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Physiological Response of Eggplants Grown Under Different Irrigation Regimes to Antitransplant Treatments

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Abstract

Eggplants were grown under four irrigation regimes relevant to 100, 80, 60 or 40% of evapotranspiration (ET) values and treated with film-forming "vapor gard" or reflcetive-typy "white wash" anti-transpirants (ATs) in order to examine there effects on different physiological parameters, growth, transpiration, relative water content (RWC), total carbohydrates, water use efficiency (WUE) and yield. Results revealed that all growth parameters, chemical constituents and yield were strongly influenced by both irrigation regimes and ATs treatments. The irrigation regimes corresponding to 100% of ET alone or 80% of ET with ATs treatments gave the greatest effect on plant growth parameters, while high water stress treatments adversely affected the growth parameters. The ATs treatments particularly whitewash (WW) had favorable affect on the growth parameters under all levels of irrigation, but this effect was more obvious at lower levels of irrigation. Antitranspirant treatments reduced the transpiration rate, RWC, and carbohydrates were decreased by decreasing irrigation levels but ATs treatments had relieving effects of water stress and increased them. Both types of ATs increased the yield more than the control.

Key words: water stress, antitranspirants, eggplant, growth, water relations.

Introduction

Plants are prodigal in the water use. In this concern, roughly 1% of the water taken up by a plant is used for its growth and development while the remaining 99% is lost by transpiration into the atmosphere (Larcher. 1980; Salisbury and Ross. 1992). Whilst drainage and evaporation play a considerable part in water loss, it is clear that much of the water used in plant irrigation is lost through transpiration alone (Mengel and Kirkby, 1987). Therefore, it is important to find ways by which available water could be economically utilized. One way, to achieve this goal, is to reduce the transpiration rate, consequently, irrigation water could be minimized substantially.

Transpiration could be reduced by the application of certain compounds, which have the potential to increase leaf resistance to the diffusion of water vapor away from the leaf. Certain chemicals with some biological activities could be used to reduce the transpiration rate. These antitranspirants (ATs) may be film-forming which coat leaf surface with films impervious to water vapor; or reflective materials that reflect back a portion of the incident radiation falling on the upper surface of leaves; or metabolic types which induce stomatal closure.

Film forming and reflecting ATs were found to be non toxic and have longer period of effectiveness than metabolic types (Patil and De, 1978; Gawish, 1992). In contrast to most film-forming ATs which are impermeable to CO_2 exchange and thus may reduce the rate of photosynthesis (Davenport et al., 1974; Kramer and Kozlowski, 1979), pinoline-base AT such as Vapor Gard (VG) has not been reported to reduce photosynthesis, it has had beneficial effects on plant water relations and it is safe for human use. It has been used on various fruit crops (Barmore et al., 1974; Davenport et al., 1974; Symmes, 1978; Attia et al., 1991).

Most physiological researches were focused on fruit and ornamental crops but only some were reported on field crops. Hence, it is of interest to investigate the effect of vapor gard emulsion (a polyterpene compound, film forming material) and whitewash suspension (WW) (calcium carbonate, reflecting material) on growth behavior, physiological response, chemical constituents and yield of eggplant, grown under different irrigation regimes. The ultimate objective of this study is to find out a way by which available water could be maximally utilized.

Materials and Methods

This study was carried out at the Agricultural Experimental Station, Qassim University during the summer season of 2006 to investigate the physiological effects of the antitranspirants Vapor Gard (VG) and White Wash (WW), on eggplant.

Seeds of eggplant (*Solanum melongena* var. Black Beauty) were sown in trays on 20 of February, 35 days later, uniform seedlings were transplanted in 30 cm diameter plastic pots (one plant per pot). Each pot was filled with 10 kg of air dried soil. physical and chemical properties of the soil were determined to be sandy in texture, with pH of 8.2, organic matter of 0.23% and E_{ce} of 2.06.

All plants were normally irrigated in order to obtain good plant establishment. Plants were fertilized using Sangral compound fertilizer (20%N 20%P 20%K + necessary trace elements). Irrigation regimes and antitranspirant treatments were established 4 weeks after transplanting. A split-plot design, with irrigation regimes as main-plot treatments and ATs as sub-plot treatments, with 3 replications, was used.

Irrigation procedures

At the beginning of water treatments (4 weeks after transplanting), all pots were irrigated up to the field capacity. After 7 days, the evapo-transpiration was measured gravimetrically and the amount of water lost during this period was recovered completely by irrigation, in control pots only. Other pots received either 80%, 60% or 40% of that added to the control plants. This procedure continued every week till the end of the experiment.

ATs treatments

Depending on results obtained from the preliminary experiment, the following concentrations were used: i) distilled water (as control); ii) 2% Vapor Gard emulsion and, iii) 6% Whitewash suspension. Plants were sprayed with a fine mist of ATs using a hand pressure sprayer till run-off, with care being taken to cover all plant parts; no surfactants or other wetting agents were needed. During the experimental period, plants received 3 spray applications at 2 week intervals.

Physiological parameters

Since the ATs effects are not accumulative, two representative samples (3 plants each) were taken randomly from each sub-plot; first sample was taken one week after the second ATs treatment, and the second sample was taken 2 weeks later (one week after the third ATs treatment). The following plant characters were considered:

I- Plant growth parameters

Plant height, leaf area (determined by the leaf area meter, planimeter), and oven-dry weights of shoots and roots were recorded.

Relative growth rate **(RGR),** was determined, according to Larcher (1980) using the following equation:

$RGR=(\ln W_2-\ln W_1)/(t_2-t_1)\ mg.g^{-1}.day^{-1}$

where W_2 and W_1 are the plant dry weights at the time of t_2 and t_1 corresponding to the second and first sampling, respectively.

Net assimilation rate (NAR), was determined, according to McCollum (1978) following the equation:

$NAR= [(W_2 - W_1)/(L_2 - L_1)] \times [(\ln L_2 - \ln L_1) / (t_2 - t_1)]\ mg.g^{-1}.day^{-1}.cm^{-2}$

where W_2, W_1, t_2 and t_1; as described before; and L_2 and L_1 are the leaf area at t_2 and t_1 corresponding to the second and first sampling, respectively.

Transpiration and evaporation measurements daily transpiration was determined gravimetrically as described by Larcher (1980) and was determined on the leaf area basis. The amount of water evaporated from soil surface was determined using 4 pots without plants watered to 40, 60, 80 and 100% evapo-transpiration (ET). The loss in weight was considered as the amount of water lost by evaporation.

Relative water content (RWC) was determined according to Larcher (1980) following up the equation:

RWC = |(FW - DW) / (TW - DW)] x 100 where. FW= fresh weight of leaf discs, TW= full turgid weight of the floated discs for 6 h on distilled water, DW= dry weight of discs (at 105°C for 48h). A cork borer was used to punch leaf discs at three places in the leaf, upper, middle and bottom portions of three plants from each sub-plot, 24 hour after each ATs treatment. Discs were cut midway between the base and tip of each leaflet blade, excluding the midrib. The RWC was determined at 7 am and 3 pm. The mean of three measurements was considered in the discussion.

Water use efficiency (WUE), was carried out only when ATs and irrigation regimes treatments were started. Thus, a plant sample was taken at that date to determine plant dry weight. The difference in plant weight at this stage and at the end of the experiment was used in WUE calculation as described by the equation of Salisbury and Ross (1992) as follow: WUE = [weight of water used (kg)] / [total plant dry weight (g)] x 100.

Total carbohydrates: were determined using the phenol/ sulfuric acid method (Dubois *et al*. (1956).

II- Yield analysis:

Total number of flowers and fruits per plant, fruit set percentage and total yield per plant were recorded.

All data were statistically analyzed using the ANOVA (analysis of Variance) with the aid of COSTAT computer program test. Differences indicated to be significant at 5% significance level as described by Snedecor and Cochran (1967).

Results and Discussion

I- Vegetative growth

Data presented in Table 1 indicated that plant height and leaf area at both sampling dates were strongly influenced by irrigation regimes and, the 100% treatments showed the highest values of the investigated parameters. There was a strong relationship between the irrigation regimes and the reduction in these parameters, such relationship became more obvious with plant age; as, the reduction becoming greater in the second sampling date comparing with the first one; however, the inhibition of plant growth was coincided with a decrease in water supply and leaf area. These results confirm the findings of Miller and Gardner (1972) and may indicate that eggplant require full season of adequate water supply. The decrease in the leaf area under low levels of irrigation regimes may be ascribed to the decrease in the leaf water content, which in turn reduces the turger pressure in leaf cells, thereby inhibiting cell division and elongation (Pardossi *el al*., 1994).

The above results also showed that all growth parameters, including shoot and root dry weights (Figs. 1 and 2), were significantly increased by VG and reflective WW. However, WW gave the highest values of growth parameters, therefore both plant height and leaf area were increased significantly as compared with the control.

At any level of irrigation, it was clear that the interaction between irrigation regimes and AT's treatments showed significant increase in the growth parameters, with the superiority of WW over VG, at lower levels of irrigation than at higher levels. These results are in accordance with those obtained by De et al. (1983), who reported that stomata react sensitively to water stress treatments, therefore, stomatal conductance may be declined with ATs treatments compared with that of untreated control. This reduction in stomatal conductance (increase in stomatal resistance) could result in low transpiration rate, maintaining reasonable leaf turger under water stress condition (Yoon, 1995), showing positive effects at low levels of soil moisture.

Relative growth rate (RGR) and net assimilation rate (NAR)

It is clear that both RGR and NAR were significantly depressed under low irrigation treatments and increased at high irrigation treatments (Table 2). Data collected at

Table 1. Effect of irrigation regimes and antitranspirants (ATs) on both plant height (cm) and leaf area (cm^2) of eggplant at two sampling dates.

ATs (B)	Irrigation regimes (A)									
	100	80	60	40	mean	100	80	60	40	mean
	first sample					second sample				
	Plant height (cm)									
Cont	34.4	31.2	27.1	20.4	28.3	68.2	61.9	57.8	54.4	60.6
VG	36.2	32.6	29.6	23.4	30.5	71.6	66.2	60.6	57.7	64.0
WW	37.7	35.3	31.2	27.5	32.9	73.4	70.6	65.5	61.2	67.4
Mean	36.0	33.0	29.3	23.8		71.1	66.2	61.3	57.8	
LSD5%	A= 3.2 B= 2.1 AB= 3.4					A= 5.2 B= 2.3 AB= 6.4				
	Leaf area (cm^2/plant)									
Cont	472	455	407	364	424	1062	947	907	856	943
VG	531	482	452	411	469	1166	1012	978	907	1015
WW	569	553	512	480	528	1203	1173	1009	946	1083
Mean	524	497	457	418		1144	1044	965	903	
LSD5%	A= 35 B= 29 AB= 26					A= 112 B= 64 AB= 94				

A = LSD5% for the means of irrigation regimes; B = LSD5% for the means of ATs treatments; AB = LSD5% for the interaction between irrigation regimes and ATs.

Table 2. Effect of irrigation regimes and antitranspirants (ATs) on both RGR and NAR of eggplant at two sampling dates.

ATs (B)	Irrigation regimes (A)									
	100	80	60	40	mean	100	80	60	40	mean
	first sample					Second sample				
	RGR (mg/g/day)									
Cont	0.46	0.40	0.32	0.28	0.37	0.51	0.48	0.40	0.34	0.43
VG	0.50	0.46	0.41	0.37	0.43	0.53	0.50	0.44	0.40	0.47
WW	0.52	0.50	0.46	0.41	0.47	0.55	0.52	0.48	0.42	0.49
Mean	0.49	0.45	0.40	0.35		0.53	0.50	0.44	0.39	
LSD5%	A= 0.05	B= 0.04	AB= 0.07			A= 0.04	B= 0.02	AB= 0.06		
	NAR (mg/cm/day)									
Cont	0.52	0.48	0.42	0.37	0.45	0.60	0.56	0.51	0.44	0.53
VG	0.56	0.54	0.47	0.44	0.51	0.62	0.58	0.54	0.46	0.56
WW	0.58	0.56	0.50	0.46	0.52	0.63	0.62	0.58	0.53	0.59
Mean	0.55	0.53	0.46	0.42		0.62	0.59	0.54	0.48	
LSD5%	A= 0.05	B= 0.04	AB= 0.06			A= 0.06	B= 0.02	AB= 0.07		

A, B and AB as explained in Table (1).

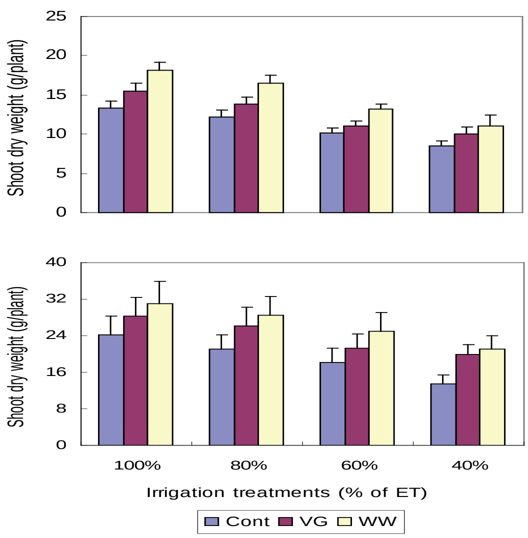

Fig 1. Effect of irrigation regimes and antitranspirants on dry weight of eggplant shoots at the first (A) and the second (B) sampling dates.

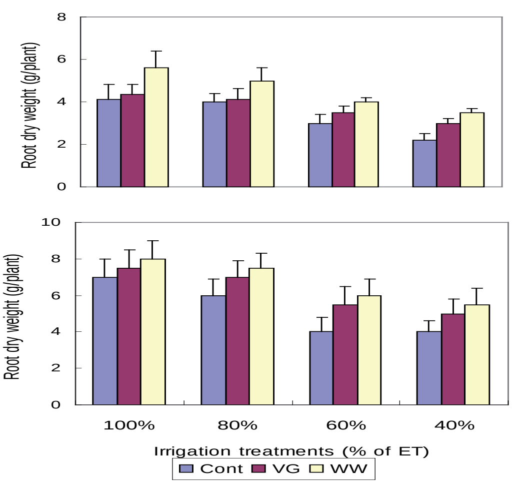

Fig 2. Effect of irrigation regimes and antitranspirants on dry weight of eggplant roots at the first (A) and the second (B) sampling dates.

the two sampling dates showed also that the reduction in RGR and NAR values under water stress condition increased with plant age. The reduction in the uptake of nutritional elements under drought conditions reported by Socias & Medrano (1994) and the consequent reduction in the photosynthetic rate as well as the disturbance in the physiological processes needed for normal plant growth might be an important reason for decreasing RGR and NAR under water stress.

The positive effect of WW and VG in maintaining active photosynthetic rate, and therefore increasing dry matter deposition in treated plants, might be one of the reasons responsible for increasing RGR and NAR. These results confirm other finding obtained by Attia et al. (1991) who found that the rate of dry matter production in eucalyptus treated with ATs was higher than that of the untreated plants.

Assuming that stomatal conductance correlates well with transpiration, the ATs treatments appeared to reduce transpiration more than photosynthesis (Davenport et al., 1974). Consequently, the water status of the treated plants would be more favorable for assimilation than that of the control plants, thereby encouraging the assimilation rate and metabolites and enhancing the rate of growth.

Although the interaction effect of ATs and water regime on RGR and NAR was insignificant at full watering regime, it was obvious that the favorable effect of ATs treatments was more pronounced at lower levels of irrigation regimes.

Transpiration

Results in Fig (3) indicated that soil moisture significantly influenced the daily transpiration rates which were markedly decreased at the lowest level of irrigation regime compared with those of the highest ones. In addition, transpiration rate was gradually decreased with time after irrigation at all levels of water regimes. This behavior may be ascribed to the soil dryness with time, partial desiccation and partial stomatal closure in plants grown under low moisture regime. Concerning this matter, Bennett and Sulivan (1981) reported that the differential in leaf water potential between well-watered and stressed plants became somewhat larger as the duration of the stress treatment increased, therefore transpiration was reduced with time.

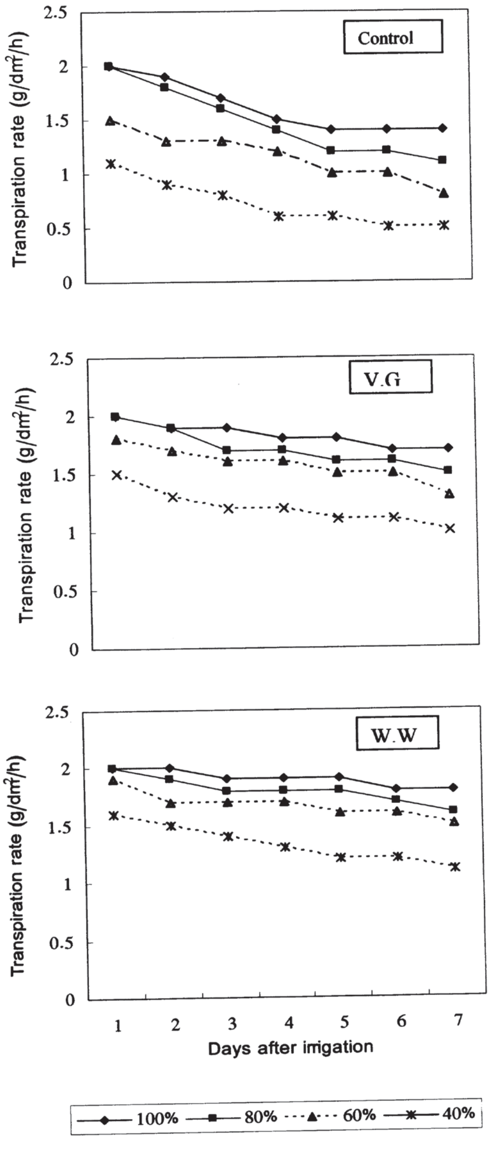

Fig 3. Effect of irrigation regimes and antitranspirants on transpiration rates of eggplantss.

It was clear that both ATs significantly reduced transpiration rate within about 24 hours, this reduction was about 40% and 50% with VG and WW, respectively. These results are in agreement with those obtained by Attia et al. (1991) for V.G and by Gawish (1992) for W.W. It seems that, VG, when sprayed on the foliage, dries out to form invisible discontinuous thin film that hinder the escape of water vapor from the leaves; while, WW reduces the transpiration via increasing the reflectivity of incident radiation particularly in the visible region (Socias and Medrano, 1994). This would reduce net energy uptake, lower leaf temperature and, subsequently, would decrease the transpiration rate. Data recorded in the figures showed also that the reduction in transpiration rate was gradually diminishing with time and then tended to rise again. This may be due to the cracking of the film over the stomatal pores as well as to the gradual wearing-off of the WW. The decay of ATs effectiveness may be, also, due to organ's growth and addition of new leaf surface as plants grew up.

Relative Water Content (RWC)

Due to the high evaporative demand of the atmosphere and the relatively low root ability to absorb water from the dry soil caused the RWC values of plant leaves to be lower at 3 pm than at 7 am (Fig. 4). In general, RWC decreased as levels of moisture regimes decreased. Since water flows along thermodynamic gradients in water potential of the soil-plant-atmosphere continuum (Salisbury and Ross, 1992), the reduction in RWC can be ascribed to greater resistance to water flow at soil-root interface and/or to decreased hydraulic conductivity of the soil at low soil moisture. In this concern, Nobel and Huang (1992) found that the drought-induced decreases in root hydraulic conductivity were primarily caused by dehydration of cortical cells and increased the suberization of the endodermis.

ATs–treated plants showed greater RWC than untreated control. This favorable effect was more observed at the afternoon period. The highest value of RWC was obtained

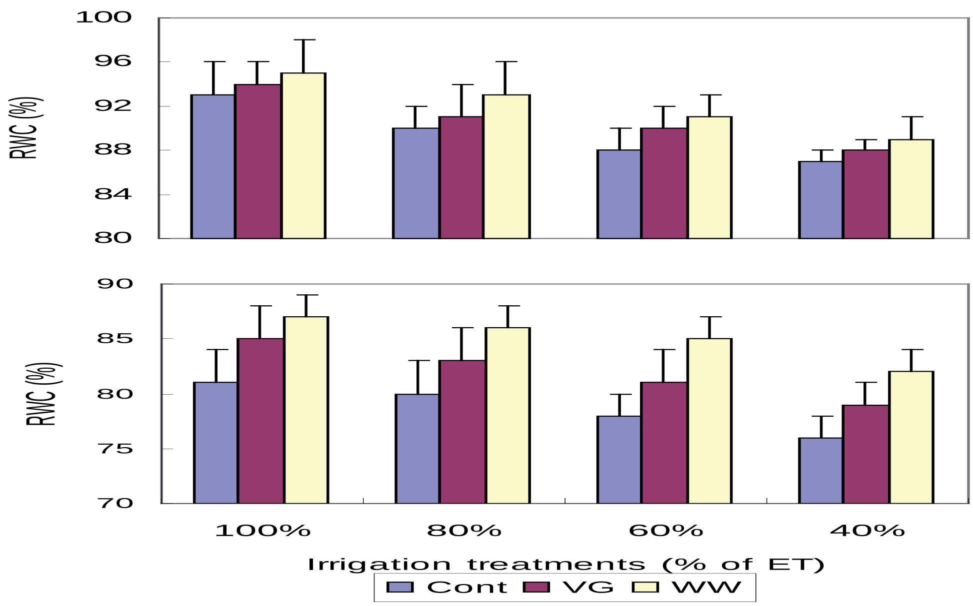

Fig 4. Effect of irrigation regimes and antitranspirants on relative water content (RWC) of eggplant at time period of 7 am (A) and 3 pm (B).

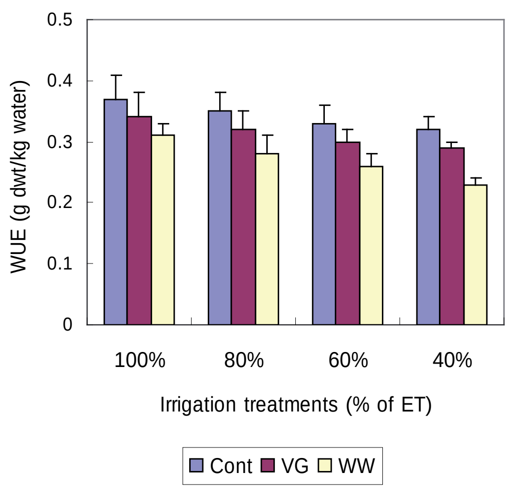

Fig 5. Effect of irrigation regimes and antitranspirants on water use efficiency (WUE) of eggplants.

in plants treated with WW which was better than VG in improving plant water status under hot dry conditions at 3 pm, particularly at low level of soil moisture. The highest total carbohydrate values were registered at 100 and 80% irrigation regimes (Table 3). However, 60 and 40% irrigation treatments reduced the carbohydrate in the leaves. Total carbohydrates at 40% irrigation were reduced by about 23% and 25% in the first and second sample, respectively, compared with 100% irrigation. Loss of K^+ from the guard cells, partial stomatal closure and reduction of C02 assimilation (Larcher, 1980) could be all contributed to reduce the total carbohydrates at low water regimes.

Both ATs markedly increased carbohydrate content, this positive effect was more obvious under low irrigation treatments (severe moisture stress). The concentration of carbohydrate was increased by 12% and 13%, in the first and second sampling dates, respectively; under VG treatments and 40% irrigation, while the corresponding increases at 100% irrigation were only 7% and 6% of control plants. The WW was even more effective in increasing the carbohydrates of stressed plants. The increase in leaf area and vegetative growth of ATs-treated plants may increase the PAR (photosynthetic active radiation) interception, improve the photosynthetic activity and consequently, stimulate carbohydrate synthesis. This positive effect was reported also in earlier study by Davenport et al. (1974) who found that film-forming anti-transpirants increased leaf water potential and guard cells turgidity in *Vicia faba* leaves making wider stomata and increasing net photosynthesis. Recently, Bernier (1993) found that increasing plant water content, as a result of increasing soil moisture, led to an increase in water use efficiency (WUE) and leaf area (LA), therefore chloroplast division and content increases and, in turn. photosvnthetic capacity stimulated and thus carbohydrate concentration increased as a consequence.

II- Yield analysis

Number of flowers and total yield/plant were decreased gradually as the available soil moisture decreased (Table 4). While the moisture regime of 100% gave the highest yield. These results agreed with those obtained on snap bean (Gawish, 1992). The detrimental effect of water stress on the yield and its components may be attributed to the reduction in vegetative growth. Salisbury and Ross (1992) found that low soil water potential adversely affects hormonal balance, plant development and assimilate translocation.

WW and VG improved the number and weight fruits/ plant. The superiority of WW over VG in improving vegetative growth was reflected on the yield. Moreover, Ben-Poralli and Grcenblat (1994) found that the film-forming anti-transpirant, Vapor Gard or Folicate, increased fruits of apricots.

Water use efficiency (WUE):

Fig. 5 show that the amount of water required for dry matter accumulation was gradually decreased (WUE increased) as soil water stress increased; whereas WUE was lower at high, than at low, soil moisture. In accordance with results obtained by Gawish (1992) for snap beans, the present data imply that high soil moisture increased the amount of water required to produce the unit value of dry matter. It was clear that ATs treatments had a favorable effect on WUE with the superiority of the WW on the VG. These results suggested that, WW-reated leaves were always cooler and used water

Table 3. Effect of irrigation regimes and antitranspirants (ATs) on total carbohydrates of eggplant at two sampling dates.

ATs (B)	Irrigation regimes (A)									
	100	80	60	40	mean	100	80	60	40	mean
	first sample					second sample				
	Carbohydrate (mg/g)									
Cont	24.8	22.7	20.4	18.9	21.7	30.2	28.6	26.6	25.0	27.6
VG	26.2	24.3	22.3	21.6	23.6	34.5	32.2	30.8	28.0	31.4
WW	30.5	27.4	25.5	23.8	26.8	37.7	35.8	33.0	31.2	34.4
Mean	27.2	24.8	22.7	21.4		34.1	32.2	30.1	28.1	
LSD5%	A= 1.6 B= 1.4 AB= 2.3					A= 2.1 B= 2.7 AB= 3.2				

A, B and AB as explained in Table (1).

Table 4. Effect of irrigation regimes and antitranspirants (ATs) on flowering and yield of eggplant.

ATs (B)	Irrigation regimes (A)									
	100	80	60	40	mean	100	80	60	40	mean
	Number of flowers/plant					Fruit yield g/plant				
Cont	58.5	52.2	41.3	22.7	43.7	3250	3106	1495	658	2127
VG	57.6	53.7	47.3	31.1	47.4	3255	3188	2044	960	2361
WW	59.8	56.6	50.4	41.2	52.0	3261	3212	2197	1110	2445
Mean	58.6	54.2	46.3	31.6		3255	3168	1912	909	
LSD5%	A= 11.8 B= 4.8 AB= 14.6					A= 266 B= 225 AB= 345				

A, B and AB as explained in Table (1).

more efficiently than other treatments. Similar conclusion was reported by Gawish (1992) on bean plants.

High WUE of ATs treated plants may be attributed to the increase in dry matter production and to the decrease in water use through the reduction of transpiration. The increased WUE by film-forming and reflective materials has been also reported by Ben-Porathi and Grcenblat (1994).

In conclusion, the present study indicated that eggplant growth and yield decreased with low water supply and, antitranspirant materials can, to a limit extend, overcome this problem. In order to obtain the highest growth and yield by the antitranspirant application, whitewash foliar coating material was found to be a suitable treatment for that when soil moisture was in the range of 80% to 60% of the evapo-transpiration (ET).

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الاستجابة الفسيولوجية لنباتات الباذنجان النامية تحت مستويات من الري المختلفة والمعاملة بمضادات النتح

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الملخص

تم زراعة ونمو نباتات الباذنجان تحت مستويات ري مختلفة (١٠٠، ٨٠، ٦٠، ٤٠٪ من قيمة النتح-بخر) مع المعاملة بنوعين من مضادات النتح "فابور جارد" و "وايت ووش" لبيان تأثيرها على السلوك الفسيولوجي لكل من المتغيرات (محتوى الماء النسبي والكربوهيدرات الكلية و كفاءة استهلاك الماء، وكمية المحصول). وقد دلت النتئج المتحصل عليها أن كل من مستويات الري ومضادات النتح أثرت تأثيرا معنويا على النمو والسلوك الفسيولوجي للنباتات. فقد تم الحصول على أحسن قياسات للنمو عند مستويات الري ١٠٠٪ من البخر-نتح بدون مضادات نتح وأيضا عند ٨٠٪ في وجود مضادات النتح. أوضحت النتائج أيضا أن «وايت ووش» كان هو الأكثر فاعلية من الفابور جارد في تلافي الضرر الناتج عن الإجهاد المائي الذي تعرضت له النباتات تحت مستويات الري المنخفضة. وقد أدت المعاملة بمضادات النتح إلى خفض معدل النتح، وتناقص الكربوهيدرات. بينما نمت النباتات الموجودة تحت مستويات الري المنخفضة بحالة جيدة عند معاملتها بمضادات النتح، وهذا أدى إلى زيادة المحصول بالمقارنة بالكنترول خاصة عند مستويات الري الأكثر انخفاضا.

كلمات دالة: الإجهاد المائي، مضادات النتح، الباذنجان، النمو، العلاقات المائية.