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EFFECT OF IRRIGATION WATER QUANTITY, ANTITRANSPIRANT AND HUMIC ACID ON GROWTH, YIELD, NUTRIENTS CONTENT AND WATER USE EFFICIENCY OF POTATO (*Solanum tuberosum* L.).

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ABSTRACT

The research was conducted during two successive Nili seasons of 2007/2008 and 2008/2009 at private farm near Mansoura city, Dakahlia Governorate, Egypt (+ 7m altitude, 31° 35' latitude and 30° 58' longitude), to investigate the effects of three irrigation water quantities (800, 1600 and 2400 m^3/fed.) and three reducing water requirements substances (distilled water as a control treatment, Kaolin as antitranspirant, and humic acid) as well as their interactions on growth, yield, nutrients content and water use efficiency of potato cv. Cara. The experimental design was a split plot, where water quantity was in the main plots, substances to minimize water requirements allocated in the sub plots with three replications.

The most important finding could be summarized as follows:

- Increasing irrigation water quantity from 800 to 2400 m^3/fed increased potato growth characters of both seasons. Humic acid and Kaolin led to significant increase in most vegetative growth traits compared to control. Second level of water irrigation (1600 m^3/fed) with application of humic acid had the most significant effect of most vegetative growth characters, in both seasons of study.
- No significant differences were found in total and marketable tuber yield between 1600 m^3 and 2400 m^3 per feddan in both seasons. Application of humic acid or Kaolin was significantly increased in total and marketable tuber yield as well as tuber quality compared with the control in both seasons. The maximum value of total tuber yield was obtained when potato plants treated with humic acid under the 2^{nd} level of irrigation (1600 m^3/fed) in comparison with other treatments.
- The first level of irrigation water quantity (800 m^3/fed) and/or Kaolin had significant increases in photosynthetic pigments. On the other hand, increasing water quantity applied to potato plants up to the highest used level (2400 m^3/fed) and/or Kaolin significantly enhanced both free and total water (%) in potato leaves in comparison with the other treatments.
- Plant analysis revealed that N, P and K content as well as micronutrients increased gradually with increasing water supply to the soil. Humic acid led to increases in macro and micronutrients in comparison with the other treatments, in both seasons of study.
- Generally, it could be concluded that humic acid or Kaolin application under water quantity of 1600 m^3/fed was the best combination for potato production aimed at maximum water use efficiency in this study.

Keywords: Potato, Kaolin, Humic acid, Water requirements and Nutrient content.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a member of the family Solanaceae and is a major world food crop and by far the most important vegetable crop in terms quantities produced and consumed world wide. The total area of potato was 213,151 feddan, which produced 2,139,351 tons, and total potato export was 3296,287 ton/year for 2005. The winter season is considered the main cultivated season in Egypt for exported potato production (FAO, 2006). Shani and Dudley (2001) and Kijne *et al.* (2003) referred to the economic tuber yield divided by the volume of water consumed in the production of that yield expressed in kilogram tuber per cubic meter water.

In last decades, Egypt suffers from reducing natural water resources for irrigation the cultivated area. On the other hand, irrigation water quantity is considered as on of the main factors that greatly affect on plant growth and yield, so, efforts should be directed to minimize water requirements, improved water use efficiency in all crops including potato.

An adequate water supply is required from tuber initiation up until near maturity for high yield and good quality. Excessive irrigation of potatoes results in water loss and significantly increases of run off and soil erosion from production field. Leaching can lead to contamination of the ground water due to lixiviation of fertilizers and other chemical products (Feibert *et al.*, 1998; Waddle *et al.*, 2000; Al-Jamal *et al.*, 2001; Shock *et al.*, 2001).

Irrigation in excess of potato needs increases production costs, can reduce yield by affecting soil aeration and root system respiration, and favors the occurrence and severity of diseases and pests. Deficient irrigation promotes a reduction of tuber quality and lower yield due to reduce leaf area and/or reduce photosynthesis per unit leaf area (van Loon, 1981). In this respect, Abdrabbo *et al.* (2007) showed that increasing irrigation level from 0.60 to 1.00 of crop evapotranspirat (ET) increased potato growth characters of both cultivars (Valor and Desiree). The highest yield was obtained from the 1.00 (ET) compared with 0.60, 0.80 and 1.20 (ET). In another study, Ghosh *et al.* (2000) reported that tuber yield decreased with decreasing soil moisture, with the greatest reduction at 45% field capacity compared to 60 or 75% field capacity. El-Banna *et al.* (2001) reported that the total tuber yield and WUE value were significantly increased at 1560 m^3/fed compared to 1450 and 1850 m^3/fed by using drip irrigation system. On the other hand, the yield was increased by using furrow irrigation at the rate of 2350 m^3/fed, while it was significantly decreased at 1950 m^3/fed. Furthermore, Kashyap and Panda (2003) indicated that potato fresh tuber yield was significantly higher under 60 and 75% of maximum available depletion (MAD) of available soil water (ASW), which resulted in minimum fresh tuber yield. Bao-Zhong *et al.* (2003) found that total fresh tuber yields and marketable tuber yields (>85 g) increased with increasing amount of irrigation water. Finally, Youssef (2007) reported that irrigation potato plants with 2500 m^3/fed were the most efficient treatments for improving marketable and total yield.

Humic acid and antitranspirants with considerable resistance to soil moisture deficient has been considerable an economic and efficient means of utilization drought-prone areas when appropriate management practices to reduce water losses are needed (Pereira and Shock, 2006). In general, Humic acid has a number of potential benefits for plants: increased water and nutrient holding capacity; increased reserve of slow release nutrients; enhanced solubility of phosphorus, zinc, iron, manganese, and copper; increased resistance to soil pH change; improved soil aggregation; enlarged root system and increased stimulation of plant-growth due to hormones (Stevenson, 1994; Bryan and Stark, 2003; Mikkelsen, 2005). Shankle *et al.* (2004) indicated that application of humic acid plus nutrients increased total marketable yield (US No.1) of sweet potato than the standard fertility program. Seyedbagheri and Torell (2001) found that applied humic acid at 84 kg ha^{-1} increased potato yield, increased soil fertility, improved tilth and facilities aeration and water penetration, they also, found that the highest yields of the grown crops were obtained when humus content in the soil was 2.3-2.5%. Also, humic acid enhance photosynthetic process, stimulate root growth and development of chlorophyll and proliferation of desirable micro-organisms in soil (Liu *et al.*, 1998).

Lipe (1979) found that the use of antitranspirants of potato plants during the tuber enlargement reduces plant water use and increase the yield of larger potatoes (US No.1). Suryanarana and Venkateswarlu (1981) indicated that the yield of tomato increased (55-55.75 t/ha.) from plants treated with the antitranspirants (Kaolinte) or Mg CO_3 at 6 % and irrigated every 15 days. Gawish and Fattahallah (1997) stated that covering all leaf surface of *Colocasia esculenta* with kaolin (9 g/m^2) combined with wilt-pruf (4 g/m^2) reduced the transpiration rate by 50-60%. Anwar (2005) found that the combination between water quantity at the level of 1500 m^3/fed and spraying with kaolin or $CaCO_3$ at 6% was the superior treatment regarding plant growth and potato tuber weight/plant as well as total yield / feddan.

The objective of this study was to investigate the effect of irrigation water quantity with reducing water requirements substances and their interactions on quantitative and qualitative yield characters of potato.

MATERIALS AND METHODS

The experiment was carried out at private farm near Mansoura city, Dakahlia Governorate, Egypt (+ 7m altitude, 31° 35' latitude and 30° 58' longitude) during two successive Nili seasons of 2007/08 and 2008/09. The treatments comprised three water irrigation quantities (800, 1600, and 2400 "common used" m^3/fed) and three treatments of distilled water as control, Kaolin as "transpirant" and humic acid were used to improve water use efficiency and reduce water requirements. The experiment was designed in a split plot arrangement with three replications. Irrigation water quantities were in the main plots. Substances used to minimize water requirements were allocated in the sub plots. Potato cv. Cara was used, and dates of cultivating were September 25 and 28 of 1st and 2nd seasons respectively. All other agriculture practices of cultivation were performed as recommended by normal practices. Chemical properties of the soil of the experiment were analyzed before cultivation according to Page (1982) and the results are tabulated in Table 1. The permanent wilting point (PWP) and field capacity (FC) of the trial soil were determined according to Israelsen and Hansen (1962) Table 2.

Table 1:Some physical and chemical properties of the experimental soil.

Physical properties	Value		Chemical Properties	Value	
	1st season	2nd season		1st season	2nd season
Sand (%)	27.2	27.5	pH value	8.1	7.9
Silt (%)	31.5	31.4	EC dSm^{-1} in soil paste	0.9	0.8
Clay (%)	41.3	41.1	Total N (%)	0.03	0.04
Texture class	Clay-loam	Clay-loam	Available P (ppm)	11.3	11.5
$CaCO_3$	3.1	3.2	Available K (ppm)	306	298
Organic matter (%)	1.4	1.2			

Table 2: The soil moisture constant (% by weight) and bulk density of the experimental soil.

Constants depth (cm)	Saturation percentage S. (%)		Field capacity (%)		Wilting point (%)		Available water (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
0-15	80.4	80.6	40.2	40.3	16.42	16.46	18.61	19.18
15-30	81.8	81.4	40.9	40.7	16.71	16.62	19.22	19.30
30-45	82.6	82.3	41.3	41.2	16.87	16.81	20.13	20.02

Plot area was 121.5 m^2 (18 m length x 6.75 m width). Each sub plot area was 13.5 m^2 comprising of three rows, 0.75 m wide and 6 m long. Plant distances were 25 cm apart. A distance of 2 m was left between each two irrigation treatments to avoid the overlapping infiltration of irrigation or spraying solutions. Drip irrigation was used from the beginning to the end of the two seasons. The total amount of drip irrigation at different treatment was calculated and expressed in terms of time based on the rate of water flow through the drippers (4 L/h.) to give such amount of water for each treatment (EC of water irrigation 0.8 dS/m). Irrigation number, the time and water quantity (m^3) in every irrigation are shown in Table 3.

All treatments received equal amounts of water during emergency (100 m^3/fed.). The irrigation treatments started after 20 days from planting and were added by three days intervals. The water was added using water counter and pressure at 0.5 bar.

Table 3: The time (minute) and amounts of applied irrigation water (m^3/fed as well as /plot) in every irrigation during the growth period of potato via dripper lines with discharge of 4 liter /h. for each dripper at 0.5 bar.

Water quantity (m^3/fed*)	Irrigation numbers	Irrigation time in every irrigation (min.)	Water quantity (m^3/fed*) in every irrigation	Water quantity (m^3/plot**) in every irrigation
800	33	78	24.24	0.701
1600	33	97	48.48	1.402
2400	33	146	72.73	2.103

*feddan=4200 m^2 **main plot area=121.5 m^2

Potato plants were sprayed by the antitranspirants (Kaolin solutions 4%; as aluminum silicate) was applied at 40 and 60 days after planting. Plants were sprayed with a fine mist of Kaolin till run-off, with care being taken to cover all plant parts. The control plants (check) were sprayed with distilled water and spreading agent only. Humic acid 4% in a solid form (HA 85%) as K-humate were added after diluted 1: 100 beside potato plants at same time of antitranspirants application.

Data recorded:

1. Growth parameters:-

A representative sample of five plants was taken randomly from each plot at 70 days after planting, in both seasons of study, for measuring the growth characters of potato plants expressed as follows:

- Plant height (cm)
- Number of main stems/plant
- Dry weight of shoots/plant (gm)
- Leaf area/plant (cm^2).

2. Yield and yield components:-

At 130 days after planting, the tuber yield of plants was harvested, and the data were recorded for the following traits:

- Weight of tuber yield/ feddan
- Marketable yield/feddan: Yield of good shapes healthy tubers which from 30:60 mm and more than 60 mm
- Unmarketable yield/feddan: Yield of culls (offshape, blemished, green, diseased) and less than 30 mm.

3. Tuber quality properties:-

A representative sample of 10 to 15 healthy tubers from each experimental plot was selected from the largest sizes to obtain quality data:

- Dry matter content in tubers
- Specific gravity of tubers.

4. Photosynthetic pigments:-

At 70 days after planting, photosynthetic pigments were determined according to the method described by Wettestein (1957).

5. Plant water relations:-

Total, free and bound water in the fourth upper leaf of potato plants were determined at 70 days after planting according to the method described by Gosev (1960).

6. Nutrient content:-

The dry matter of tubers at 130 days after planting was finely ground and wet digested for N, P and K determination. Total Nitrogen, phosphorus and potassium contents were determined according to the methods described by Olsen and Sommers (1982). Fe, Mn and Zn contents in dry matter of tubers were determined by atomic absorption according to Rangana (1979).

7. Water use efficiency (WUE)

It was calculated according to equation of Begg and Turner (1976) as follows

$$\text{Water use efficiency} = \frac{\text{Yield (kg/fed)}}{\text{Water quantity (m}^3\text{/fed)}} = \text{kg/m}^3$$

The data were statistically analyzed as split plot design according to the procedure described by Snedecor and Cochran (1982). Comparisons among means of treatments were tested using Duncan multiple range test.

RESULTS AND DISCUSSION

1. Vegetative growth:

Data presented in Table 4 show that the vegetative growth characters of potato expressed on plant height, number of main stems per plant (except 2nd season), dry weight per plant and leaf area per plant were significantly influenced by water quantity in both seasons. The highest water quantity; i.e., 2400 m^3/fed came in the first rank in this respect. On the other hand, the lowest value of all plant growth characters were obtained under water stress; i.e., 800 m^3/fed in both seasons.

It could be suggested that increasing water quantity applied to potato plant led to keep higher moisture content in the soil and this in turn might favored the plant metabolism that leads to increase the plant growth characters and to produce higher dry matter. Water stress, on the other hand, led to cause a reduction in the uptake of nutritional elements that might causes a disturbance in the physiological processes needed for plant growth (Salter and Goode, 1967). Water stress also affects carbohydrate metabolism, protein synthesis and the activities of many enzymes that may reflect a change in the balance between rates of synthesis and degradation leading to decrease in plant growth and dry matter accumulation (Hamlyn, 1986).

On the other hand, Marschner (1995) reported that, under sufficient water conditions, there were decrease in abscisic acid (ABA) and increase in cytokinin (CYT), gibberellins (GA) and indole-3-acetic acid (IAA) reflecting good growth and dry matter content.

Theses results are in agreement with those reported by Hang and Miller (1986), Jerez *et al.*(1991), Stark *et al.* (1993), Foti *et al.* (1995), Gameh *et al.* (2000), El-Banna *et al.* (2001) and Anwar (2005) on potato. They found that increasing water quantity levels increased plant growth characters of potato.

Table 4: Vegetative growth characters of potato as affected by water quantity, reducing water requirements substances and their interactions in 2007/08 and 2008/09 seasons.

Treatments:-		Plant height (cm)		No. main stems/plant		Dry weight/plant (g)		Leaf area/plant (cm^2)	
		2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09
Irrigation water quantity (m^3/fed):-									
1. 800		59.89 b	56.78 b	3.82 b	4.00 a	26.47 b	27.42 b	4324 b	4175 b
2. 1600		62.78 a	59.11 a	4.00 ab	4.20 a	32.93 a	31.58 a	4698 a	4622 b
3. 2400		62.78 a	59.89 a	4.20 a	4.40 a	33.64 a	32.40 a	4701 a	4656 a
Reducing water requirements substances:-									
1. Control		60.00 c	55.67 b	3.73 c	3.91 a	29.18 c	28.95 c	4351 c	4324 c
2. Kaolin		62.00 b	58.78 a	4.02 b	4.29 a	30.71 b	30.19 b	4563 b	4494 b
3. Humic acid		63.11 a	61.33 a	4.27 a	4.40 a	33.14 a	32026 a	4808 a	4634 a
Interaction:-									
800 m^3/fed^{-1}	1. Control	58.67 d	54.67 d	3.60 a	3.80 a	24.16 d	25.18 d	4182 g	4116 f
	2.kaolin	59.67 cd	56.33 c	3.80 a	4.07 a	26.72 c	26.38 d	4309 f	4185 ef
	3. Humic acid	61.33 bc	59.33 b	4.07 a	4.13 a	28.53 c	30.71 bc	4481 e	4224 e
1600 m^3/fed^{-1}	1. Control	60.67 bcd	55.67 cd	3.67 a	3.93 a	31.11 b	29.88 c	4431 e	4429 d
	2. Kaolin	62.67 ab	59.67 b	4.07 a	4.27 a	32.28 b	31.90 ab	4658 d	4600 c
	3. Humic acid	64.00 a	62.00 a	4.27 a	4.40 a	35.40 a	32.96 a	5005 a	4837 a
2400 m^3/fed^{-1}	1. Control	60.67 bcd	56.67 c	3.93 a	4.00 a	32.28 b	31.80 ab	4442 e	4426 d
	2. Kaolin	63.67 a	60.33 b	4.20 a	4.53 a	33.13 ab	32.28 a	4723 c	4698 b
	3. Humic acid	64.00 a	62.67 a	4.47 a	4.67 a	35.50 a	33.11 a	4939 b	4842 a

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Moreover, it is evident from the date in Table 4 in both seasons that application of both humic acid and antitranspirant had significant effect on vegetative growth parameters expressed as plant height, dry weight and leaf area, and number of main stems (1st season only) compared to check treatment (control). These results could be due to the role of humic acid which increased water and nutrient holding capacity, enhance photosynthesis process, stimulate root growth and development of chlorophyll Table 5, as well as proliferation of desirable micro-organisms in soil (Stevenson, 1994; Liu *et al.*, 1998; Bryan and Stark, 2003; Mikkelsen, 2005). Also foliar spray with Kaolin led to reduce the transpiration rate, and this in turn led to keep higher water content in the plant tissues and hence might favor the plant metabolism, the physiological processes, photosynthetic rate, carbohydrate metabolism and many other important functions that directly affect plant growth. Increases in growth resulted from antitranspirant treatment was attributed primarily to their effect on increasing plant water potential at a time when the growth of that particular plant part was more dependent on water status than on photosynthesis (Boyer, 1970). Obtained results are agreeable with those reported by Upadhyaya and Mathur (1992) on wheat and Kadbane and Mungse (1997) on mung beans with respect to Kaolin; Gawish and Fattahallah (1997) on taro with respect to whitewash ($CaCO_3$) and Anwar (2005) on potato with respect to Kaolin.

The interaction between irrigation quantity and reducing water requirements treatments had significant effect on growth parameters except number of main stems per plant in both season of study. Second level of water irrigation (1600 m^3/fed) and application humic acid had the most significant effect of plant height, dry weight and leaf area per plant. These results may be due to the role of humic acid to keep more water content in plant tissue, and this in turn led to enhance the growth rate photosynthesis and enzymes activities that finally led to increase in dry matter and leaf area Table 4.

2. Yield and yield components as well as tuber quality:

Data listed in Table 5 show the effect of irrigation water quantity on total tuber yield/fed and yield components as well as tuber quality in both seasons. No significant differences in total tuber and marketable yields were evident between the 2nd and 3rd irrigation water levels in both seasons; and both treatments had significant effect on total and marketable tuber yields compared with stressed treatments (800 m^3/fed). Regarding dry matter and specific gravity, the data show that second level of irrigation quantity (1600 m^3/fed) had a significant effect in this respect (in 1st season).

A significant increases in unmarketable yield and significant decrease in tuber quality were evident in the first level of irrigation (800 m^3/fed). This is true in both season of study. The results obtained with yield and yield components as well as tuber quality reflected similar trend to that obtained with plant growth.

Table 5: Total tuber yield and yield components as well as tuber quality of potato as affected by water quantity, reducing water requirements substances and their interactions in 2007/08 and 2008/09 seasons.

Treatments:-		Total tuber yield (ton/fed.)		Marketable yield (ton/fed.)		Unmarketable yield (ton/fed.)		Dry matter in tubers (%)		Specific gravity of tubers	
		2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09
Irrigation water quantity (m^3/fed):-											
1. 800		9.367 b	8.971 b	8.508 b	8.040 b	0.860 a	0.930 a	18.674 c	18.879 b	1.0782 c	1.0783 b
2. 1600		11.140 a	11.079 a	10.468 a	10.750 a	0.673 b	0.461 c	21.308 a	21.046 a	1.0912 a	1.0931 a
3. 2400		11.143 a	11.086 a	10.726 a	10.466 a	0.417 c	0.616 b	20.276 b	21.052 a	1.0871 b	1.0894 a
Reducing water requirements substances:-											
1. Control		9.053 c	8.692 c	8.240 c	7.967 c	0.814 a	0.725 a	18.155 c	18.406 c	1.0780 b	1.0817 b
2. Kaolin		10.654 b	10.732 b	10.050 b	10.236 b	0.605 b	0.609 b	21.590 a	21.735 a	1.0895 a	1.0896 a
3. Humic acid		11.994 a	11.711 a	11.413 a	11.034 a	0.531 c	0.673 ab	20.513 b	20.835 b	1.0889 a	1.0894 a
Interaction:-											
800 m^3/fed^{-1}	1. Control	8.540 f	8.242 h	7.632 e	7.130 g	0.908 c	1.112 a	18.231 d	18.093 f	1.0728 e	1.0710 e
	2. Kaolin	8.681 ef	8.480 g	7.715 e	7.673 f	0.968 b	0.807 bc	19.473 c	19.650 d	1.0785 d	1.0792 de
	3. Humic acid	10.880 c	10.190 e	10.176 c	9.319 d	0.704 d	0.871 b	18.317 d	18.893 e	1.0823 d	1.0846 cd
1600 m^3/fed^{-1}	1. Control	9.100 de	9.200 f	7.978 e	8.862 e	1.122 a	0.338 d	18.186 d	18.093 f	1.0803 d	1.0856 cd
	2. Kaolin	11.175 c	11.536 d	10.722 c	10.842 c	0.453 e	0.694 c	22.918 a	22.862 a	1.0982 a	1.0974 a
	3. Humic acid	13.150 a	12.900 a	12.705 a	12.548 a	0.445 ef	0.352 d	22.821 a	22.183 b	1.0950 ab	1.0962 ab
2400 m^3/fed^{-1}	1. Control	9.521 d	8.635 g	9.108 d	7.909 f	0.413 ef	0.726 c	18.048 d	19.033 e	1.0810 d	1.0886 bc
	2. Kaolin	12.105 b	12.580 b	11.712 b	12.254 a	0.393 f	0.327 d	22.380 a	22.693 a	1.0918 bc	1.0923 abc
	3. Humic acid	11.803 b	12.044 c	11.358 b	11.235 b	0.445 ef	0.796 bc	20.400 b	21.430 c	1.0886 c	1.0874 cd

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

It could be suggest that increasing the quantity of water applied to the soil increases the soil moisture content, that makes the nutritional elements more available to the plant (Table 7), and this in turn might favored the plant growth characters (Table 4) and most of the physiological processes, that directly affect the yield and yield components. In addition, higher water quantity applied to plants led to keep higher water content in the plant tissues, and this turn produced tubers heavier than those under water stress.

Similar findings were reported by Steyn *et al.* (1992), Foti *et al.* (1995), Bezerra *et al.* (1998), Ghosh *et al.* (2000), Belanger *et al.* (2002), El-Banna *et al.* (2001), Bao-Zhong (2003) and Abdrabbo *et al.* (2007).

Data in Table 5 also reveal that application of humic acid was significantly increases in total and marketable yields as well as tuber quality compared with other treatments in both seasons. On the other hand, foliar spray with Kaolin had significant increase in tuber dry matter (only 1st season). The percentage increase over the control (distilled water) in total tuber yield amounted to 24.52 and 25.78 % in both seasons, respectively. Under insufficient water quantity (800 m^3/fed), the unmarketable yield was achieved.

The results illustrated by Chen and Avid (1990)and Stevenson (1994), they demonstrated that humic materials increase the permeability plant membranes, promote the uptake of nutrients, increase soil moisture holding capacity, and stimulate plant growth (higher biomass production; Table 4) by accelerating net photosynthesis, consequently tuber development (Zhang *et al.*, 2003)

Also, it could be suggested that spraying with antitranspirant led to form a layer on the foliage surface, which in turn decreased transpiration rate, and hence led to keep more water in plant tissues that would reflect favorable effect on plant metabolism, photosynthetic rate and increased outward transportation of photosynthesis from the foliage to the tubers. These results are in harmony with Lipe (1979) and Anwar (2005) they found that the use of antitranspirants of potato plants during the tuber enlargement reduces plant water use and increase the yield of larger potatoes. Similar results were found by Suryanarana and Venkateswarlu (1981) on tomato, and Gawish and Fattahallah (1997) on taro (*Colocasia esculenta*).

In this connection, Marschner (1995), under sufficient water conditions, reported that there were decrease in ABA and increase in CYT, GA and IAA reflecting good growth, good synthesis of carbohydrates and protein and finally attained higher yield. Obtained results are in good line with those reported by Seyedbagheri and Torell (2001), Shankle *et al.* (2004).

The interaction between irrigation water quantities and substances had significant effects on yield and yield components as well as tuber quality in both seasons (Table 5). The maximum value of total tuber yield was obtained when potato plants treated with humic acid under the 2nd level of irrigation (1600 m^3/fed) in comparison with other treatments. On the other hand, unmarketable yield increased significantly due to control treatment (without treated under 1st level of irrigation=800 m^3/fed). It could be suggest that adding sufficient water + reducing water requirements treatments markedly favored the total yield via its favorable effect on plant growth, as it is well known that water plays great role and has important functions in all physiological processes starting from minerals absorption from the soil up to building different components inside the plant and finally the yield is the sum of plant growth and development and its availability to store foods in their storage organs; i.e., tubers.

Regarding tuber quality, data in Table 5 show that treated potato with Kaolin or humic acid under 2nd level of irrigation gave the positive effect in this respect. The result may be due to increase of availability of elements and water holding capacity, consequently increasing their absorption by plant and transfer to the storage part (tubers) as reported by Salib (2002) who worked in humic acid and Anwar (2005) who worked in Kaolin.

3. Photosynthetic pigments:

Regarding photosynthetic pigments, they were significantly affected by irrigation water quantity as shown in Table 6. More intensive of chlorophyll a, b and carotenoids in leaves were observed under lower water quantity levels; i.e., 800 m^3/fed. Moreover, as increasing water quantity applied to plants, the photosynthetic pigments decreased because both of free and total water in the leaf tissues were higher under the highest water quantity level (2400 m^3/fed) as shown in Table 6. Whereas, low water quantity applied to potato plants resulted in lowering the water content in leaf tissues and this in turn increased the intensity of the chlorophylls and carotenoids of leaves.

Concerning the treatments which reduce the water requirements, Kaolin antitranspirant had significant effects on photosynthetic pigments in two seasons of study, compared with humic acid and check treatments.

Regarding the interaction effect, results in Table 6 show that the values of chlorophyll a and b as well as arytenoids were significantly increased due to spraying potato plants with antitranspirant under 1st irrigation level, in both seasons. These results are in agreement with those reported by Anwar (2005).

4. Plant water relations:

As for the effect of water quantity, it is obvious from the data in Table 6 that increasing water quantity applied to potato plants up to the highest used level (2400 m^3/fed) significantly increased both free and total water (%) in potato leaf tissues.

Concerning bound water (%), maximum values were obtained under water stress or irrigation with 800 m^3/fed and this trend was opposite to that of free or total water percentages. In other words, the highest the applied water quantity to the plants, the highest the free and total water content, and the lowest the bound water content in leaf tissues, and vice versa under water stress.

These results agree with those reported by Abdel-Rheem (2003), Anwar (2005), and Youssef (2007) on potato. They found that both free and total water (%) in leaf tissues increased with increasing water quantity applied to plants.

In both seasons of study, it is obvious that both free and total water were at the highest levels after spraying with Kaolin as shown in Table 6.

Table 6: Photosynthetic pigments of potato leaves as well as plant water relations of potato leaves as affected by water quantity, reducing water requirements substances and their interactions in 2007/08 and 2008/09 seasons.

Treatments:-		Chlorophyll A (mg/g F.W.)		Chlorophyll B (mg/g F.W.)		Carotenoids (mg/g F.W.)		Free water (%)		Bound water (%)		Total water (%)	
		2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09
Irrigation water quantity (m^3/fed):-													
1. 800		9.87 a	9.77 a	19.25 a	19.14 a	17.26 a	17.25 a	30.63 c	31.20 c	52.15 a	52.05 a	82.71 c	83.35 c
2. 1600		8.96 b	8.97 b	16.26 b	16.63 b	15.10 b	15.23 b	37.42 b	37.85 b	49.43 b	48.62 b	86.37 b	86.77 b
3. 2400		8.29 c	8.29 c	12.17 c	11.92 c	12.36 c	11.86 c	44.03 a	44.30 a	46.61 c	45.53 c	89.44 a	90.03 a
Reducing water requirements substances:-													
1. Control		8.99 b	8.94 b	15.98 b	15.68 b	15.33 a	15.18 a	34.41 c	34.96 c	50.97 a	50.23 a	84.65 c	85.26 c
2. Kaolin		9.21 a	9.23 a	16.57 a	16.65 a	15.48 a	15.25 a	39.41 a	39.62 a	49.13 b	48.64 b	87.41 a	87.79 a
3. Humic acid		8.93 b	8.87 b	15.13 c	15.35 c	13.92 b	13.90 b	38.26 b	38.77 b	48.12 c	47.33 c	86.47 b	87.01 b
Interaction:-													
800 m^3/ fed^{-1}	1. Control	9.88 a	9.76 ab	19.22 b	18.94 b	17.62 a	17.75 a	28.10 h	28.67 i	54.18 a	53.98 a	81.50 g	82.03 e
	2. Kaolin	10.00 a	10.01 a	19.89 a	19.92 a	17.93 a	17.96 a	31.31 g	31.92 h	51.00 bc	51.90 b	83.86 e	84.10 d
	3.Humicacid	9.75 a	9.56 b	18.66 b	18.54 b	16.23 b	16.03 b	32.81 f	33.02 g	51.27 b	50.26 c	82.76 f	83.92 d
1600 m^3/ fed^{-1}	1. Control	8.93 bc	8.90 d	16.02 d	16.10 d	15.41 c	15.63 c	34.99 e	35.11 f	50.33 cd	49.50 d	84.32 e	85.02 d
	2. Kaolin	9.22 b	9.19 c	16.91 c	17.29 c	15.73 bc	15.91 b	39.25 c	39.82 d	49.69 d	48.73 e	87.96 c	88.10 bc
	3.Humicacid	8.75 cd	8.82 d	15.85 d	16.48 d	14.17 d	14.16 d	38.03 d	38.62 e	48.27 e	47.63 f	86.84 d	87.18 c
2400 m^3/ fed^{-1}	1. Control	8.18 e	8.14 f	12.70 e	11.99 f	12.96 e	12.18 e	40.13 c	41.10 c	48.31 e	47.21 f	88.12 c	88.72 b
	2. Kaolin	8.42 de	8.49 e	12.90 e	12.75 e	12.77 e	11.90 f	47.67 a	47.12 a	46.69 f	45.28 g	90.41 a	91.18 a
	3.Humicacid	8.29 e	8.23 f	10.90 f	11.03 g	11.36 f	11.51 g	44.28 b	44.68 b	44.83 g	44.11 h	89.63 b	90.20 a

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Whereas, the effect of reducing water substances on bound water was opposite to that of their effects on both free and total water. Thus, it could be concluded, from such data in Table 6, that these treatments which showed maximum content of free and total water showed in the meantime the least values of bound water.

It could be concluded that Kaolin treatment increase leaf resistance to diffusion of water vapor. Similar findings were reported by Zowain and Narang (1991) on wheat and Anwar (2005) on potato, they found that increased relative water content in leaves.

With respect to the interaction between water quantity and substances, it is evident from the data in Table 6 that all plant water relations; i.e., free, bound and total water (%) were significantly affected by the interaction treatments.

It is quite clear that treating potato plants with Kaolin was the superior under 2nd water quantity when compared with other interaction treatments regarding both free and total water content in the leaf tissues. On the other hand, the highest value of bound water was obtained when plants received distilled water under the lowest irrigation water quantity (800m^3/fed).

5. Nutrient content (macro and micronutrients):

As for NPK contents and micronutrients in tubers dry matter, it is evident from the data illustrated in Table 7 that, water quantity reflected significant effect on N, P and K contents and microelements (Fe, Mn and Zn).

The highest and second levels of water irrigation show significant effect on minerals content compared with water stress (800 m^3/fed). That was true in two seasons of study.

As it was previously mentioned, increasing the applied water to the soil increased the moisture content that makes minerals more available to the plant, which led to enhance mineral concentration and their uptake. These results agree with those reported by Abdel-Rheem (2003), Anwar (2005), and Youssef (2007) on potato. They found that NPK concentration increased gradually with increasing water supply to the soil.

Data in Table 7 reveal that humic acid had significant effect on leaf NPK contents as well as microelements in tubers dry matter.

These results may suggest that humic acid stimulate root growth and better uptake on nutrients (Liu *et al.*, 1998; Zhang *et al.*, 2003)

As for the interaction effects on NPK and micronutrient contents, results in Table 7 show significant differences in this respect. Application of humic acid to potatoes under 2nd or 3rd levels of irrigation significantly increased macro and micronutrients in comparison to other treatments, in both season of study.

6. Water use efficiency (WUE):

Regarding the effect of irrigation water quantity on water use efficiency WUE the results presented in Table 8 show that, the maximum value of water use efficiency was obtained under the lowest water quantity (800 m^3/fed) compared to 1600 and 2400 m^3/fed, in both seasons of study.

Table 7: Macro-and micronutrients content of potato tubers as affected by water quantity, reducing water requirements substances and their interactions in 2007/08 and 2008/09 seasons.

Treatments:-		N uptake (mg/100g)		P uptake (mg/100g)		K uptake (mg/100g)		Fe (mg/kg)		Mn (mg/kg)		Zn (mg/kg)	
		2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09	2007/08	2008/09
Irrigation water quantity (m^3/fed):-													
1. 800		528.00 b	529.46 b	55.45 b	65.10 b	814.65 b	852.61 b	31.50 b	31.76 b	15.08 b	15.16 b	11.89 b	12.08 b
2. 1600		736.32 a	747.18 a	85.85 a	82.70 a	1188.46 a	1176.71 a	41.62 a	41.08 a	17.19 a	16.83 a	13.33 a	13.40 a
3. 2400		700.01 a	706.22 a	85.79 a	83.70 a	1202.81 a	1235.51 a	41.67 a	40.36 a	17.50 a	17.00 a	13.42 a	13.57 a
Reducing water requirements substances:-													
1. Control		583.41 c	573.00 c	70.27 b	64.23 c	971.70 c	967.99 c	35.16 c	34.58 c	15.28 c	15.00 c	12.19 c	11.71 c
2. Kaolin		644.84 b	646.00 b	75.64 b	74.70 b	1043.92 b	1077.82 b	38.48 b	37.56 b	16.78 b	16.61 b	12.78 b	13.28 b
3. Humic acid		736.09 a	763.88 a	81.19 a	83.57 a	1190.31 a	1219.02 a	41.15 a	40.96 a	17.77 a	17.38 a	13.68 a	14.05 a
Interaction:-													
800 m^3/ fed^{-1}	1. Control	513.45 g	502.41 f	52.61 f	51.92 h	791.14 g	786.20 g	27.71 h	27.64 g	14.03 f	14.22 e	10.93 d	11.22 f
	2. Kaolin	528.87 fg	532.67 e	55.61 e	56.10 g	809.16 fg	821.13 g	31.09 g	31.03 f	15.10 e	15.20 d	11.85 c	12.13 e
	3. Humicacid	541.72 f	553.30 e	58.14 d	60.27 f	843.65 f	950.51 f	35.69 f	36.60 e	16.12 d	16.07 c	12.90 b	12.90 d
1600 m^3/ fed^{-1}	1. Control	626.26 e	618.32 d	79.09 c	65.68 d	1040.25 e	1018.33 e	38.12 e	37.92 d	16.13 d	15.80 c	12.80 b	11.92 e
	2. Kaolin	692.31 d	703.18 c	86.21 b	87.23 b	1207.37 c	1202.12 c	42.56 b	41.85 b	17.20 c	16.76 b	13.17 b	14.00 bc
	3. Humicacid	890.38 a	920.03 a	92.26 a	95.20 a	1317.09 b	1308.35 b	44.18 a	43.47 a	18.25 b	17.93 a	14.03 a	14.28 b
2400 m^3/ fed^{-1}	1. Control	610.52 e	598.25 d	79.10 c	75.10 d	1083.03 de	1098.11 d	39.64 d	38.18 d	15.69 de	14.98 d	12.82 b	12.00 e
	2. Kaolin	713.34 c	702.11 c	85.10 b	80.76 c	1115.22 d	1210.22 c	41.78 c	40.08 c	18.03 b	17.88 a	13.31 b	13.73 c
	3.Humicacid	776.18 b	818.31 b	93.18 a	95.23 a	1410.18 a	1398.20 a	43.58 a	42.81 a	18.92 a	18.13 a	14.11 a	14.98 a

Means followed by the same letter (s) within each column do not significantly differed using Duncan's Multiple Range Test at the level of 5%.

Table 8: Water use efficiency (WUE) by potato plants as affected by water quantity and reducing water requirements substances in 2007/08 and 2008/09 seasons.

Treatments / Seasons	Water quantity (m^3/fed)			Reducing water requirements substances x water quantity:-								
				Control			Kaolin			Humic acid		
	800	1600	2400	800 m^3/fed	1600 m^3/fed	2400 m^3/fed	800 m^3/fed	1600 m^3/fed	2400 m^3/fed	800 m^3/fed	1600 m^3/fed	2400 m^3/fed
2007/2008	11.71	6.96	4.64	10.68	5.69	3.97	10.85	6.98	5.04	13.60	8.22	4.92
2008/2009	11.21	7.01	4.62	10.30	5.75	3.60	10.60	7.21	5.24	12.74	8.06	5.02
Average	11.46	6.99	4.63	10.49	5.72	3.62	10.73	7.10	5.14	13.17	8.14	4.97

The value of WUE gradually decreased with increasing water quantity up to the highest level and showed opposite trend to that of total yield (Table 5).

The results are in accordance with those obtained by Franke *et al.* (1994), Costa *et al.* (1997), Anwar (2005), and Youssef (2007) on potato. They found that, the efficiency of water use was increased by applying deficit water irrigation.

Regarding the interaction between water quantity and reducing irrigation water substances, the results in Table 8 show significant effect among the different combinations. The highest value of water use efficiency was obtained in plants grown under the lowest level of irrigation along with application of humic acids (average two seasons).

It is worthwhile to mention that, each factor effected the interactions as individually effect on water use efficiency.

On the basis of the forcited results, it could be recommended that irrigation of potato plants with 1600 m^3/fed with application of humic acid as K-humate or spray with Kaolin "antitranspirant" was the most efficient treatment for growth, yield, quality and WUE of potato plants grown in clay loam soil (Dakahlia Governorate). This means that about 800 m^3/fed of the used irrigation quantity can be saved. Once again, 800 m^3/fed of irrigation water x about 200.000 fed grown potato in Egypt equal 160 million m^3 of irrigation water can be saved to use other reasons.

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تأثير كمية مياه الري و مضاد النتح (الكاؤلين) والأحماض الدبالية علي النمو والمحصول والحالة الغذائية وكفاءة استخدام المياه في البطاطس

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تعتبر البطاطس من المحاصيل المهمة في العالم وفي مصر والتي تزرع في مساحات كبيرة وتحتاج الي كميات كبيرة من المياه بالنسبة لمحاصيل الخضر الأخري .

وتمثل الأدارة المزرعية المثلى لمياة الرى تحديا رئسيا لتحسين كفاءة استخدام المياة وزيادة محصول البطاطس فى مصر ونظرا لندرة المياة وزيادة التوسع الأفقى فى استصلاح الأراضى فانه يلزم دراسة كيفية ترشيد استهلاك المياه ومن أجل ذلك أجري هذا البحث بهدف تقنين كمية المياه التي يحتاجها هذا المحصول .

وفى هذا الإطار نفذت تجربتان حقليتان فى تربة طمبية طينية بمزرعة خاصة بجوار مدينة المنصورة – محافظة الدقهلية خلال الموسمين النيليين ٢٠٠٧/٢٠٠٨ و ٢٠٠٨/٢٠٠٩ لدراسة تأثير٣ كميات من مياه الرى وهى (٨٠٠، ١٦٠٠، ٢٤٠٠ م^3/ فدان) وتمثل الكمية الأخيرة المعاملة الكنترول بالنسبة للمزارعيين بالاضافة الى استخدام بعض المواد التى تساعد على تقليل استهلاك كميات المياه ورفع كفاءتها وهى (كنترول "الرش بالماء المقطر"، الرش بمضاد النتح "الكاؤلين" ، المعاملة بحامض الهيوميك أضافة أرضية بجوار النباتات) بالأضافة الى التفاعل بينهما وتأثير ذلك على النمو والمحصول والحالة الغذائية وكفاءة استخدام المياة فى نباتات البطاطس صنف كارا وكانت أهم النتائج كما يلى :

- أدى رى نباتات البطاطس خلال موسمي الدراسة بمعدل١٦٠٠ أو٢٤٠٠م٣/فدان إلي زيادة معنوية في معظم صفات النمو الخضري بالنسبة للنبات وكذلك صفات المحصول الكلي بالنسبة للفدان والمحصول القابل للتسويق بالمقارنة بالمستوى الأقل من كمية الري، ولم تكن هناك أي فروق معنوية بين المستوي الثاني والثالث من كمية مياه الري بالنسبة لصفات المحصول ومكوناته وكذلك صفات الجودة، كما أدي أضافة حامض الهيوميك الي نفس التأثير بالنسبة لصفات النمو الخضري والمحصول وجودة الدرنات.
- أدي ري نباتات البطاطس بمعدل ٨٠٠ م^3/فدان واستخدام مضاد النتح الكاؤلين الي زيادة معنوية في معظم صبغات البناء الضوئي. وبالنسبة للعلاقات المائية فإن استخدام المعدل الأعلي من الري وكذلك الرش بمضاد النتح أدي الي زيادة معنوية في نسبة الماء الحر والكلي في أنسجة النبات وذلك في موسمي الدراسة.
- أدي زيادة معدلات الري الي زيادة معنوية في المحتوي الغذائي من العناصر الكبري والصغري ولم تكن هناك اي فروق معنوية بين المستوي الثاني والثالث من مياه الري في هذه الحالة في كلا الموسمين.
- وبالنسبة لكفاءة استخدام المياه سجلت أضافة ماء الري بالمعدل الأقل مع استخدام حامض الهيومك أعلي النتائج في موسمي الدراسة.
- ومن ناحية أخري أثر التفاعل بين عاملي الدراسة معنويا علي جميع الصفات المدروسة في كلا الموسمين.

وخلصت الدراسة الي أنه يمكن ري حقول البطاطس بمعدل ١٦٠٠ م^3/فدان تحت ظروف الأراضي الطمبية مع أضافة حامض الهيومك أو الرش بمضاد النتح (الكاؤلين) وذلك لأنتاج مثالي من المحصول والجودة وأفضل كفاءة في استخدام المياه. وعلي الجانب الأخر فأنه باستخدام هذه المعاملات يمكن توفير ٨٠٠ م^3/فدان من مياه الري وعلي أساس أن المساحة الكلية المنزرعة بمحصول البطاطس تفوق ٢٠٠ألف فدان فأنه يمكن توفير ما يفوق ١٦٠مليون م^3 من مياه الري من الممكن استخدامها في أغراض أخري.

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