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Enhancing Water Use Efficiency in Sandy Soil Using some Organic and Mineral Additives under Deficit Irrigation during Vegetative Growth of Peanut

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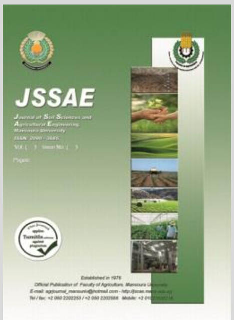

ABSTRACT

A field experiment has been carried out at the Ismailia Agricultural Research station, Agricultural Research Center (ARC), Egypt, during the summer seasons of 2017 and 2018. It aimed to study the effect of deficit irrigation during vegetative growth and addition of humic acid (Hu), gibberellic acid (GA3), silicon (Si), potassium (K) and calcium (Ca) on peanut yield and its components. The present work included three irrigation treatments, T1 irrigation with amount of 100% ETc, imposed from 10 days after sowing until harvest, T2 irrigation with amount water equal to 60%ETc imposed 10 days after sowing until 38 days after sowing after which with 100% ETc until harvest, T3 irrigation with amount of water equal to 80% ETc imposed from 10 days after sowing until 38 days after sowing follows with 100% ETc maintained until harvest. Foliar spray included 5000 ppm Hu, 150 ppm GA3 and 200 ppm Si. Potassium K was added as soil application before sowing at a rate of 100 kg ha^{-1} as K_2SO_4 and Ca was applied during soil preparation as $CaSO_4$ at rate of 500 kg ha^{-1}. The fully irrigated treatment T1 100% ETc yielded the highest pods and kernel yield but non-significant difference from T2 and T3. WUE and IWUE increased by deficit irrigation during vegetative growth. Application of Hu, GA3, Si, K and Ca significantly increased peanut pods and kernel yield and had significant effect on WUE and IWUE.

Keywords: Deficit Irrigation;Plant Growth Regulators;Sandy Soil; Water Use Efficiency

INTRODUCTION

Agriculture is the largest water user on Egypt consuming. Chai *et al* (2014a) pointed out that many of the world irrigation water has been over exploited over used and fresh water shortage is becoming critical in the arid and semi-arid areas. Consequently, water resources available will need to be nationalized to satisfy the developmental need for other sector.

Regulated deficit irrigation defined as irrigation practice whereby a crop is irrigated with an amount of water below the full requirement for optimal plant growth; this is to reduce the amount of water used for irrigation crops, improves the response of plant to certain degree of water deficit in positive manner, and reduce irrigation amounts or increase the crop water use efficiency (WUE) (Chai *et al*. 2014a).

Several researchers have involved the drought in the early season of pre flowering drought of peanut can increase yield (Puangbut *et al*., 2010 and Nuatiyat et at. 1999). Rao*et al*.,1988 observed that drought during the pre-flowering phase of peanut followed by adequate water availability result in increased pod yield of peanut between 13% and 19% greater than fully irrigated crop (Puangbut *et al* 2010a and 2010) pointed out that drought during vegetative phase or pre- flowering has only small effects on yield. Ronald *et al* (2012) studied the effect of seasonal water deficit (50-75) on peanut and concluded that water deficit in the first 45 days after planting followed by 100% irri-gation were success full at sustaining yield and/or crop value.

Puangbut *et al*., (2013) found that deficit irrigation at 1/3 available water from emergence to 40 days after emergence increased number of pegs, pods and mature pods compared to full irrigation.

Humic acid (HA) is one important component of soil humus and composed, structure and properties are directly related to soil fertility. Humic substances are mainly composed of C, H, O, N, P, S and small amounts of Ca, Mg, Fe, Si and other elements (Tan 2014).

Humic substances play a vital role in agricultural system through its benefits to both plant and soil. It enhances plant growth and development, improves soil properties and increase penetration within soil which led to increase root ability to draw more moisture content, which increase water use efficiency (WUE) particularly in sandy soil (Sarhan *et al*. 2011, and Moghadam *et al*., 2014).

Zaky *et al*. (2006) pointed out that addition of humic acid at rate 1 g/L as foliar application (300Lha)significantly increased yield and yield components of beans. Mahmoud *et al*. (2011) found that application of humic acid as soil and foliar spray increased N, P, and K contents in soil, as well as seed yield and yield components of soybean.Dogan *et al*. (2014) concluded that adding humicincreased lentil yield and its components. El-Shafey and Zen-Dein (2016) pointed out that foliar spray of humic acid on maize and lentil plants increased yield and yield components. They attributed these results to role of humic acid as nutritional supply which increases soil fertility and increases nutrient availability.

Plant growth regulators (PGRs) are extensively used in crops to enhance plant growth and improves yield and yield components (Singh *et al*. 2017). Application of PGRs also mitigates the adverse effect of such environmental stress such as salinity and drought (Shohani *et al*. 2014).

Gibberellic acid (GA_3) constitutes a group of plant hormone that control development processes such as germination, shoot elongation, tuber formation, flowering and fruit set and growth in diverse species (Davies 1995, Rafeek *et al* 2002 and Kumar *et al* 2017).

Stalker *et al*., (2017) found that application 400Lha of GA3 at rate 176 ppm on peanut plants significantly increased

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seed. Mursed (2006) stated that foliar spray of GABA on sesame at 30 day after sowing increased growth and yield. Hassan 2018 *et al* 2013 concluded that the highest, pods kernel and haluim yield of peanut was obtained at application of 100 mg [levels of GA3 during wet and dry season.

Hassan and Ismail (2018) studied the effect of different concentration of GA3 addition on peanut plants and found that the addition of 150 mg/L GA3 significantly increased plant height, number of branches, plant total dry weight, and number of pods per plant, pods yield, seed yield and shelling percentage.

Silicon (Si) is abundant element, which supplied to plant, confirms increased vigor and resistance to exogenous stress, as well as enhanced stem mechanical strength (Epestein 1994). Silicon application also has an impact on other abiotic stress including physical stress such as loading temperature extreme and UV irradiation as well as chemical stresses from salt, metal application on groundnut growing under water stress. Toxicity and nutrient imbalance,and enhanced the uptake of major essential elements in plant exposed to water deficit (Eneje *et al* 2008).

The increase in yield observed in many studies after applying foliar nutrition with Si, was caused by improvement of all of some of the yield components. Hanafy *et al* (2008) and White *et al* (2017) pointed out that in most cereals, Silicon application increased spike density, number of kernel by spike and 1000 grain weight. Amin *et al* (2016) found that Si application increased the number of grain per cob and grain yield of maize. The highest yield of soybean caused by Si foliar application resulted for increase in number of pods and weight of 1000 seed weight (Artyszak 2016). Hussien (2018) found that Si application increased lentil yield as compared to control without Si.

The function of potassium (K) in plant was reported by many researchers. Imas and Bansal (1999) pointed out that application of potassium increases plant growthand resistance against drought, frost and diseases. Kraus and Jin Jiyun (2000) stated that the function of potassium in plant has several roles, such as enzyme activation, photosynthesis, carbohydrate metabolism and translocation, as well as water regulation.

Ali and Mwafy (2003) found that application of potassium significantly increased pods and seeds yield and oll yield peanut. Mohamed and Gobarah (2005) studied the effect of potassium application on peanut plant grown in sandy soil and concluded that yield and yield components increased due to this application. Mekki 2015 showed that potassium application increased yield, yield components, oil and protein contents of Peanut plant. In study by Mekki (2015) was found that potassium foliar application on peanut increased 1000 seed weight, shelling percentage, seed yield and oil content.

Calcium is important nutrient for peanut seed and pods development. Keisling and Walker (1982) pointed out that plant obtained Ca from surrounding soil. Sommer *et al* (1988) concluded that adequate Ca in pegging zone is essential for good development of peanut. Calcium is also effect the water status and membrane permeability of peanut leaves under stress conditions. Chari *et al* (1986) studied the effect of Ca application on groundnut growing under water stress. They found that extent of membrane and loss of water is less severing in leaves of Ca compared to no receiving a Ca supplement. El-Kammar *et al* (2018) found that addition of Ca as gypsum significantly increased pods and seed yield of peanut. The relative increases over control were 21.2 and 23.8% for pods and seeds, respectively, due to the addition of 1.5 Mg ha^{-1} gypsum.

MATERIALS AND METHODS

Two field experiments were conducted during 2017 and 2018 growing seasons at Ismailia agricultural research station, agricultural research center, Egypt, to study the deficit irrigation at vegetative growth and addition of humic acid (Hu), gibberellic acid (GA3), silicon (Si), calcium (Ca) and potassium (K) on peanut yield and its components. The soil texture is sandy (TypicTorripsimment, Entisol (FAO 2014). Soil samples before cultivation were taken to determine some physical and chemical analysis (Table 1).

Table 1. Some characteristics of the experiment soil

Character		
Particle size distribution (%)	Coarse sand	66.6
	Fine sand	29.1
	Silt	1.9
	Clay	2.4
Texture class		Sandy
$CaCO_3$ (%)		1.90
Organic Matter OM (%)		0.51
pH (1:2.5 soil : water suspension)		7.90
Electrical Conductivity EC (dS m^{-1}) (1:5 soil : water extract)		0.40
Available nutrients ($mgkg^{-1}$)	N	25.0
	P	8.1
	K	62.0

Experimental design

A split plot design with three replicates was used to implement the field experiment. The irrigation treatments occupied the main plots and Humic (Hu), Gibberellic (GA3), Ca and K occupied the sub-plots.

Water treatments

T1: Irrigation with amount of water equal to 100% crop evapo-transpiration (ETc) imposed from 10 days after sowing until harvest.

T2: irrigation with amount of water equal to 60% ETc imposed from 10 days after sowing until 38 days follows with 100% ETc maintained until harvest.

T3: irrigated with amount of water equal to 80% ETc imposed from 10 days after sowing until 38 days follows which with 100% ETc maintained until harvest.

Measurements and calculations

The values of ET_o were calculated using data obtained from metrological station using Month of equation CROPWAT model (Alen *et al*. 1998).

The crop evapo-transpiration portion values were calculated according to the following equation:

$$ETc = ET_o \times KC$$

Where ETc = crop evapo-transpiration (mm/day)

T_o= reference evapo-transpiration (mm/day)

KC = crop coefficient value for peanut (FAO 56)

Applied irrigation water:

The amount of applied water calculated by the equation given by Vermirer and Topling (1984) as follows:

$$AIW = \frac{ETc \times Kr}{Ea\ (1 - LR)} \times I$$

AIW = head of applied irrigation water (mm/day)

ETc = crop evapo-transpiration (mm/day)

Kr = evapo-transpiration reduction coefficient that depends on grown cover (A value 1.0 was used where the spacing between raw is less than 1.8 m, FAO 56)

I_{irrig}= irrigation interval (day)

Ea = irrigation efficiency of sprinkler system (an average 75% was used)

LR = leaching requirement (10% of the calculated irrigation water was applied per-irrigation during the growing season for leaching purpose

Water efficiencies:

Water use efficiency (WUE, kg/ha mm) and irrigation use efficiency (IWUE, kg/ha mm) were calculated as follows:

$$WUE = \frac{\mathbf{Y}}{\mathbf{ETc}}$$

$$IWUE = \frac{\mathbf{Y}}{\mathbf{I}}$$

Where Y = yield (kg/ha),

ETc = seasonal evapo-transpiration (mm),

I = seasonal irrigation (mm)

Calcium was added as gypsum at a rate of 500 kg ha^{-1} and K at a rate of 100 kg K ha-1 as potassium sulphate during soil preparation. Foliar application of 5000 ppm, 150 ppm GA3, 200 ppm Si (400Lha)were carried out carried out 20, 35 and 45 days after sowing.

All treatments were fertilized with 100 kg P_2O_5 as calcium super phosphate during soil preparation. Nitrogen fertilizer was applied during growing season at rate 150 N kg ha^{-1} as ammonium sulphat on two doses after 10 and 30 days after planting. Peanut seed (CV. Giza 5) supplied by Field Crop Research Institute, Agricultural Research Center, Giza, Egypt, was planted, manually, two seed per hole at 20 cm. seeds spacing with 0.70 cm row spacing. Irrigation season was started directly after planting, water applied over the entire field via sprinkler to ensure uniform growth, and subsequent irrigation were applied based on ETc.

Each main plot was 12 m wide by 60 m long and irrigated by 12 sprinkler. The sprinkler lateral were spaced 10 m apart, also the distance between sprinklers on the laterals were 10 m apart. The distance of sprinkler distribution patterns was 8 m with overlapping 75% between sprinklers. The peanut crop was harvested after 6 days from end of irrigation on 25 September. The yield of each plot separated to straw and pods, then located outside for 10 days, then weighed. 250 gm of dried mature pods were selectedthen separated to shell and seed to determined shelling percentage.

RESULTS AND DISCUSSION

Effect of water treatments on peanut yield and yield components

The peanut yield as affected by different irrigation treatments is shown in Table 2. The fully irrigated treatments (T1) yield the highest, but not significantly differences from T1 to T3 where deficit irrigation imposed during vegetative growth at 80 and 60% ETc following by adequate water supply at 100% ETc. Pods yields were 3.96, 3.89 and 3.82 Mg ha-1 while the kernele yields were 2.89, 2.277 and 2.70 Mg ha-1 for irrigation treatments T1, T2 and T3, respectively. also, there is non-significant differences for 100 kernel weight and shelling percentage between three treatments were found.

Table 2. Effect of Irrigation treatments on pods and kernel yield and shelling percentage (mean combined of two seasons)

Treatments	Mg ha^{-1}		Weight of 100-kernel (g)	Shelling (%)
	Pods	Kernel		
T1	3.96	2.85	96	72.1
T2	3.89	2.77	94	71.2
T3	3.82	2.70	93	70.9
L.S.D. $P=.05$	N.S.	N.S.	N.S.	N.S.

Irrigation water amount at different irrigation treatment

The cumulative irrigation water for entire growing season of peanut were 634, 606, and 585 mm. for T1, T2 and T3, respectively. Deficit irrigation by 80 and 60% ETc during vegetative growth period decreased irrigation amount by 4.4 and 8.52% compared full irrigation (T1 100% ETc). Cumulative applied water of T2 was close to full irrigation T1. This may be due to water requirement of peanut during vegetative growth is small compared with other growing stages.

Regular deficit irrigation DDI has been found to be successful for a range of crops (Puangbut *et al*. 2013). Simmonds and Ong (1987). found out that peanut is drought resistance is due to its ability to maintain a vible root system during water stress. Water stress at early stage growth stimulates the growth of peanut root into deeper soil. Peanut root can effectively extract soil water to depth 180 cm in fine sandy soil. Many researchers have revealed that drought during vegetative growth of peanut have the putential to at least maintain and some cases even increase yield (Nageswara Rao *et al*, 1985, Nuatiyal *et al* 1999, Puangbut *et al* 2010 and Poangbat *et al* 2013).

Effect of Hu, GA3, Si, K and Ca on peanut yield and its components

Data presented in Table 3 show the effect of Hu, GA3, Si, K and Ca on peanut pods and kernel yield and shelling percentage. Addition of materials significantly increased peanut yield and its components.

Table 3. Effect of Hu, GA3, Si, K and Ca treatments on pods and kernel yield and shelling percentage (mean combined of two seasons)

Treatments	Mg ha^{-1}		Weight of 100-kernel (g)	Shelling (%)
	Pods	Kernel		
Control	3.41	2.35	87	68.9
Hu	4.01	2.89	98	72.1
GA3	4.27	3.04	96	71.9
Si	4.05	2.87	97	71.4
K	3.81	2.73	95	71.7
Ca	3.81	2.75	95	72.2
L.S.D. $P=.05$	0.12	0.11	5.31	2.25

Application of Hu increased pods and kernel yield by 17.6 and 22.99%, respectively, compared to control. The beneficial effect of Hu on peanut yield and it components may be due to enhanced plant growth and development, improving soil properties, increase root penetration within the soil (Sarhan 2011 ,Moghadam *et al*., 2014 and Hussien *et al* 2018). This results is in harmony with those explained by Zaky *et al* 2006, Mahmud *et al*, 2011) El-Shafe and Zen-El-Dein 2016 and Hussien *et al* 2018).

Addition of GA3 significantly increased peanut pods and kernel yield, 100 weights seed and shelling percentage, compared to control. The relative increase over the control are 25.2 and 29.36% for pods and kernel, respectively. The benefit effect of GA3 in peanut yield may be due to that GA3 it constitute a group plant hormone that control development processes as germinations, shoot elongation and flowering (Rafeek *et al* 2002), and also mitigate the adverse effect of such environmental stress such as salinity and drought (Shohai *et al* 2014).

These data confirm with data obtained by Yakubu *et al* 2013, and Hassan 2018 who found that application of GA3 as foliar spray with concentration of 100 and 150 ppm significantly increased pods and kernel yield.

Silicon application significantly increased pods, kernel, 100-kernel weight and shelling percentage of peanut. The relative increases over control are 18.76 and 22.12% for pods and kernel, respectively. it may be due to that Si play an essential role in development of secondary and rotarts cells of endoderms which allow for increase root resistance in dry soil (Artyszak and Kucin 2016). Also, Si has impact on other biotic stress such as loading temperature extreme (Eneji *et al* 2008). These data confirm with data obtained by White *et al* 2017 and Hassan 2018, and Hussien *et al*., 2018).

Table 4. Interaction effect of irrigation treatments and Hu, GA3, Si, K and Ca treatments on peanut pods and kernel yield (mean combined of two seasons)

Treatments	Irrigation treatments					
	Pods			Kernel		
	T1	T2	T3	T1	T2	T3
Control	3.41	3.48	3.32	2.40	3.38	2.78
Hu	4.09	3.92	4.00	2.96	2.86	2.85
GA3	4.30	4.27	4.24	3.13	3.02	2.98
Si	4.07	4.09	3.99	2.92	2.89	2.80
K	3.92	3.80	3.71	2.81	2.73	2.63
Ca	3.93	3.78	3.70	2.9	2.76	2.67
	3.95	3.89	3.83	2.85	2.77	2.70
L.S.D. P= .05	N.S.					

Potassium application significantly increased pods, kernel yield, and 100-seed weight and shelling percentage of peanut (Table 3). The relative increase over the control was by 11.73 and 16.17% for pods and kernel, respectively. This increase may be that K has several role in plant as enzyme activation, photosynthesis, carbohydrate metabolism and translocation. As well as water regulation and drought (Karus and JinJiyun2008) The beneficial effect of K on peanut confirm with data obtained by Mekki *et al* and Mohamed *et al* 2005, who found that potassium addition significantly increased yield and yield component of peanut grown in sandy soil.

Calcium addition significantly increased pods and kernel yield of peanut and also, 100-seed weight and shelling percentage. The relative increase over the control is 11.73% and 18.2% for pods and kernel, respectively. This may be due to that Ca very important for pods and kernel development (Summer *et al*., 1988). Pointed out that adequate Ca in pigging zone is essential for good development of peanut. Calcium also effect on the water status and membrane permeability of peanut leaves under stress conditions (Aza and Abd-wahb, 2014 and Yang, 2014)

There is non-sigmficant interaction effect between of irrigation and treatments addition of HU, GA3, SI, Ca and K (tabl 4)

Effect of irrigation treatments on water use efficiency (WUE) and Irrigation use efficiency (IWUE)

Water use efficiency (WUE) and Irrigation water use efficiency (IWUE) for the different irrigation treatments are shown in Table 5. Deficit irrigation during vegetative growth significantly affected WUE and IWUE. Water use valus efficiency were 9.04, 9.55 kg ha^{-1} mm^{-1} 10.66 and 6.49, 6.77 and 7.10 kg ha^{-1} mm^{-1} for pods and kernel for T1, T2 and T3, respectively. Irrigation water use efficiency were 6.25, 6.41, 6.63 and 4.49, 4.57, 4.66 for pods and kernel for T1, T2 and T3, respectively.

The feasibility of increasing either the WUE or IWUE is decision that nead to based not only on the biophysical respons of crop but also on economic factors often the objective of producers is not to increase yields but to increase profits(Norton *et al* 2000, Oweis and Hachum *et al* 2004. This study has shown that moderately reducing irrigation during early vegetative growth stage may allow producer to maintain economic viable peanut yield under reduced water resources in the arid region. In particular, strategies impose mild water deficit early in the season with full irrigation for the reminder

Table 5. Irrigation water use efficiency and water use efficiency as affected by different water treatments (Mean combined of two seasons)

Treatments	IWUE, kg ha^{-1}mm^{-1}		WUE, kg ha^{-1}mm^{-1}	
	Pods	Kernel	Pods	Kernel
T1	6.23	4.49	9.04	6.49
T2	6.41	4.57	9.55	6.77
T3	6.63	4.66	10.66	7.10
L.S.D. *P= .05*	0.163	0.151	0.75	0.48

Effect of Hu, GA3, Si, K and Ca on WUE and IWUE

Adding of Hu, GA3, Si, K and Ca significantly affected WUE and IWUE of all treatments (Table 6). Values changed considerably with different treatments ranged from 8.55 to 10.24 and 5.84 to 7.39 for pods and kernel, respectively. IWUE values ranged from 5.71 to 7.14 kg ha^{-1} mm^{-1} for pods and 3.92 to 5.11 kg ha^{-1}mm^{-1} for kernel. The highest values of WUE and IWUE were obtained for addition of GA3 (10.75 kg ha^{-1}mm^{-1} and7.14 kg ha^{-1}mm^{-1}, respectively.

Table 6. Irrigation water use efficiency and water use efficiency for pods and kernel yield as affected by Hu, GA3, Si, K and Ca additions (Mean combined of two seasons)

Treatments	IWUE, kg ha^{-1}mm^{-1}		WUE, kg ha^{-1}mm^{-1}	
	Pods	Kernel	Pods	Kernel
Control	5.71	3.92	8.55	5.84
Hu	6.69	4.86	9.75	7.21
GA3	7.14	5.11	10.24	7.39
Si	6.75	4.78	9.94	7.04
K	6.36	4.55	9.37	6.61
Ca	6.35	4.60	9.45	6.65
L.S.D. *P= .05*	0.2	0.18	0.41	0.31

Interaction effect between deficit irrigation during vegetative growth and Hu, GA3, Si, K, and Ca on WUE and IWUE

Interaction effect between deficit irrigation during vegetative growth and Hu, GA3, Si, K, and Ca on WUE and IWUE on peanut was significant (Table 7). The highest increase of WUE and IWUE is obtained from irrigation treatment T3 and addition of GA3 for pods and kernel. WUE values are 10.75 and 7.84 kg ha^{-1}mm^{-1} for pods and kernel, respectively, while IWUE is 7.58 kg ha^{-1}mm^{-1} for T3 × Hu and 5.39 kg ha^{-1}mm^{-1} for pods for treatment T3 × GA3.

Table 7. Interaction effect of irrigation treatments and Hu, GA3, Si, K and Ca for pods on WUE and IWUE (mean combined of two seasons)

Treatments	WUE			IWUE		
	T1	T2	T3	T1	T2	T3
Control	8.07	8.62	8.96	5.44	5.74	5.94
Hu	9.09	9.72	10.45	6.43	6.50	7.15
GA3	9.72	10.27	10.75	6.79	7.06	7.58
Si	9.37	9.93	10.53	6.42	6.75	7.10
K	8.9	9.34	9.86	6.21	6.24	6.64
Ca	9.08	9.43	9.84	6.20	6.23	6.62
L.S.D. *P= .05*		0.42			0.28	

The benefit effect of the studied materials; Hu, GA3, Si, K, and Ca on WUE and IWUE may be due to their effect on plant yield through enhanced plant growth, and shoot elongation have impact on abiotic stress such as loding extremes, chemical stress and nutrient imbalance and enhanced uptake of major essential elements in plant exposed to water deficit (Epesteint 1994, kraus and Jin Jiyun 2000, Shohants *et al*. 2014, Singh *et al*. 2017, Hussien 2018 *et al*.)

Table 8. Interaction effect of irrigation treatments and Hu, GA3, Si, K and Caadditionforkernel on WUE and IWUE (mean combined of two seasons)

Treatments	WUE			IWUE		
	T1	T2	T3	T1	T2	T3
Control	5.52	5.76	6.24	3.78	3.92	4.07
Hu	6.81	6.97	7.84	4.68	4.72	5.18
GA3	7.12	7.44	7.61	4.98	5.00	5.36
Si	6.71	7.19	7.21	4.60	4.72	5.00
K	6.38	6.60	6.86	4.42	4.51	4.71
Ca	6.44	6.66	6.86	4.50	4.55	4.75
L.S.D. $_{P=.05}$		.029			.040	

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رفع كفاءة استخدام المياه فى الأراضى الرملية باستعمال بعض المواد العضوية والمعدنية تحت ظروف نقص الرى خلال فترة النمو الخضرى للفول السودانى

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اجريت تجربتان حقيقتان فى موسمى صيف 2018/2017 للدراسة رفع كفاءة استخدام المياه بواسطة بعض الاضافات العضوية والمعدنية تحت ظروف نقص الرى خلال فترة النمو الخضرى. للفول السودانى وكانت المعاملات هى الرش بواسطة حامض الهيوميك بمعدل 5000 جزء فى المليون ، وحمض الجبريليك بمعدل 150 جزء فى المليون والسليكون بمعدل 200 جزء فى المليون وتم اضافة اليوتاسيوم الى الأرض بمعدل 100 كيلو جرام / هكتار وذلك فى صورة كبريتات بوتاسيوم والكالسيوم بمعدل 500 كيلو جرام هكتار فى صورة كبريتات كالسيوم واستخدمت ثلاثة معاملات رة كالاتى : الرى بمعدل100 ،80 ، 60% من كمية النتح بخر أثناء فترة النمو الخضرى . وجد أن أعلى محصول تم الحصول عليه عند الرى بمعدل 100% من كمية النتح بخر أثناء النمو الخضرى بدون فرق معنوى مع المعاملات الاخرى .كما أن إضافة المعاملات المعدنية والعضوية أدت إلى زيادة معنوية فى محصول الفول السودانى وكذلك أدى الرى باستخدام 60% ، 80% من كمية النتح بخر أثناء النمو الخضرى الى رفع كفاءة استخدان المياه وكذلك إضافة الهيوميك ، والجبريليك ، والسليكون والبوتاسيوم والكالسيوك إلى زيادة كفاءة استخدام المياه.