulic conductivity variations due to the application of humate and moisture tension in different levels. Overall, the saturated hydraulic conductivity coefficient was more affected by the humate application rate than by the moisture tension level.
Diving into more detalis, the first significant difference appeared at the moisture tension 400 milli bar for the (M3=3.6 kg/d) treatment with a high addition rate by (2.71 m/d) The high moisture tension 800 millibars took the same behavior until the first significant difference appeared by (4.17 m/d) at the same application rate of humate (3.6 kg/d) compared to the two treatments without adding humate. It is also noted that at the same application rate of the humate, the moisture tension did not have a significant effect on the saturated hydraulic conductivity. This may be due to the fact that the humate affected the distribution of the porous system in the soil in favor of intermediate pores over air pores that play a key role on the saturated hydraulic conductivity.
The use of potassium humate in the soil as an organic source led to improve the physical condition of the soil by improving the stability of the overall structure of the soil and reducing soil compaction, which leads to a decrease in the bulk density and an increase in soil porosity, and ultimately improving water infiltration (Zeleke et al., 2004) [44],which is reflected on the saturated conductivity, which increases with the increase in the potassium humate application rate(Ijaz et al.,2015) [45] .We can say that the positive effect of humate is due to the increase in the stability of the structure and not to the increase in the size of the air pores.

Table 6 :Saturated hydraulic conductivity (m/day) under the influence of different levels of humate and moisture tension

Application rate / Moisture tension	M0	M1	M2	M3	$LSD_{0.05}$
Ψ1 400 milli bar	3.91	4.85	4.65	6.62	1.82
Ψ2 600 milli bar	5.05	3.57	4.64	6.9	2.08
Ψ3 800 milli bar	4.25	5.23	5.31	8.42	1.99
$LSD_{0.05}$	2.7	2.56	1.47	2.28	

Effect of potassium humate and moisture tension on aggregates stability
Soil structure affects the water and air movement through the soil, which greatly affects the ability of the soil to sustain life and perform its other vital functions. Soil structure and high stability are important to improve soil fertility, increase agricultural productivity, and reduce
erosion. Structure stability is a reflection of soil building because it depends on the balance of physical, chemical and biological factors (Brevik et al., 2015) [46]. The table below represents aggregate stability variations after the application of potassium humate and moisture tension in different levels.
In general, the structure stability was similar in its linear improvement for all levels of moisture with the gradual increase in the rates of humate application, as well as with the increase of moisture tension at the same rate of humate amendment.
It was found that structure stability gradually increased at the same moisture tension with an increase in the rate of humate application at all levels of moisture, which reached a peak of (1.35). at the amendment rate of

3.6 kg humate/d and a moisture tension (800 millibar) while at the same rate of humate amendment, the stability rises with the increase in moisture tension in treatments that received humate. Previous research also mentioned that the higher aggregates stability values were reached at the moisture tension values are 1000 cm water column (Alderfer and Merkle, 1942) [47]. And it is close to our moisture tension (800 millibars), perhaps this is due to the effect of wetting and drying cycles on the soil, as the soil whose moisture remains for a long time close to the field capacity (400 millibars) is affected negatively comparedto the soil that is exposed to wetting and drying at a moisture tension greater than 400 mbar (Hartge and Horn, 1991), although the aggregates stability remained within the medium range 1.2-4.5.

In this regard, organic matter contributes to stability by reducing wetting by increasing the hydrophobicity of the complexes (Caron et al., 1996) [48], and stability occurs as a result of the formation of complexes between humates and clay that protect the soil from the effects of dispersal [18]. The high specific surface has a high affinity for adsorption of humic compounds, thus stabilizing aggregations (Caravaca et al., 1999) [49]. Piccolo et al. [18] recorded increments ranging from 40% to 120% in the structure stability of a number of dry and semi-dry soils in the Mediterranean basin at low application rates for humate 0.1-0.05 g humate/kg soil.

Table 7. Aggregate stability (mm) under the influence of different levels of humate and moisture tension

	M0	M1	M2	M3
Ψ1 400 milli bar	2.59	2.29	2.22	2.14
Ψ2 600 milli bar	2.05	2.14	1.86	1.76
Ψ3 800 milli bar	2.08	1.95	1.85	1.35

Effect of potassium humate and moisture tension on the leaf area (cm^2)

The leaf area plays an important role in light interception, which has a significant impact on growth, respiration, and dry matter accumulation processes. Table (8) shows the leaf area of corn plants after 63 days of cultivation under the effect of different levels of potassium humate and moisture tension. Overall, Corn leaf area differed in its response to potassium humate and moisture tension. In addition, it shows that the leafarea increases at the same moisture tension with the increase in the humate rate addition, whereas, leaf area diminished significantly at the same application rate with an increase in moisture tension to (800 millibars) at the control treatment that did not receive humate and at the high addition rate when compared to the low tension (400 millibars).

To be more specific, at 400 millibars the first significant response to moisture tension was at the high rate of addition (M3=3.6 kg humate/dunum) while at 600 millibars the significant response to moisture tension started from the first rate of potassium humate, and continued until the highest rate of application reaching a summit of (2476 cm^2) at (M2=1.8 kg/d). This seems consistent with Gomaa et al. (2014) [50] who found that plants that received an application rate of 1.4 kg humate/dunum had the highest indicators of vegetative growth such as leaf area and plant height.

However, the increase in the growth properties of humate treatments may be due to the improvement in the absorption of major elements such as nitrogen, phosphorous and sulfur, as well as the case for microelements (Fe, Mn, Cu, Zn) (Chen et al., 1999) [51].

In the same vein, the response to humate continued with an increase in moisture tension to 800 millibars until the highest added rate of 3.6 kg/dunum. At 800 millibars, the leaf area was less than at 400 and 600 millibars, and this may be due to water stress in the soil that led to the decrease in the leaf area.

This variation in the response to humates depending on moisture tension appears to be related to the texture of Celtic clay soils, which are able to retain good amounts of available water with an increase in moisture tension.

Table 8. Leaf area cm^2 after 63 days of cultivation

	M0	M1	M2	M3	$LSD_{0.05}$
Ψ1 400 milli bar	1677.8	1888.6	1632	2165.8	142.2
Ψ2 600 milli bar	1724.0	2158.6	2476.0	2051.1	205.5
Ψ3 800 milli bar	1055.1	1716.2	1639.8	1731.6	164.4
$LSD_{0.05}$	168.4	196.1	161.3	207.6	

CONCLUSIONS AND RECOMMENDATIONS

1. The results show that the soil's bulk density at all moisture tension levels decreased significantly with the increase of humate application rate in all treatments compared to the treatment without adding potassium humate
2. The available water percentage in the soil at the application rate of 3.6 kg humate / dunum increased by 5.47-5.32-5.14%, respectively, at the moisture tension levels (400-600-800 millibars) compared to the treatments for the same moisture tension and without the addition of humate.
3. The study showed that the empirical constants (a), (b) increase with the increase in the humateapplication rate at all levels of moisture tension.
4. The addition of potassium humate led to an increase in the leaf area with an increase in the application rate at the same moisture tension

Based on that, we recommend the following:

1. Conducting the study on other types of soils to find out the appropriate level of potassium humate in improving the physical properties of the soil.
2. Recommend the use of organic fertilizer (Humate) at a rate of 1.8 kg/dunum for maize plants on clay silty soil .

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