Effect of Drip Irrigation Intervals and Some Antitranspirants on the Water Status, Growth and Yield of Potato (*Solanum tuberosum* L.)

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Abstract: In order to reduce the quantity of water applied by irrigation, increase the water use efficiency and determine the appropriate period for irrigation potato crop, a field experiment was implemented at vegetables field, Department of Plant Production, Agriculture Technical College, Mosul, Iraq, during spring season of 2014. This study involved four irrigation intervals (3, 4, 5 and 6 d) under drip irrigation system, with spraying by five antitranspirant substances (control, kaolin 5 g/L, MgCO_3 3 g/L, liquid paraffin 2% and Nu-film 17 1%), which subjected in a factorial experiment within split plot system in a randomized complete block design with three replications. The results showed that increasing irrigation intervals from 3 d to 6 d decreased the total water content of the leaves from 83.59% to 81.81%, the rate of relative transpiration from 0.174% to 0.162%, stomata area from $1.620 \mu\text{m}^2/\text{stomata}$ to $0.921 \mu\text{m}^2/\text{stomata}$, plant yield from 542.22 g to 425.80 g, total yield of tubers from 25.808 tons/ha to 20.253 tons/ha and marketable yield of tubers from 24.471 tons/ha to 18.822 tons/ha, whereas caused an increase in the leaf water deficit from 19.19% to 23.86% and water use efficiency from 8.63 kg/m^3 to 13.32 kg/m^3 . Spraying potato plants with liquid paraffin 2% led to the highest total water content 83.37%, stomata area $1.466 \mu\text{m}^2/\text{stomata}$, the lowest relative transpiration 0.152%, the lowest leaf water deficit 20.33%, the highest plant yield 509.22 g, total yield 24.236 tons/ha, marketable yield 22.770 tons/ha and water use efficiency 11.83 kg/m^3 . On the other hand, the interaction treatments between irrigation intervals and antitranspirants resulted in a significant effect in many studied parameters.

Key words: Potato, drip irrigation, antitranspirants, tuber, stomata, kaolin, liquid paraffin.

1. Introduction

Potato (*Solanum tuberosum* L.) belonging to Solanaceae family is one of the most important vegetable crops in the world, and in terms of human consumption came in the fourth grade after wheat, rice and corn. It is rich in carbohydrate, nutrients and amino acids [1]. Many factors affected potato production, including cultivars, weather conditions, planting date, nutrition and irrigation. Potato plants are sensitive to the changes in the soil moisture content and the decrease of water (water stress), leading to a significant reduction in tubers quantity and quality. The requirement for water irrigation of

potato plants vary in different plant growth stages; tubers initiation and tubers bulking are the more sensitive stages in the plant growth life [2]. Increasing irrigation rates (109, 123, 145, 203 and 239 mm/acre) led to a significant increase in plant wet weight, shoot dry weight and plant length [3]. In the study of Hegazi and Awad [4], they noticed that the reduction of irrigation water amount from $753 \text{ m}^3/\text{acre}$ to $565 \text{ m}^3/\text{acre}$ caused a significant decrease in the leaf area of potato plant from $3,401 \text{ cm}^2$ to $2,869 \text{ cm}^2$ and plant height from 72.70 cm to 70.14 cm. Potato is one of the sensitive crops to water stress, and soil moisture is an important factor affecting the quantity and quality of tubers, as Bao-Zhong et al. [5] noticed; they used 0.25, 0.5, 0.75, 1.0 and 1.25 times of the basin evaporation of irrigation water and obtained an increase in plant height, water content of the leaves, total number of

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tubers, average tuber weight and total yield of tubers by increasing the amount of irrigation water. Also Wang et al. [6] used six different drip irrigation frequencies in potatoes which irrigate once every 1, 2, 3, 4, 6 and 8 d, and they noticed that reducing irrigation frequency from 1 d to 8 d resulted a significant yield reduce by 33.42% and 29.1% in 2001 and 2002, respectively.

Applying different drip irrigation levels (100%, 80%, 60% and 40%) from the rate of evaporation by Badr et al. [7], they noticed that the treatment of 100% gave the highest yield of tubers with a significant difference than the other treatments, and the average weight of the tuber was more affected by the lack of water than the number of tubers. Irrigated potato by drip irrigation with three levels (100%, 75% and 50% of the basin evaporation) gained a significant increase in plant height, number of aerobic stems, leaf area, plant dry weight and total tubers yield by increased irrigation level [8]. Crops, which are cultivated in arid and semi-arid regions accompanied by a reduction in the soil moisture content and low water potential of the plant, lead to increase stomata resistance for permeability of CO₂ and decrease photosynthesis rate [9]; and transpiration is the main path of water loose from the plant. Potato plants are irrigated usually to reduce the strength of water stress. There is a short period of stress happened in the plant between irrigation periods when the transpiration rate is more than the plant ability of water absorption by roots [10], so antitranspirants substances used to reduce the rate of transpiration, reduce water loss from the soil, maintain plant cells turgid, reduce water consumption and increase the water use efficiency in the plants suffering from water stress [11]. It was found by Stark and Dwelle [12] that there are three types of antitranspirants, a waxy compounds, chemical compounds or a reflected radiation compounds reducing leaf temperature, but the first type is the most widely used in the field, which include waxes, emulsified oils, strong alcohol, silicon and plastic. The

advantage of antitranspirants is to increase the water potential of the plant by reducing water loss from soil; at the time, the plant growth depends on the water status of the plant more than depends on photosynthesis. Spraying potato plants by folicot (10%) led to a significant increase in relative water content of the leaves, plant length, plant fresh weight, tuber average weight and tubers total yield, and reduce the amount of irrigation water added by 9.6%, and hence increases the water use efficiency by 20.6% as compared with the control treatment [13]. Also Abdel-Nasser and El-Gamal [14] found that spraying sweet potato plants with folicot (1% and 2%) resulted in a significant increase in the relative and total water content, free water, water use efficiency, plant fresh weight, average root weight and tubers root total yield, in addition to reduce the amount of water consumption. Spraying cucumber plants with liquid paraffin 2% concentration (once, twice or three times), led to a significant increase in total water content of the leaves, plant yield, number of fruits per plant and fruits total yield [15]. In the study of Al-Aubiady [16], it was found that spraying potato plants with liquid paraffin 2% concentration resulted in a significant increase in the total water content, total chlorophyll in leaves and yield parameters (number of tubers per plant, tuber average weight, plant yield, tubers total and marketable yield). It was investigated that spraying eggplant plants with antitranspirant (Dyrotan 2%) led to a significant increase in vegetative growth parameters (plant height, number of branches, fresh and dry weight of leaves) and yield parameters (number of fruits per plant, fruit average weight, plant yield, early and total yield) [17]. The use of antitranspirants (Vapor gard and Armorax) to potato plants for two seasons in 2011 and 2012, significantly increased plant height, number of leaves and leaf area per plant [18]. The aim of this experiment is to study the effect of drip irrigation intervals and some antitranspirants substances on the water status, growth and yield of potato, and to overcome the problems of water stress

and lack of irrigation water in some potato cultivation regions of Iraq.

2. Materials and Methods

In order to reduce the amount of water irrigation, increase the water use efficiency and determine the appropriate period to irrigate potato crop, a field experiment was implemented in vegetables field of Plant Production Department at Agricultural Technical College, Mosul, Iraq, during spring season of 2014. The experiment included four irrigation intervals each 3, 4, 5 and 6 d under drip irrigation system and used five antitranspirants substances, namely:

- (1) Control treatment (spray with water);
- (2) Spray with kaolin 5 g/L;
- (3) Spray with MgCO_3 3g/L;
- (4) Spray with liquid paraffin 2%;
- (5) Spray with Nu-film 17 1%.

So the experiment included over 20 different treatments, subjected in a factorial experiment in randomized complete block design with three replications. Potato seeds of Universa cultivar were sown in 22th of January 2014, with the furrows width 75 cm and the distance between tubers 30 cm in a loamy soil.

Spraying with antitranspirants was done twice times: the first one at tuber initiation stage and the second after month of the first one. Tubers were harvested on June 8 for all experimental unit plants and recorded the following measurements:

1. Water status of the plant:

(a) Total water content (*TWC*) of the leaves: it was registered after 2 d of the second spraying of antitranspirants using the following equation:

$$TWC\% = (\text{wet weight} - \text{dry weight}) / \text{wet weight} \times 100 \quad (1)$$

(b) Relative transpiration (*RT*): it was measured by taking a fixed area (100 cm²) of the leaves and an equal water surface in glass dishes; the samples were left at 30 °C for 6 h period and then measured the loss

weight from each, using the following equation to calculate the relative transpiration:

$$RT = (\text{weight of water loss from plant leaves} / \text{weight of water loss from water surface}) \times 100 \quad (2)$$

(c) Leaf water deficit (*LWD*): it was estimated by weighing a plants leaves taken randomly at the early morning (wet weight); then placed on the surface of distilled water for 1 h until saturated and then weighed again (saturated weight); then dried in oven and weighed (dry weight). The *LWD* was calculated as follows:

$$LWD\% = (\text{saturated weight} - \text{wet weight}) / (\text{saturated weight} - \text{dry weight}) \times 100 \quad (3)$$

(d) Stomata area (μm²/stomata): it was measured by the microscope from the upper epidermis of the leaf.

All the four measurements above were repeated three times.

2. Yield measurements:

- (a) Number of tubers per plant;
- (b) Average weight of the tuber (g);
- (c) Plant yield (g);
- (d) Tubers total yield per unit area (tons/ha);
- (e) Tubers marketable yield (tons/ha);
- (f) Water use efficiency (kg/m³): it was calculated by the following equation:

$$\text{Water use efficiency (kg/m}^3\text{)} = \text{total yield of tubers (kg/ha)} / \text{amount of water added (m}^3\text{/ha)} \quad (4)$$

The amount of water added to drip irrigation treatments has been estimated by calculating the discharge of pipe drippers in drip irrigation for several drippers in several times, which equals to 1.1 L/h, multiplied by the number of drippers per experimental, multiplied by the number of irrigation hours for all growing season and then turned to hectare area. And the amount of water added was 2,920 m³/ha for the treatment of irrigation each 3 d; 2,220 m³/ha for the treatment of irrigation each 4 d; 1,790 m³/ha for the treatment of irrigation each 5 d; and 1,520 m³/ha for the treatment of irrigation each 6 d. The results were analyzed statistically according to the statistical analysis system (SAS) [19] and compared with the

means by Duncan multiple rang test at 0.05 level [20].

3. Results and Discussion

Table 1 shows the effect of irrigation intervals and antitranspirants on water status of potato plants. The increase in irrigation interval from 3 d to 6 d led to a significant decrease in the total water content of leaves from 83.59% to 81.81%, the rate of relative transpiration from 0.174% to 0.162% and the stomata area from 1.620 $\mu\text{m}^2/\text{stomata}$ to 0.921 $\mu\text{m}^2/\text{stomata}$ while the leaf water deficit increased from 19.19% to 23.86%. Spraying antitranspirants (liquid paraffin and Nu-film 17) resulted in a significant increase in the total water content 83.23% and 83.20%, respectively, and the stomata area 1.466 $\mu\text{m}^2/\text{stomata}$ and 1.558 $\mu\text{m}^2/\text{stomata}$, respectively; whereas, a significant decrease obviously noticed in the relative transpiration 0.152% and 0.154%, respectively, and the leaf water deficit 20.33% and 20.71%, respectively.

Table 2 illustrates the effect of interaction between irrigation intervals and antitranspirants on water status of potato plants. The highest total water content 84.98% was resulted from the interaction between irrigation every 3 d and spraying with liquid paraffin. While the highest rate of relative transpiration 0.202% was produced from the interaction between the irrigation every 5 d and without spraying antitranspirants which significantly superior over most other interaction. The

highest leaf water deficit 24.92% was obtained from the interaction between irrigation every 6 d with control. Whereas the lowest stomata area 0.42 $\mu\text{m}^2/\text{stomata}$ was from the interaction between irrigation every 6 d without antitranspirants application and the highest stomata area 1.86 $\mu\text{m}^2/\text{stomata}$ produced from the interaction treatment between irrigation every 3 d and spraying Nu-film 17. The decrease in total water content of the leaves, relative transpiration rate and stomata area, and the increase in leaf water deficit, when prolonged the irrigation period from 3 d to 6 d, may be due to the low content of the soil moisture, especially in the surface layer of the soil (20-30 cm), where the distribution of most potato roots [21] leads to exposure the plants to water stress and reduce the efficiency of roots water absorption, and thus lead to a decline in the total water content of the leaves and the relative transpiration rate and stomata area. These findings are in harmony with Refs. [2, 5, 6].

As for the role of antitranspirants (liquid paraffin and Nu-film 17) in increasing the total water content and stomata area and reducing relative transpiration rate and leaf water deficit, it may be due to the activity of this substances in partial closing of stomata, which helps in reducing the rate of transpiration and reducing water loss through stomata containing a waxy layer above it. It has been mentioned by Refs. [2, 11, 13] that

Table 1 Effect of irrigation intervals and antitranspirants in water status of potato plant.

Treatments	Leaf total water content (%)	Relative transpiration rate (%)	Leaf water deficit (%)	Stomata area ($\mu\text{m}^2/\text{stomata}$)
Irrigation intervals treatments				
3 d	83.59 ^a	0.174 ^a	19.19 ^d	1.620 ^a
4 d	82.83 ^b	0.177 ^a	20.29 ^c	1.411 ^b
5 d	81.60 ^b	0.174 ^a	22.56 ^b	1.221 ^c
6 d	81.81 ^b	0.162 ^b	23.86 ^a	.0921 ^d
Antitranspirants treatments				
Control	81.02 ^c	0.197 ^a	22.62 ^a	0.961 ^d
Kaolin	82.48 ^b	0.184 ^b	21.73 ^b	1.168 ^c
MgCO ₃	82.23 ^b	0.173 ^c	21.60 ^b	1.313 ^b
Liquid paraffin	83.37 ^a	0.152 ^d	20.73 ^c	1.466 ^a
Nu-film 17	83.20 ^a	0.154 ^d	20.71 ^c	1.558 ^a

Means followed with the same latter are not significantly different according to Duncan multiple range test at the probability of 0.05 levels.

Table 2 Effect of interaction treatments between irrigation intervals and antitranspirants in water status of potato plant .

Irrigation treatment	Antitranspirants treatments	Leaf total water content (%)	Relative transpiration rate (%)	Leaf water deficit (%)	Stomata area ($\mu\text{m}^2/\text{stomata}$)
3 d	Control	81.46 ^{b-e}	0.201 ^{ab}	20.36 ^f	1.36 ^{def}
	Kaolin	82.80 ^{a-d}	0.182 ^{cd}	19.65 ^f	1.48 ^{cd}
	MgCO ₃	84.12 ^{abc}	0.170 ^{efg}	19.45 ^f	1.63 ^{abc}
	Liquid paraffin	84.98 ^a	0.162 ^{fgh}	18.38 ^g	1.77 ^{ab}
	Nu-film 17	84.62 ^{ab}	0.158 ^{ghi}	18.12 ^g	1.86 ^a
4 d	Control	81.42 ^{b-e}	0.196 ^{abc}	21.46 ^e	1.16 ^{efg}
	Kaolin	82.90 ^{a-d}	0.193 ^{abc}	20.35 ^f	1.24 ^{efg}
	MgCO ₃	82.32 ^{a-d}	0.180 ^{de}	20.15 ^f	1.38 ^{de}
	Liquid paraffin	83.86 ^{abc}	0.157 ^{ghi}	19.66 ^f	1.62 ^{bc}
	Nu-Film 17	83.66 ^{abc}	0.162 ^{fgh}	19.86 ^f	1.65 ^{abc}
5 d	Control	80.30 ^{de}	0.202 ^a	23.76 ^{bc}	0.90 ^h
	Kaolin	82.30 ^{a-d}	0.190 ^{bcd}	22.82 ^{cd}	1.13 ^{fg}
	MgCO ₃	81.20 ^{cde}	0.188 ^{cd}	22.94 ^c	1.22 ^{efg}
	Liquid paraffin	88.14 ^{a-e}	0.150 ^{hij}	21.86 ^{de}	1.34 ^{def}
	Nu-film 17	82.08 ^{a-e}	0.144 ^{ij}	21.46 ^e	1.51 ^{cd}
6 d	Control	80.90 ^{cde}	0.191 ^{bcd}	24.92 ^a	0.42 ⁱ
	Kaolin	81.94 ^{a-e}	0.174 ^{ef}	24.12 ^{ab}	0.82 ^h
	MgCO ₃	81.28 ^{cde}	0.154 ^{hij}	23.87 ^{bc}	1.02 ^{gh}
	Liquid paraffin	82.50 ^{a-d}	0.142 ^j	23.07 ^c	1.13 ^{fg}
	Nu-film 17	82.46 ^{a-d}	0.152 ^{hij}	23.41 ^{bc}	1.21 ^{efg}

Means followed with the same latter are not significantly different according to Duncan multiple range test at the probability of 0.05 levels.

waxy type antitranspirants increases the total and relative water content of the leaves by reducing the rate of transpiration and water loss from the soil, increasing water use efficiency of the plant and improving plant growth in a time, when plant growth depends on the water status of plant more than photosynthesis. And this result is agreement with Refs. [2, 14-18].

Table 3 shows that reducing the irrigation interval from 6 d to 3 d led to a significant increase in the number of tubers per plant from 5.51 to 6.71, average weight of the tuber from 77.15 g to 81.00 g and plant yield from 425.80 g to 542.22 g. On the other hand, application of antitranspirants has a significant effect on number of tubers, average tuber weight and plant yield. The largest tubers number is 6.38 results from spraying MgCO₃, the larger average weight of tuber 84.25 g is produced from spraying Nu film 17, and the highest plant yield 509.22 g was found from spraying liquid paraffin.

Table 4 exhibited the effect of interaction between irrigation intervals and antitranspirants in number of tubers, average tuber weight and plant yield. The largest number of tubers per plant 7.27 results from interaction between irrigation every 3 d with spraying MgCO₃, which is significantly superior over many other interaction treatments. While the largest average weight of tuber 90.25 g was from the interaction between irrigation every 4 d with application Nu film 17. And the highest plant yield 583.21 g was produced from the interaction between irrigation every 3 d with spraying liquid paraffin, which is significantly superior over other interaction treatments exclusive the treatment of irrigation every 3 d with spraying Nu film 17.

Table 5 revealed the effect of irrigation intervals and antitranspirants in the total yield, marketable yield of tubers and water use efficiency. It was noticed that irrigation every 3 d gave the highest total yield 25.808 tons/ha and marketable yield of tubers 24.471 tons/ha,

which was significantly superior over all other treatments. While water use efficiency increased from 8.63 kg/m³ to 13.32 kg/m³, when increasing irrigation intervals from 3 d to 6 d. Spraying liquid paraffin and Nu-film 17 caused a highest total yield 24.236 tons/ha and 23.684 tons/ha, respectively; marketable yield

22.770 tons/ha and 22.304 tons/ha, respectively; water use efficiency 11.83 kg/m³ and 11.68 kg/m³ respectively, which were significantly superior over all other treatments.

Table 6 illustrates the effect of interaction between irrigation periods and antitranspirants in total and

Table 3 Effect of irrigation intervals and antitranspirants in number of tubers, average tuber weight and plant yield of potato.

Treatments	Number of tubers per plant	Average tuber weight (g)	Plant yield (g)
Irrigation intervals treatments			
3 d	6.71 ^a	81.00 ^{ab}	542.22 ^a
4 d	6.04 ^b	82.53 ^a	508.78 ^b
5 d	5.91 ^b	79.36 ^{bc}	466.91 ^c
6 d	5.51 ^c	77.15 ^c	425.80 ^d
Antitranspirants treatments			
Control	6.06 ^{ab}	76.06 ^c	461.51 ^c
Kaolin	6.00 ^c	79.75 ^b	477.68 ^b
MgCO ₃	6.38 ^a	76.12 ^c	483.72 ^b
Liquid paraffin	5.90 ^c	83.87 ^a	509.22 ^a
Nu-film 17	6.15 ^{ab}	84.25 ^a	497.57 ^a

Means followed with the same latter are not significantly different according to Duncan multiple range test at the probability of 0.05 levels.

Table 4 Effect of interaction treatments between irrigation intervals and antitranspirants in number of tubers, average tuber weight and plant yield of potato.

Irrigation treatments	Antitranspirants treatments	Number of tubers per plant	Average tuber weight (g)	Plant yield (g)
3 d	Control	6.46 ^{a-d}	76.58 ^{ef}	500.76 ^{cd}
	Kaolin	6.52 ^{abc}	79.96 ^{c-f}	530.18 ^b
	MgCO ₃	7.27 ^a	73.46 ^{fg}	532.62 ^b
	Liquid paraffin	6.87 ^{ab}	85.14 ^{abc}	583.21 ^a
	Nu-film 17	6.31 ^{b-e}	89.87 ^a	564.37 ^a
4 d	Control	6.48 ^{a-d}	76.28 ^{ef}	492.78 ^{cde}
	Kaolin	6.52 ^{abc}	77.37 ^{ef}	500.64 ^{cd}
	MgCO ₃	5.84 ^{cde}	86.89 ^{ab}	508.34 ^{bc}
	Liquid paraffin	5.70 ^{cde}	81.90 ^{b-e}	529.35 ^b
	Nu-film 17	5.75 ^{cde}	90.25 ^a	512.62 ^{bc}
5 d	Control	5.81 ^{cde}	75.95 ^{ef}	451.20 ^{ghi}
	Kaolin	5.56 ^{de}	84.47 ^{a-d}	460.31 ^{fgh}
	MgCO ₃	6.82 ^{ab}	68.43 ^g	465.43 ^{e-h}
	Liquid paraffin	5.44 ^e	89.21 ^a	483.52 ^{c-f}
	Nu-film 17	6.16 ^{b-e}	78.75 ^{c-f}	474.12 ^{d-g}
6 d	Control	5.42 ^e	75.43 ^{ef}	401.32 ^k
	Kaolin	5.47 ^e	77.22 ^{ef}	419.32 ^{jk}
	MgCO ₃	5.76 ^{cde}	73.70 ^{ef}	428.51 ^{ij}
	Liquid paraffin	5.56 ^{de}	79.25 ^{c-f}	440.65 ^{hij}
	Nu-film 17	5.54 ^{de}	78.15 ^{def}	439.22 ^{hij}

Means followed with the same latter are not significantly different according to Duncan multiple range test at the probability of 0.05 levels.

Table 5 Effect of irrigation intervals and antitranspirants in total yield, marketable yield and water use efficiency in potato.

Treatment	Total tubers yield (tons/ha)	Marketable tubers yield (tons/ha)	Water use efficiency (kg/m ³)
Irrigation intervals treatments			
3 d	25.808 ^a	24.471 ^a	8.63 ^d
4 d	24.215 ^b	22.869 ^b	10.90 ^c
5 d	22.224 ^c	20.817 ^c	12.41 ^b
6 d	20.253 ^d	18.822 ^d	13.32 ^a
Antitranspirants treatments			
Control	21.967 ^c	20.584 ^c	10.81 ^d
Kaolin	22.733 ^b	21.354 ^b	11.18 ^{cd}
MgCO ₃	23.023 ^b	21.712 ^b	11.33 ^{bc}
Liquid paraffin	24.236 ^a	22.770 ^a	11.83 ^a
Nu-film 17	23.684 ^a	22.304 ^a	11.63 ^{ab}

Means followed with the same latter are not significantly different according to Duncan multiple range test at the probability of 0.05 levels.

Table 6 Effect of interaction treatments between irrigation intervals and antitranspirants in total yield, marketable yield and water use efficiency in potato.

Irrigation treatments	Antitranspirants treatments	Total tubers yield (ton/ha)	Marketable tubers yield (ton/ha)	Water use efficiency (kg/m ³)
3 d	Control	23.833 ^{cd}	22.620 ^{de}	8.161 ⁱ
	Kaolin	25.236 ^b	24.021 ^{bc}	8.64 ^{hi}
	MgCO ₃	25.352 ^b	24.111 ^b	8.68 ^{hi}
	Liquid paraffin	27.760 ^a	26.172 ^a	9.50 ^{fg}
	Nu-film 17	26.862 ^a	25.432 ^a	9.19 ^{gh}
4 d	Control	23.455 ^{cde}	21.832 ^{ef}	10.56 ^{fg}
	Kaolin	23.830 ^{cd}	22.620 ^{de}	10.73 ^{fg}
	MgCO ₃	24.196 ^{bc}	22.843 ^{cde}	10.89 ^{ef}
	Liquid paraffin	25.197 ^b	23.951 ^{bc}	11.35 ^e
	Nu-film 17	24.400 ^{bc}	23.102 ^{bcd}	10.99 ^{ef}
5 d	Control	21.477 ^{ghi}	20.053 ^{ghi}	11.99 ^d
	Kaolin	21.910 ^{fgh}	20.365 ^{gh}	12.24 ^{cd}
	MgCO ₃	22.154 ^{e-h}	20.873 ^{fg}	12.37 ^{cd}
	Liquid paraffin	23.015 ^{c-f}	21.645 ^{ef}	12.86 ^b
	Nu-film 17	22.568 ^{d-g}	21.151 ^{fg}	12.60 ^{bc}
6 d	Control	19.102 ^k	17.832 ^k	12.56 ^{bc}
	Kaolin	19.959 ^{jk}	18.412 ^{jk}	13.13 ^{ab}
	MgCO ₃	20.397 ^{ij}	19.021 ^{ij}	13.41 ^a
	Liquid paraffin	20.974 ^{hij}	19.314 ^{hij}	13.79 ^a
	Nu-film 17	20.906 ^{hij}	19.532 ^{hij}	13.75 ^a

Means followed with the same latter are not significantly different according to Duncan multiple range test at the probability of 0.05 levels.

marketable yield of tubers and water use efficiency. The highest total yield of tubers 27.760 tons/ha and marketable yield 26.172 tons/ha resulted from the interaction between irrigation every 3 d and liquid paraffin, which was significantly superior over all other interaction treatments, except the interaction

between irrigation every 3 d with spraying Nu film 17. And the higher water use efficiency 13.79 kg/m³ was produced from the interaction between the irrigation every 6 d and liquid paraffin. A significant decline in the number of tubers, average weight of tuber, plant yield, total and marketable yield of tubers, when the

irrigation interval increases from 3 d to 6 d, possibly was due to the reduction of soil moisture content and the water status of the plant (Table 1), which affected the absorption rate of nutrient elements from the soil. And it was reflected in decreasing photosynthesis rate [22], which reduced cell division and elongation and consequently reduced plant leaf area, activity of plant enzymes and hormones [23]. Also the exposure of plants to the water stress negatively influenced the growth of stolons, which decrease tubers number of the plant [24]. It was mentioned by Belanger et al. [25] that there is a reduction in tubers bulking rate by 40% in the water stress treatment than normal irrigation treatment, which causing a decline in tuber average weight. Such reduction in the rate of photosynthesis, number of tubers and average weight of tubers caused a decrease in the plant yield, total and marketable yield of tubers. This agrees with Refs. [2, 4, 16, 25-28], who said that exposing potato plants to water stress at tubers formation stage caused a reduction in the number of tubers, tuber average weight, plant yield, tubers total and marketable yield. The positive impact of spraying liquid paraffin and Nu-film 17 on a significant increase of yield parameters, may be due to the active role of the waxy substance in maintaining the cells turgid and reducing water loss from the plant by partial closing of stomata and reducing the rate of transpiration [11]. It helps keeping soil moisture, increasing water use efficiency [2] and keep continues of the normal rate of biological processes, especially photosynthesis, and this is reflected in the positive growth and yield of plant. It has been noticed by Refs. [13, 14] that the effect of antitranspirants in plant growth is through improving water potential of the plant in the stage that plant growth supports on the water status more than photosynthesis. This increase in the growth will produce a good leaf area, which stimulate photosynthesis [29]. These results are in harmony consistent with Refs. [2, 10, 13, 15, 16]. The increase in the water use efficiency 13.32 kg/m³, when increasing irrigation period to 6 d, maybe return in

decreasing the amount of irrigation water used in this treatment (1,520 m³/ha) during the growing season, as compared with the amount used in the treatment of irrigation every 3 d (2,920 m³/ha). This result agrees with what finding by Refs. [2, 6, 7].

The increase in the water use efficiency, when spraying the plants with liquid paraffin and Nu-film 17 was 11.83 kg/m³ and 11.63 kg/m³, respectively. It may be related to the role of these antitranspirants substances in reducing water loss from plants through transpiration, as a result of the partial closing of the stomata [2, 13]. It helps the healthy growth of the plant, and increases the plant yield (Table 3) and the tubers total yield (table 5); and this is reflected in increasing water use efficiency for this two treatments compared with the other treatments. This result is in agreement with Refs. [2, 13, 14].

4. Conclusions

It can be concluded from this study that irrigated potato plants by drip irrigation method at interval every 3 d is preferable to get the best water status for plants, in addition to the highest plant yield and total tubers yield per unit area. The use of waxing type antitranspirants (liquid paraffin and Nu-film 17) was contributed to improve water status of the plant and reduce water loss through transpiration, as a result of the partial closure of the stomata. It means that antitranspirants can be used for water lacking in arid and semi-arid regions, in addition to lowering the effect of water stress on growth and yield of plants.

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