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Improving Alfalfa Forage Yield and Water Use Efficiency under Irrigation Water Stress and Humic Acid Applications in Calcareous Soil

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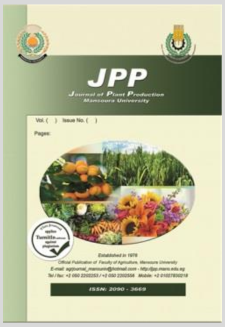

ABSTRACT

This Investigation was carried out at Nubaria Agricultural Research Station (30° 54´ N, 29° 57´ E, and 15m above sea level), Agricultural Research Centre (ARC), Ministry of Agriculture and Land Reclamation (MALR), El-Behiera Governorate, Egypt, during 2016-2018 period to study the effects of application liquid humic acid on alfalfa forage yield and quality under irrigation water regime. Three irrigation water regime treatments were100%, 80% and 60% of ETp and three humic acid rates 0, 3 and 6 L/ha humic acid were tested in a strip-plot design. As water requirements decreased forage yield significantly decreased, in the 4 seasons for each year. No significant differences were found between the fresh or dry forage yields or leaf/stem ratio under 100% water requirement without humic acid and 80% water requirement with 6 L/ha humic acid. No significant differences were found between protein content under the interaction between irrigation water requirements and humic acid rate. Irrigation water use efficiency increased under water stress as an application of humic acid rate increased. The previous results indicate that, under experimental conditions, it is possible to save 20% of the amount of added water when adding 6 L/ha humic acid with an insignificant increases in yield amount to 11.421 t /ha.

Keywords: Alfalfa, (*Medicago sativa L.*), Humic acid, Irrigation, Forage yield, Water use efficiency, Leaf/stem ratio, Protein, Water stress.

INTRODUCTION

Water stress is considered to be one of the major problems in global field crop production which led to a decrease in growth and yield, especially in arid and semiarid regions where there is not enough rain (Thomas *et al*., 2004). Water deficit caused between 11 and more than 40% reduction of biomass across the forage crops due to a decline in leaf gas exchange and leaf area. Harvest index decreased as a result of irrigation withholding in different growth stages. Limited irrigation water availability poses the question as to when and how much to irrigate to achieve optimum production and water uses efficiency. It is quite sensitive to water stress when compared to a series of other crops (Al-Shareef *et al*., 2018). The reduction in yield in case of less irrigation water supply might be due to the decreased photosynthetic. Overall fewer yields were recorded in treatments where less irrigation water was supplied (Pandey *et al*., 1984).

Drought stress has the highest percentage (26%) when the usable areas on the earth are classified in view of stress factors (Blum, 1986). Water stress affects crop phenology, leaf area development, and flowering, reduces the rate of photosynthesis, uptake of nutrients and finally results in low yield. The leaf chlorophyll content is one of the most important indices showing the environmental stress on plants, which reduces under stress conditions (Zarco-Tejada, 2000). Water stress reduces photosynthesis; the most important physiological process that regulates the development and productivity of plants (Athar and Ashraf, 2005). Reduction in leaf area causes a reduction in crop photosynthesis in plants leading to dry matter accumulation Yield loss is depending on the time and intensity of the stress, thus in water deficit environments, matching crop development and water demand with the soil water availability will enable plants to utilize the limiting water resource more efficiently (Costa, 2002).

Water deficit in plant disturbs normal turgor pressure, and the loss of cell turgidity may stop cell enlargement that causes reduced plant growth. It increases root shoot ratio, the thickness of cell walls and the amount of cutinization and lignification (Srivalli *et al*., 2003).

Focusing on techniques that can improve water availability in the summer growing season might be increased the production of summer crops. Because, without any management rain or irrigation water may be percolating beyond the root-zone, resulted in environmental consequences and diminishes water reserves. Using humic acid causes a great impact on the yield and yield components of potato and has an important role to play in achieving the goals of sustainable agriculture (Fadaee and Bagherzadeh, 2017). Soil amendments represent a management strategy that could conserve moisture in soils. Soil amendment compounds are materials added to soil to improve its physical and fertility properties, i.e., water retention, permeability, water infiltration, drainage, aeration, and structure and nutrients availability. Integrated application of organic and inorganic fertilizers increased field crop yield and yield components and soil nutrients (Admas *et al*., 2015). By this, a better environment for roots in addition to the plant growth is provided (Davies *et al*., 2004). Humic acid improves the physical (Varanini *et al*., 1995), chemical and biological properties of soils (Mikkelsen, 2005). The role of humic acid is well known in controlling, soil-borne diseases and improving soil health and nutrient up-take by plants and mineral availability (Mauromicale *et al*., 2011). Humic acid-based fertilizers increase crop yield (Mohamed *et al*, 2009), stimulate plant enzymes/hormones and improve soil fertility (Sarir *et al*., 2005). Humic

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compounds can help to improve the soil structure by increasing the amount of pore space and enhancing the air exchange, water movement, water holding capacity and root growth. As a result, better drought resistance and reduction in water usage can be done (Khattak and Muhammad, 2006 and Sharif *et al*., 2003). Besides water conservation, soil amendments have different, other benefits to quality of crop and soil (Peter *et al*., 2005 and Piccolo *et al*., 2007).

In plants, humic acids have positive effects on enzyme activity, plant nutrients, and growth stimulants. The contents of humic substance from plant nutrients act as organic fertilizers and are energy sources for bacteria, fungi, and earthworms that live in the soil. Besides their contents from nutrients, humic substances can chelate soil nutrients consequently improve nutrient uptake, especially phosphorous, sulfur and nitrogen because they act as a storehouse of N, P, S, and Zn (Davies *et al*., 2004). The barley growth and yield components increased with the application of humic acid and gel polymers amendments. However, the best results were obtained from the humic acid treatment.

This study aims to use the humic acid as a soil amendment to reduce the adverse effects of the reduction in irrigation water requirements on alfalfa forage yield grown in calcareous soil.

MATERIALS AND METHODS

A filed experiment was carried out during the 2016-2018 period at the experimental farm of Nubaria Agricultural Research Station (30° 54´ N, 29° 57´ E, and 15m above sea level), Agricultural Research Centre (ARC), Ministry of Agriculture and Land Reclamation (MALR), El-Behiera Governorate, Egypt. Three irrigation water regime treatments and three humic acid rates were tested for their effects on alfalfa (*Medicago sativa* L.) Cuf 101 cultivar.

Soil analysis

Soil samples were collected from two depths (0-30 and 30-60cm) to determine main soil physical and chemical properties at the experimental site. The soil physical parameters (particle size distributions and soil texture class) were determined according to the FAO (1970), soil-moisture constants (soil field capacity, F.C.; wilting point. W.P.; and available soil moisture, ASM) were determined on a mass basis by a pressure extractor apparatus, and soil bulk density values were determined in undisturbed soil samples using the core method (Black and Hartge, 1986). The soil chemical parameters (electrical conductivity (EC), soil reaction (pH), cations, and anions concentrations) were determined according to Pansu and Gautherou (2006). The main physical and chemical properties of the soil at the experimental site are listed in Tables (1 a and b).

Meteorological Data

The main agrometeorological data during the two growing years at the experimental site are presented in Table 2.

Table 1.a. Practical size distribution and field capacity (FC), wilting point (WP), available soil moisture (ASM), and bulk density (BD) values of the soil at the experimental site.

Soil depth (cm)	Sand %	Silt %	Clay %	Texture Class	FC (%)	WP (%)	ASM (%)	BD (gcm-1)
0 -30	56.3	18.6	25.1		24.28	11.36	12.92	1.38
30-60	53.1	18.0	28.9	Sandy Clay Loam	23.89	11.31	12.58	1.42
Average	54.7	18.3	27.0		24.09	11.34	12.75	1.40

Table 1.b. Chemical of the soil at the experimental site.

Soil depth (cm)	EC dS/m	pH	$CaCO_3$ %	Soluble cations and anions (meq/L)						
				Ca2+	Mg2+	Na+	K+	HCO3-	Cl-	SO42-
0-30	2.66	8.06	23.88	12.54	3.67	8.26	2.11	2.14	13.45	10.99
30-60	3.26	8.12	24.21	15.27	4.06	9.82	3.42	1.96	16.56	14.05

Table 2. Monthly average agrometeorological data at the experimental site.

Month	Tmin (ºC)	Tmax (ºC)	Wind (m/s)	RH (%)	Rainfall Total (mm/mon.)	Rainfall Effective (mm/mon.)	Sunshine (hr)
Sep-2016	22.16	32.21	3.23	57.56	0.40	0.40	12.21
Oct-2016	19.63	29.01	2.99	64.62	11.70	11.48	11.26
Nov-2016	16.08	24.31	3.15	64.12	30.10	28.65	10.42
Dec-2016	11.27	18.17	3.57	67.52	50.10	46.08	10.00
Jan-2017	8.47	16.89	3.06	68.38	5.70	5.65	11.60
Feb-2017	8.97	18.67	2.68	67.36	12.90	12.63	11.00
Mar-2017	11.49	21.56	3.39	63.91	0.20	0.20	11.80
Apr-2017	13.03	24.90	3.21	59.78	0.90	0.90	12.80
May-2017	16.99	29.11	3.25	56.61	0.10	0.10	13.60
June-2017	20.35	32.59	3.30	54.74	8.10	8.00	14.00
July-2017	22.86	34.46	3.42	57.23	4.00	3.97	13.80
Aug-2017	23.47	33.45	3.17	59.28	0.00	0.00	13.20
Sep-2017	21.12	31.89	3.22	60.22	0.00	0.00	12.20
Oct-2017	18.49	27.72	3.31	61.37	21.10	20.39	11.33
Nov-2017	14.75	23.03	2.72	66.16	20.90	20.20	10.55
Dec-2017	12.89	20.34	3.03	70.26	8.60	8.48	8.00
Jan-2018	10.25	18.11	5.15	69.10	40.98	38.29	10.23
Feb-2018	10.82	20.72	3.63	65.21	11.60	11.38	10.90
Mar-2018	12.41	24.86	4.00	55.56	1.27	1.27	17.77
Apr-2018	14.49	27.06	3.98	54.67	5.63	5.58	12.70
May-2018	18.70	30.88	3.37	54.13	0.00	0.00	13.50
June-2018	21.21	32.98	3.30	51.97	0.00	0.00	11.70
July-2018	22.80	33.92	3.68	58.13	2.40	2.39	13.80
Aug -2018	23.49	33.64	3.36	59.56	0.00	0.00	13.20

Experimental design and studied treatments:

A strip -plot design with four replicates was used. The main- plots vertical were assigned to three irrigation water regime treatments as water requirements are (100%, 80 and 60% of ETp), while the sub-plots horizontal were assigned to three humic acid rates (0.0, 3.0 and 6.0 liter/ha). Main- plots were separated from each other by 2.5 meters distance to avoid interference between irrigation treatments. Each sub-plots area was 42 m^2 containing 7.0 m length and 6.0 m width.

Alfalfa seeds which inoculated by *Rizobium meliloti* at the rate of 48 kg ha^{-1} drilled in the first of September 2016. Calcium superphosphate (15.5%P_2O_5) was applied at the rate of 148 kg P_2O_5 ha^{-1} during land preparation and nitrogen fertilizer in the form of ammonium nitrate (33.5%N) at the rate of 47.6 kg N/ ha was added in two equal doses after 21 and 42 days from planting for the first year and after the 9^{th} and 10^{th} cuts for the second year. Soil application of potassium fertilizer treatments in the form of potassium sulphate (48%K_2O) at the rate 57.14kgK_2O/ha was applied on two equal doses with N fertilizer application in the two experimental years. All other agricultural practices (Weeds control …etc.) were followed as common at the site.

Nine cuts/year were harvested from alfalfa, with a total of 18 cuts during the experimental period, the first cut was taken after 80 days from sowing and followed every 45 days in winter, spring and autumn seasons and every 30 days in summer season. Annually alfalfa cultivar was harvested at 1/10 bloom stage of maturity or when crown shoots reached 4-5 cm in length. Alfalfa forage yield (t/ha) was measured by harvesting each plot (6.0 m^2) and subsamples were collected (fresh forage of about 200g) weighed exactly and then returned to the lab for oven drying and reweighed to determine the dry matter% and forage dry weight. Fresh and dry forage yields for each cut and each plot were accumulated to calculate the total fresh and dry forage yield (t/ha) for each season during the two experimental years.

Ten representative plants were collected randomly from each plot before cutting to determine some growth parameters including; leaf/stem ratio. Leaves of alfalfa plant samples were separated from stems then leaves and stem samples were oven- dried at 70 C° to till constant weight, then the dry separated leaves and stems were weighed and the leaf/ stem ratio (L.S.R) was calculated for each treatment.

Crude protein % was determined according to A.O.A.C. (2000). The protein percentage was calculated by multiplying the total nitrogen percentage by factor of 6.25.

The tested variables in this experiment were as follows:

Irrigation Water Regime treatments:

I_1= irrigation with amounts of water equal to 100 % of potential evapotranspiration (ETp)

I_2= irrigation with amounts of water equal to 80% of ETp

I_3= irrigation with amounts of water equal to 60% of ETp

Humic acid rates:

H_1= Control (without Humic acid)

H_2= 3.0 Liter humic acid per hectare (four times).

H_3= 6.0 Liter humic acid per hectare (four times).

Humic acid was added to four doses, before the first, third, fifth and seventh cut for each year.

Irrigation water was controlled and measured by using a water flow-meter connected to an irrigation pump placed very close to the experimental plots to ensure high water application efficiency.

The potential evapotranspiration (ETp) in mm/day values, that were calculated according to class A pan evaporation method (F.A.O.1979),

$$ETp = E\ pan \times K\ pan$$

Where:

ETp = potential evapotranspiration in mm/day
Epan = pan evaporation daily values in mm day-1
Kpan = pan coefficient depended on the relative humidity, wind speed and condition, Kpan value of 0.75 was used for the experimental site.

Daily water requirements (WR) in mm/day were calculated as follows:

$$WR = \frac{ETp \times Kc}{Ea\ (1 - LR)}$$

Where:

Kc = crop coefficient for alfalfa crop as reported by F.A.O 1984).
Ea = application efficiency % (60% for control surface irrigation system).
LR = leaching requirements, (not considered under the present experiment)

Irrigation time was calculated before each irrigation event by the following equation:

$$t = \frac{AIW \times A}{q}$$

Where:

t = irrigation time (h)
A =plot area (m2)
q = pump discharge (m3/h)
AIW = applied irrigation water (mm)

Total water applied (AIWt) to the crop is expressed as:

$$AIWt = AIW + Reff$$

Where:

Reff: is the effective rainfall (mm/period).

It is calculated according to the formula reported by USDA-Soil Conservation Services (Dastane, 1974) as:

$$Reff = Rmonth * \frac{(125 - 0.2 * Rmonth)}{125} \qquad \{for\ Rmonth < 250\ mm\}$$

$$Reff = 125 + 0.1 * Rmonth \qquad \{for\ Rmonth > 250\ mm\}$$

Water utilization efficiency (IWUE): The IWUE values were calculated according to Jensen (1983) as follows:

$$\text{IWUE} = \frac{\text{Alfalfa fresh or dry yield (kg/ha)}}{\text{Applied irrigation water } (m^3/ha)}$$

Statistical analysis

The obtained data in each experiment for each season was statistically analyzed through analysis of variance procedures to determine the significance of the treatments and the interactions and LSD test was used to compare between the means after applying the statistical analysis assumptions according to El-Nakhlawy (2010) using SAS (2014).

RESULTS AND DISCUSSION

Results

Ⅰ. Irrigation regime:

The presented data of Table 3 showed the total of alfalfa fresh and dry forage yield and the mean values of leaf /stem ratio and protein content under the three water regime treatments (WR) under different rates of humic acid treatments (HA) as incomes of different seasons and total year of the two studied years.

1-Fresh forage yield:

The statistical comparisons between the fresh forage yield under the three studied irrigation regimes during the four seasons of each year showed that the 100% water regime produced the highest yield in all seasons followed by 80% and the lowest yield produced under 60% water regime. Spring and summer seasons significance differences were found between the three water regimes during autumn and winter seasons no significant difference was found between 100% and 80% water regime besides in winter no significant differences were detected between the three- water regime midmost in both years. Comparisons of total fresh yield/ha/year showed significant differences between the three water regimes in both seasons (Table3). In the first year, total fresh forage yield/year was 171.45t/ha under 100% water regime then decreased to 148.776 t/ha and 126.522 t/ha under 80% and 60% water regime, respectively, by decreasing rate are 13% and 26% from the 100% water regime, respectively. In the second year, the highest yield was 193.749t/ha then reduced by 10.59% and 21% as water requirements decreased to 80% and 60%, respectively.

2-Dry forage yield:

As shown in Table 3, alfalfa dry forage yield/cut negatively responded to irrigation water decreased especially in summer and spring seasons but in winter and autumn seasons, the decrease in dry yield cut was insignificant. Total dry yield/ha/year significantly decreased as water regime averaged in both years or here total yield attender 100% water regime were 39.291t/ha and 49.477 t/ha in the first and second years, respectively, they decreased to 33.699 t/ha and 45.522 t/ha under 80% water regime then decreased to 28.737 t/ha and 39.282 t/ha under 60% water regime in both years, respectively.

3-Leaf/stem ratio:

The obtained results (Table3) indicated no significant differences between leaf/stem ratio under 100% and 80% water regime in all seasons of the two studied years, and significantly dominated over under 60% water regime. Also, as regains of the wholly years no significant differences between 100% and 80% water regimes and summer on the 60% water regime. Leaf/ stem ratio ranged from 56.33%-50.83% in the first year and 57.76%-52.66% in the second year.

4- Crude protein %:

No significant differences were showed between the three water regimes under the different seasons or an average of each year. Crude protein % as an average of two years ranged from 22.11%-20.88% and 23.01%-22.23% in the first and second years, respectively.

Table 3. Total and mean of different alfalfa traits under the effects of irrigation regime (% of Water requirement) during two years with eight seasons.

Irrigation regime	First year					Second Year				
% of ETp	Spring	Summer	Autumn	Winter	Total year	Spring	Summer	Autumn	Winter	Total year
					Fresh forage yield (t/ha)					
100	37.746	82.059	33.234	18.41	171.45	44.349	89.965	35.302	23.502	193.119
80	33.368	67.524	29.667	18.216	148.776	38.242	84.572	30.766	22.549	176.130
60	26.930	56.690	26.867	16.034	126.522	30.590	73.155	27.994	20.573	152.313
LSD (0.05)	3.490	3.107	2.250	1.724	7.272	1.713	3.062	2.280	1.496	7.834
					Dry forage yield (t/ha)					
100	8.129	20.299	7.295	3.567	39.291	10.256	26.121	8.358	4.742	49.479
80	7.106	16.576	6.508	3.507	33.699	8.873	24.936	7.231	4.480	45.522
60	5.782	14.006	5.838	3.110	28.737	7.110	21.544	6.514	4.1133	39.282
LSD (0.05)	0.972	1.076	0.967	0.696	2.330	0.371	0.893	0.295	ns	3.139
					Means of Leaf/stem ratio					
100	59.08	58.11	54.19	53.96	56.33	59.67	59.43	58.41	53.55	57.76
80	55.37	55.01	53.22	51.83	53.85	57.33	54.64	55.91	52.35	55.05
60	52.57	52.28	50.45	48.02	50.83	53.41	52.88	53.36	51.02	52.66
LSD (0.05)	5.060	5.949	5.724	5.137	3.010	5.710	6.136	5.075	4.960	3.217
					Means of Crude Protein (%)					
100	21.83	19.80	19.85	22.06	20.88	22.80	20.22	22.64	23.26	22.23
80	22.36	20.79	21.32	22.39	21.71	23.32	20.70	22.83	23.53	22.59
60	22.71	21.2	21.95	22.58	22.11	23.56	21.53	23.34	23.63	23.01
No. of cuts	2	3	2	2	9	2	3	2	2	9
LSD (0.05)	Ns	ns	ns	ns	Ns	ns	ns	ns	Ns	Ns

Effect of humic acid:

1-Fresh forage yield:

The results in table (4) showed that by adding humic acid to the soil the fresh forage yield was increased. The highest yield/cut or total/ year were produced by using 6 L/ha humic acid with no significant difference from 3 L/ha humic acid best significantly than 6 L/ha humic acids in all seasons in the two years except in winter season, no significant differences were found between the three humic acid rates in both years. Total yield/year significantly increased as humic acid increased. Total fresh forage yield/year ranged from159.96 t/ha-138.219 t/ha in the first year and 186.255 t/ha-161.409 t/ha in the second year.

2-Dry forage yield:

Dry forage yield/cut and/year positively responded to adding humic acid especially the rate of 6 l/ha. The highest dry forage yield in all seasons and total of the two years were detected with significant differences from without humic acid addition. Total dry forage yield/year positively affected by humic acid and it ranged from 36.534 t/h-31.473 t/ha and 47.979 t/ha-41.568 t/ha in the first and second years respectively.

3-Leaf/stem ratio:

According to the statistical comparison between the means of L/S ratio under the three humic acid rates during the studied seasons (table4), the highest L/S ratio means were detected under using 6l/ha humic acid and significantly different from 0humic acid but not significantly different from 3l/ha humic acid. As for the means of the two years the results showed as the humic acid rate increased L/S ratio significantly increased means of L/S ratio as a year means ranged from 55.95-51.95% and 56.56%-52.31% for the first and second years, respectively.

4- crude Protein (%):

The obtained results of the means of crude protein (%) under the effects of the three humic acid rates indicated no significant differences between the three humic acid rates in all two years seasons and for the grand means of the two years. L/S ratio the two years ranged from21.96%-21.12% in the first year and 23.03%-22.18% in the second year. As well the results showed not significant increase in crude protein (%) as humic acid rate increased in all seasons and in all the years (Table4).

Table 4. Total and mean of different alfalfa traits under the effects of humic acid rates (L/ha) during two years with eight seasons.

Humic acid rate (L/ha)	First year					Second Year				
	Spring	Summer	Autumn	Winter	Total year	Spring	Summer	Autumn	Winter	Total year
Fresh forage yield (t/ha)										
0	29.910	63.756	28.189	16.422	138.279	34.312	76.469	29.508	21.118	161.409
3	32.650	68.376	29.779	17.702	148.509	37.566	82.841	31.354	22.136	173.898
6	35.482	74.141	31.800	18.535	159.96	41.302	88.381	33.200	23.37	186.255
LSD (0.05)	2.079	3.473	1.925	ns	6.256	2.427	4.015	1.963	ns	6.620
Dry forage yield (t/ha)										
0	6.402	15.786	6.13	3.154	31.473	7.896	22.580	6.897	4.194	41.568
3	7.002	16.766	6.549	3.402	33.72	8.729	24.189	7.426	4.391	44.736
6	7.614	18.328	6.963	3.628	36.534	9.615	25.832	7.78	4.751	47.979
LSD (0.05)	0.36	0.736	0.37	0.195	2.594	o.488	1.088	0.411	0.248	2.977
Means of Leaf/stem ratio										
0	52.963	52.973	51.916	49.953	51.950	53.143	52.446	55.050	51.593	52..31
3	55.350	55.496	50.546	51.106	53.120	56.886	55.213	55.273	52.153	54.876
6	58.713	56.933	55.416	52.753	55.950	58.386	57.296	57.376	53.183	56.556
LSD (0.05)	3.152	3.102	3.672	3.825	3.139	3.257	3.291	Ns	ns	3.153
Means of Crude Protein (%)										
0	21.686	20.123	20.646	22.046	21.120	22.830	20.233	22.550	23.113	22.180
3	22.423	20.753	20.986	22.340	21.621	23.206	20.863	22.966	23.476	22.623
6	22.793	20.923	21.4966	22.656	21.961	23.656	21.353	23.303	23.840	23.033
LSD (0.05)	ns	ns	ns	Ns	ns	Ns	ns	Ns	ns	Ns
No. of cuts	2	3	2	2	9	2	3	2	2	9

Effect of the interaction between irrigation regime and humic acid:

1-Fresh forage yield:

The presented data of Table 5 showed the alfalfa fresh forage yield/cut under the irrigation regimes x humic acid rates interaction treatments during the two studied seasons.

1-Spring season:

Under spring season of years, the highest fresh forage yield/cut was 40.920 t/ha and 49.520 t/ha, respectively under 100% water regime and 6 L humic acid/ha without significant differences from the treatments of (100%water regime and 3 L/ha humic acid) and (80% water regime and 6 L/ha humic acid). Using humic acid significantly improved fresh forage yield/cut, especially under 80% and 60% water regimes. No significant differences were showed between fresh forage yield/cut under 100% water regime without humic acid and 80% water regime with 3 or 6 L/ha humic acid and no significant differences were found between 3 and 6 L/ha humic acid under any irrigation regime.

2-Summer season:

Fresh forage yield/cut under the nine interaction treatments ranged from 90.291 t/ha under (100%water regime and 6 L/ha humic acid) to 52.519 t/ha under (60%water regime and 0 humic acid) in the first year and from 36.881 t/ha under (100% water regime and 6 L/ha humic acid) to 26.200 t/ha under 60 water regime and 0 humic acid) in the second- year summer. No significant differences were showed between the (80% water regime and 6L/ha humic acid) and (100% water regime and 0, 3 and 6 L/ha humic acid). Using humic acid improved the yield productivity under the different irrigation regimes with pronounced values under the water stresses.

3-Autumn season:

AS shown in Table 5, fresh forage yield/cut ranged from 36.352 t/ha- 25.562 t/ha in the first year autumn and from 38.482 t/ha to 27.036 t/ha in the second year autumn under (100% water regime and 6 L/ha humic acid) and (60% water regime and 0 humic acid) in both years. No significant difference was shown between the treatments of (100% water regime and 6 L/ha humic acid) or (100% water regime and 3 L/ha humic acid) or (100% water regime without humic acid) or (80% water regime and 6 L/ha humic acid) in both years.

4-Winter season:

The obtained results in Table 5 indicated no significant differences between the nine interaction treatments in both years. Fresh forage yield /cut under winter season ranged from 19.340 t/ha – 15.574 t/ha in the first year and from 24.398 t/ha – 19.304 t/ha in the second year under (100% water regime and 6 L/ha humic acid) and (60% water regime and 0 humic acid), respectively.

5-Years:

As for the results of fresh forage yield for each year under the nine interaction treatments, the highest total yields were produced under the 100% water regime and 6 L/ha humic acid, with values of 187.903 t/ha and 209.430 t/ha in the first and second years respectively. No significant differences were showed between the second year vane fresh forage yield obtained from 100% water regime and 3 L/ha humic acid and the yield obtained from 80% water regime with adding 6 L/ha or 3 L/ha humic acid in both years. Total fresh forage yields under 80% water regime and 6 L/ha humic acid were166.689t/ha and 187.920 t/ha in the first and the second years, respectively. Fresh forage yield /year under 80% water regime and 3 L/ha humic acid were 150.770 t/ha and 176.166 t/ha in two years respectively. The lowest total fresh forage yield was obtained under 60% water regime and o humic acid in both years (Table5).

Table 5. Fresh forage yield/season of Cuf101 alfalfa cultivar (t/ha) under the effects of irrigation regime and humic acid rate interaction during 8 seasons of two successive years.

Irrigation regime % of (ETp)	Humic acid rate (L/ha)	Fresh Forage Yield (t/ha)									
		First year					Second Year				
		Spring	Summer	Autumn	Winter	Total year	Spring	Summer	Autumn	Winter	Total year
100	0.0	34.076	74.927	30.246	17.648	156.897	39.904	81.875	32.188	22.532	176.499
	3.0	38.242	80.960	33.106	18.242	170.550	43.624	90.992	35.236	23.576	193.428
	6.0	40.920	90.291	36.352	19.340	186.903	49.520	97.030	38.482	24.398	209.430
80	0.0	31.240	63.823	28.760	16.046	139.869	34.282	79.202	29.300	21.520	164.304
	3.0	32.868	67.326	29.752	18.824	148.770	38.680	84.280	30.836	22.370	176.166
	6.0	35.996	71.423	30.490	19.780	157.689	41.764	90.234	32.164	23.758	187.920
60	0.0	24.416	52.519	25.562	15.574	118.071	28.752	68.332	27.036	19.304	143.424
	3.0	26.842	56.843	26.480	16.042	126.207	30.396	73.252	27.990	20.462	152.100
	6.0	29.532	60.710	28.560	16.486	135.288	32.624	77.881	28.956	21.954	161.415
$LSD_{(0.05)}$ I*H		3.640	5.505	3.260	1.292	20.135	4.340	7.429	3.516	2.374	19.789
No.of cuts		2	3	2	2	9	2	3	2	2	9

2 Dry Forage Yield:

Table (6) showed the dry forage yield/cut/ha for the 8 seasons of the 2 studied years and total dry yield of each season /year.

1 Spring Season:

The statistical comparisons between the dry forage yield/cut under the 9 interaction treatments showed no significant differences between the highest yielding treatment of (100% water regime and 6 L/ha HA) and (100% WR + 3 L/ha Ha) or (80% WR + 6 L/ha HA). Also, no significant differences between (100% WR without HA) and ((80% WR + 3 L/ha HA) in both years. Dry forage yield/cut in 2 spring seasons ranged from 8.798 t/ha – 5.250 t/ha in the first year and from 11.438 t/ha – 6.556 t/ha in the second year.

2 Summer Season:

The highest dry forage yields /cut was recorded under (100% WR + 6 L/ha HA) with values of 22.356 t/ha and 28.267 t/ha in summer seasons of the 1st and 2nd years, respectively. No significant differences were showed between the highest yielding treatment and the treatments of (80% WR + 6 L/ha HA) or (100% WR + 3 L/ha HA) in both years. In the summer season dry forage yield/cut ranged from 22.356 t/ha to 12.940 t/ha in the first year and from 28.267 t/ha – 20.372 t/ha in the second year as shown in Table (6).

3 Autumn Season

As for the spring and summer seasons, no significant differences were found between the treatments **of** (100% WR + 6 L/ha HA), **(**100% WR + 3 L/ha HA) or (80% WR + 6 L/ha HA). Dry forage yield/cut ranged from 7.962 t/ha – 5.572 t/ha/cut in the first season and from 9.120 t/ha – 6.326 t/ha in the second season.

4 Winter Season

The obtained results of dry forage yield/cut under the interaction treatments in winter seasons of the two years cleared that the six treatments of 100% WR and 80% WR with the 3 HA rates in each were not significantly different between each other or compared with (60% WR + 6 L/ha HA). Dry forage yield/cut/ha ranged from 3.868 t/ha – 3.022 t/ha in the first year and from 5.112 t/ha – 3.898 t/ha/cut in the second year.

Table 6. Dry forage yield/season of Cuf101 alfalfa cultivar (t/ha) under the effects of irrigation regime and humic acid rate interaction during 8 seasons of two successive years.

Irrigation regime % of (ETp)	Humic acid rate (L/h)	Dry Forage Yield (t/ha)									
		First year					Second Year				
		Spring	Summer	Autumn	Winter	Total year	Spring	Summer	Autumn	Winter	Total year
100	0.0	7.368	18.85	6.576	3.314	36.108	9.298	23.75	7.51	4.424	44.982
	3.0	8.222	19.691	7.384	3.52	38.817	10.034	26.348	8.444	4.692	49.518
	6.0	8.798	22.356	7.926	3.868	42.948	11.438	28.267	9.12	5.112	53.937
80	0.0	6.588	15.569	6.242	3.128	31.527	7.834	23.62	6.856	4.26	42.57
	3.0	7.066	16.607	6.546	3.576	33.795	9.012	24.793	7.278	4.43	45.513
	6.0	7.666	17.553	6.738	3.818	35.775	9.774	26.397	7.56	4.752	48.483
60	0.0	5.250	12.940	5.572	3.022	26.784	6.556	20.372	6.326	3.898	37.152
	3.0	5.718	14.002	5.718	3.11	28.548	7.142	21.427	6.556	4.052	39.177
	6.0	6.378	15.077	6.226	3.198	30.879	7.634	22.833	6.66	4.39	41.517
LSD(0.05) I*H		0.661	1.430	0.602	0.353	6.042	0.841	1.973	0.742	0.470	7.976
No.of cuts		2	3	2	2	9	2	3	2	2	9

5 Years

The obtained data (Table 6) showed that the highest total dry forage yield/ha were recorded under the treatment of (100% + 6 L/ha HA) without significant differences from the treatments of (100% WR + 3L/ha HA) or (80% WR + 6 L/ha HA) in both years. Total dry forage yield l ha ranged from 42.948 t/ha -26.784 t/ha in the first year and from 53.937 t/ha – 37.152 t/ha in the second year.

3 Leaf/stem ratio:

The recorded results of leaf/ stem ratio under the effects of the 9 interaction treatments during the 8 seasons 2 years showed no significant differences between the means of leaf/stem ratio under the 3 HA rates in full irrigation regime and (3 L/ha HA, 6 L/ha under 80% WR) or (6L/ha HA under 60% WR) but it significantly dominated over the 0.0 or 3 L/ha HA under 60% WR (Table 7).

4 Crude Protein %:

The present results of crude protein % under the interaction treatments (Table 8) showed no significant differences in crude protein % in the 8 seasons of the 2 years as well as over the means of the four seasons in each year. Means of crude protein % overall the four seasons in the first year ranged from 22.39% - 20.53% and in the second season ranged from 23.42 % - 21.82%.

Table 7. Means of Leaf/stem ratio under the effects of the interaction between irrigation regime and humic acid rate of Cuf101 alfalfa cultivar during 8 seasons of two successive years.

Irrigation regime % of (ETp)	Humic acid rate(L/ha) (H)	Leaf/stem ratio									
		First year					Second Year				
		Spring	Summer	Autumn	Winter	Mean of year	Spring	Summer	Autumn	Winter	Mean of year
100	0.0	56.72	55.63	55.24	52.50	55.02	57.90	56.22	56.08	52.83	55.75
	3.0	59.60	58.44	47.90	53.41	54.83	59.36	59.72	58.61	53.21	57.72
	6.0	60.94	60.26	59.45	55.98	59.15	61.77	62.35	60.56	54.63	59.82
80	0.0	52.94	53.20	51.25	50.18	52.14	55.38	52.17	53.61	51.65	53.20
	3.0	55.80	55.19	53.44	51.86	54.07	57.85	54.86	55.93	52.33	55.24
	6.0	56.37	56.64	54.99	53.45	55.36	58.76	56.89	58.21	53.08	56.73
60	0.0	48.23	50.09	49.26	47.18	48.69	52.15	50.95	50.46	50.30	53.21
	3.0	50.65	52.86	50.30	48.05	50.46	53.45	51.06	51.28	50.92	51.67
	6.0	58.83	53.90	51.81	48.83	53.34	54.63	52.65	53.36	51.84	53.12
$LSD_{(0.05)}$ I*H		8.06	8.92	8.09	7.83	7.25	8.56	8.95	8.42	8.64	7.05
No.of cuts		2	3	2	2	9	2	3	2	2	9

Table 8. Means of crude protein (%) under the effects of the interaction betweenirrigation regime and humic acid rate of Cuf101 alfalfa cultivar during 8 seasons of two successive years.

Irrigation regime % of (ETp)	Humic acid rate(L/ha) (H)	Crud Protein (%)									
		First year					Second Year				
		Spring	Summer	Autumn	Winter	Mean of year	Spring	Summer	Autumn	Winter	Mean of year
100	0.0	21.37	19.31	19.57	21.89	20.53	22.38	19.61	22.35	22.94	21.82
	3.0	21.82	19.96	19.87	21.99	20.91	22.87	20.19	22.67	23.21	22.23
	6.0	22.31	20.15	20.12	22.30	21.22	23.17	20.86	22.92	23.64	22.64
80	0.0	21.64	20.23	20.97	22.02	21.21	22.97	20.12	22.54	23.11	22.18
	3.0	22.51	20.98	21.31	22.39	21.79	23.11	20.76	22.82	23.54	22.55
	6.0	22.93	21.17	21.68	22.78	22.14	23.88	21.22	23.14	23.94	23.04
60	0.0	22.05	20.83	21.40	22.23	21.62	23.14	20.97	22.76	23.29	22.54
	3.0	22.94	21.32	21.78	22.64	22.17	23.64	21.64	23.41	23.68	23.09
	6.0	23.14	21.45	22.69	22.89	22.54	23.92	21.98	23.85	23.94	23.42
No.of cuts		2	3	2	2	9	2	3	2	2	9
$LSD_{(0.05)}$ I*H		2.62	2.58	2.49	2.51		2.63	2.33	2.55	2.59	

1 Applied irrigation water

The monthly and seasonally water requirements (amount of applied irrigation water) for alfalfa crop according to the irrigation treatments, including effective rainfall, during the two growing years are listed in Table 9 . The highest monthly value of water requirements occurred during July in both years for all irrigation treatments. The total amount of water requirements for I1, I2 and I3 irrigation treatments were 127.16, 107.99 and 88.82 cm. in the 1st year, and 130.74, 109.88 and 89.02 cm. in the 2nd year, respectively.

2 Irrigation water use efficiency:

Results in Table10 represented the irrigation water use efficiency (IWUE), expressed as Kg of (fresh and dry alfalfa yield) per cubic meter of water requirements including rain, for the two growing years. Comparing the values of (IWUE) under the interaction between Humic acid rate and irrigation treatments for the summation cuts for two years, reveals that, the highest IWUE was obtained from 60% of ETp followed by 80% of ETp, and the least IWUE was recorded in 100% of ETp for both fresh and dry yield in 1st and 2nd years, indicated by means in Tables5 and 6. The value of IWUE for 100% of ETp ranged from 15.36 (I_1H_3) to 12.92 (I_1H_1) for fresh yield and from 3.75 (I_1H_3) to 3.14 (I_1H_1) for dry yield. For 80% of ETp the IWUE ranged from 15.85 (I_2H_3) to 13.95 (I_2H_1) and from 3.86 (I_2H_3) to 3.40 (I_2H_1) for fresh and dry yield, respectively. In 60% of ETp the IWUE ranged from 16.68 (I_3H_3) to 14.70 (I_3H_1) and from 4.07 (I_3H_3) to 3.59 (I_3H_1) for fresh and dry yield respectively (Table 10). IWUE increased under water stress in addition to increased Humic acid rate

Table 9. Monthly and total water requirements in cm as affected alfalfa by irrigation treatments during 2016 /2017 and 2017/2018 growing years.

2016/2017				2017/2018			
Date	Irrigation treatments			Date	Irrigation treatments		
	100%	80%	60%		100%	80%	60%
Sep-2016	19.50	19.50	19.50	Sep-2017	15.63	15.63	15.63
Oct-2016	8.55	6.84	5.13	Oct-2017	10.62	8.50	6.37
Nov-2016	7.11	5.69	4.27	Nov-2017	8.01	6.41	4.81
Dec-2016	5.31	4.25	3.19	Dec-2017	5.76	4.61	3.46
Jan-2017	4.68	3.74	2.81	Jan-2018	4.59	3.67	2.75
Feb-2017	6.30	5.04	3.78	Feb-2018	6.03	4.82	3.62
Mar-2017	8.10	6.48	4.86	Mar-2018	7.29	5.83	4.37
Apr-2017	8.91	7.13	5.35	Apr-2018	10.08	8.06	6.05
May-2017	10.62	8.50	6.37	May-2018	11.61	9.29	6.97
June-2017	11.16	8.93	6.70	June-2018	12.87	10.30	7.72
July-2017	13.23	10.58	7.94	July-2018	13.86	11.09	8.32
Aug-2017	11.88	9.50	7.13	Aug -2018	13.59	10.87	8.15
Reff	11.81	11.81	11.81	Reff	10.80	10.80	10.80
Total	127.16	107.99	88.82	Total	130.74	109.88	89.02

Table 10. Irrigation water use efficiency (IWUE) for fresh and dry alfalfa yield in Kg/m3 water during 2016 /2017 and 2017/2018 growing years.

Irrigation regime % of (ETp)	Humic acid rate(L/h)	(IWUE) for fresh alfalfa yield			(IWUE) for dry alfalfa yield		
		2016/2017	2017/2018	Average 2-year	2016/2017	2017/2018	Average 2-year
100%	0.0	12.34	13.50	12.92	2.84	3.44	3.14
	3.0	13.41	14.79	14.10	3.05	3.79	3.42
	6.0	14.70	16.02	15.36	3.38	4.13	3.75
	mean	13.48	14.77	14.13	3.09	3.78	3.44
80%	0.0	12.95	14.95	13.95	2.92	3.87	3.40
	3.0	13.78	16.03	14.90	3.13	4.14	3.64
	6.0	14.60	17.10	15.85	3.31	4.41	3.86
	mean	13.78	16.03	14.90	3.12	4.14	3.63
60%	0.0	13.29	16.11	14.70	3.02	4.17	3.59
	3.0	14.21	17.09	15.65	3.21	4.40	3.81
	6.0	15.23	18.13	16.68	3.48	4.66	4.07
	Mean	14.24	17.11	15.68	3.24	4.41	3.82

Discussion

1 Irrigation water Stress:

The adverse effects of reducing irrigation water requirements from 100% to 80% and 60% from potential evapotranspiration(ETp) on alfalfa forage yield and leaf /stem ratio in our study were showed especially during the high temperature and rarely rain seasons (summer and spring). These results might be due to decline in gas exchange and leaf area in addition to the reduction in biomass. As well as a decreasing in water requirements might be because decreasing in photosynthetic rate (Pandy *et al*., 1984). Also, water stress affects crop phenology, leaf area development, and uptake of nutrients and finally results in low yield. As well as, reduction in leaf area causes a reduction in crop photosynthesis in plants leading to low dry matter accumulation (Costa 2002).

5 Humic Acid Effects under water Stress:

The obtained results of our study showed increases in forage yield and leaf/stem ratio as humic acid rate increased in different seasons with a more pronounced positive effect during the summer and autumn seasons. The positive effects of humic acid on forage yield and leaf/stem ratio under the irrigation water stress might be due to the role of humic acid in improving physical (Varanini *et al*, 1995), chemical and biological properties of soils (Mikkelsen, 2005). The role of humic acid is well known in controlling, soil-borne diseases and improving soil health and nutrient uptake by plants and mineral availability (Mauromicale *et al*, 2011). Humic acid based fertilizers increase crop yield (Mohamed *et al*, 2009), stimulate plant enzymes/hormones and improve soil fertility in an ecologically and environmentally benign manner (Sarir *et al*, 2005). Using humic acid help to conserve water in root-zone area. Therefore, water availability is increases due to the reductions in run-off and/or deep percolation that will ultimately cause increase in crop yield. Humic compounds can help to improve the soil structure by increasing the amount of pore space and enhancing the air exchange, water movement, water holding capacity and root growth. In plants, humic acids have positive effects on enzyme activity, plant nutrients, and growth stimulant. Humic substances can chelate soil nutrients consequently improve nutrient uptake, especially phosphorous, sulfur and nitrogen because they act as a storehouse of N, P, S, and Zn (Davies *et al*., 2004).

6. Applied irrigation water and Irrigation water use efficiency

Improvement of soil structure and aggregation increase soil pore space especially in its volume. Any increase in volume pore space is met by a reduction in soil bulk density and increase in water movement. Due to the reduction in bulk density and an increase in water movement, saturated hydraulic conductivity was increased consequently increased irrigation water use efficiency by increasing humic acid application rate (Al-Shareef *et al*., 2018).

CONCLUSSION

This study mainly concluded that irrigation water stress adversely affects forage yield. Application of humic acid on the soil of alfalfa improved the water use efficiency besides increased the forage yield especially under the water stress during the summer and spring seasons. The study recommended that we can save 20% from the irrigation water requirements without significant effects on forage yield of alfalfa by using the rate of 6 L/ha humic acid on the soil during the growing season of alfalfa.

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تحسين محصول العلف وكفاءة استخدام مياه الري للبرسيم الحجازي تحت ظروف الإجهاد المائي و اضافة حامض الهيوميك فى الاراضى الجيرية

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[1]قسم بحوث محاصيل العلف – معهد المحاصيل الحقلية- مركز البحوث الزراعية - مصر

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أجريت تجربة حقلية بالمزرعة البحثية بمحطة البحوث الزراعية بالنوبارية تحت ظروف الأرض الجيرية خلال الفترة من سبتمبر ٢٠١٦ حتى سبتمبر٢٠١٨ استهدفت الدراسة تقدير تأثير معاملات الري والتسميد الأرضى بحامض الهيومك على محصول البرسيم الحجازى صنف قاف ١٠١ والاحتياجات المائية وكفاءة استخدام وحدة المياه تحت نظام الري السطحى بالأراضى الجيرية. وكانت المعاملات كالتالي : عامل الري : الري بكمية مياه تعادل ١٠٠ % من جهد البخر نتح .الري بكمية مياه تعادل ٨٠ % من جهد البخر نتح.الري بكمية مياه تعادل ٦٠ % من جهد البخر نتح.معدلات التسميد بحامض الهيومك:بدون اضافة حامض الهيو . التسميد بما يعادل ٣ لتر/هكتار. التسميد بما يعادل ٦ لتر/هكتار. تم التسميد بحامض بالهيومك قبل الحشة الأولى والثالثة والخامسة والسابعة فى كل عام.وأوضحت النتائج المتحصل عليها الآتي:التأثير السلبي للإجهاد المائي علي محصول العلف ونسبة الاوراق الي السيقان وكذلك علي كفاءة استخدام مياه الري . بينما حسن اضافه حامض الهيوميك من المحصول ونسبة الاوراق للسيقان وكفاءة استخدام ماء الري خلال المواسم المختلفة لسنتي الدراسة. وأدي اضافة معدل ٦ لتر حامض هيوميك/هكتار تحت معدل ٨٠% من البخرنتح الي تحسين محصول العلف الطازج والجاف ونسبة الاوراق للسيقان وكفائة استخدام مياه الري ولم تكن هناك فروق معنوية مع استخدام ١٠٠% من البخرنتح القياسى بدون اضافة حامض هيوميك.تشير النتائج السابقة بأنه تحت ظروف الاراضى الجيرية وتحت ظروف التجربة الى أمكانية توفير٢٠ % من كميه المياه المضافة عند اضافة معدل ٦ لتر حامض هيوميك/هكتار مع زيادة غير معنوية فى المحصول بلغت ١١,٤٢١ طن/هكتار).