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Response of Vegetative and Reproductive Parameters of Water Stressed *Tuberose* Plants to *Vapor Gard (VG)* and *Kaolin Antitranspirants (AT)*

استجابة مقاييس النمو الخضري والتكاثري لنباتات ''*التوبيرورس النامية*''تحت ظروف الإجهاد المائي للمعاملة بمضادات النتح ''فابور جارد'' و ''*الكاولين*''

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قسم إنتاج النبات ووقايته - كلية الزراعة والطب البيطري بالقصيم، ص.ب: 1482 ، القصيم، المملكة العربية السعودية

Abstract: Effects of different types of antitranspirants (ATs) on vegetative growth, flowering, marketable inflorescences, bulb production, mineral concentration, soluble sugars, and total carbohydrate concentration of tuberose (*Polianthes tuberosa L.*) cv. Double plants, grown under the irrigation regimes of 100%, 80% and 60% of total evapo-transpiration (ET) values, were investigated to select the suitable (AT) for conserving irrigation water, and with no detrimental effects on growth and production of tuberose plants grown in Al-Qassim region. Plant biomass, number of leaves, length and weight of marketable inflorescences and bulb yield, were significantly reduced by water deficit, particularly at 60% (ET). But the flowering period was markedly shortened under stress conditions. Under water deficit (N, P, K, Ca,) total carbohydrates and soluble sugars decreased in treated leaves as compared to the control plants. Both types of (ATs) effectively enhanced plant performance, flower formation, bulb production, nutrient uptake and carbohydrate synthesis at the 80% (ET) treatment, relative to the irrigation regime of 80%(ET). The particle type (AT), Kaolin, was more effective than the emulsion type (AT), Vapor Gard (VG), which might be attributed to its mechanism for reducing leaf temperature, transpiration rate, improvement of plant water status and maintaining biomass production of tuberose plants. Due to the superiority of Kaolin particle film in regulating plant performance and chemistry it is recommended for reducing water loss by plants in Al-Qassim region, Saudi Arabia.

Keywords: Al Qassim, Saudi Arabia, Water stress, *Polianthes tuberose L*, antitranspirants, growth, reproduction.

المستخلص:أجريت هذه الدراسة بمحطة البحوث والتجارب الزراعية التابعة لكلية الزراعة والطب البيطري بالقصيم، وذلك لدراسة تأثير رش كل من مضادات النتح الاستحلابية، المكونة لطبقة من المستحلب، مثل، *فابور جارد*، ومضادات النتح المكونة لطبقة من دقائق وجسيمات المادة، مثل *الكاولين*، على سطح الأوراق، في كل من النمو الخضري والزهري، وجودة النورات القابلة للتسويق، والمحتوى الكيميائي للنباتات. تم قياس عدد الأوراق ومساحتها، وزن النبات، طول النورة، عدد الأزهار في النورة، إنتاج النبات من الأبصال الحديثة، تركيز العناصر المعدنية، والسكريات الذائبة والكربوهيدرات الكلية في نباتات *التوبيروس* النامية تحت معدلات ري 100%، 80%، و60%من كمية الماء المفقود بواسطة البخر- نتح. استهدفت الدراسة أيضاً معرفة أنواع مضادات النتح الأكثر ملائمة للاستخدام تحت ظروف نقص الماء السائدة في منطقة القصيم بالمملكة العربية السعودية. وذلك في محاولة لتوفير ماء الري عن طريق تقليل الماء المفقود خلال عملية النتح. دلت نتائج هذه الدراسة على أن تعرض النباتات للإجهاد المائي، أدى إلى انخفاض الوزن الجاف، وعدد الأوراق القاعدية على الساق ومساحة الأوراق الكلية وعدد الأوراق على المحور الزهري، وقطر المحور الزهري، وطول النورة، وعدد الأزهار في النورة الواحدة، ووزن النورة. كما انخفضت درجة جودة النورات القابلة للتسويق. حيث قصر طولها وتناقص عدد الأزهار بها، وذلك تحت معدلات ري 80% و 60%. هذا وقد كان لمعدل الري الأخير تأثيراً أكثر ضرراً على جودة الأزهار، إلا أنه قد تسبب في التزهير المبكر لنباتات التوبيروس النامية، بالمقارنة بنباتات الشاهد. انخفض معنوياً تركيز العناصر المعدنية والسكريات الذائبة والكربوهيدرات الكلية في نباتات *التوبيروس* النامية تحت معدل ري 80% أو 60%، مقارنة بنباتات الشاهد. أدى رش نباتات *التوبرور* النامية، تحت ظروف الإجهاد المائي، بمضادات النتح، إلى تحسن حالة النباتات الفسيولوجية. وانعكس ذلك على نموها الخضري والزهري. وكان الرش بمادة الكاولين أكثر معنوية من *الفابور* جارد في تحسين جميع الصفات التي تمت دراستها. لذا توصي هذه الدراسة باستخدام الكاولين لتحسين نمو وإنتاجية نباتات *التوبيروس* النامية، تحت أجواء منطقة القصيم بالمملكة العربية السعودية.

كلمات مدخلية: القصيم، السعودية، التوبروز، الإجهاد المائي، مضادات النتح، النمو الخضري، الإزهار، الأبصال.

Introduction

In arid and semi-arid regions, there is a critical balance between water requirement and water consumption. Thus, saving water is a decisive aspect for agricultural expansion in such regions, where water deficit and high temperature are the main limiting factors of plant growth and productivity (Taiz and Zeiger, 2002).

Reduction of plant growth is one of the most conspicuous effects of water deficit on the plant, and is mainly caused by inhibiting leaf and stem elongation (Younis, *et al.* 2000). In addition, water deficit was found to affect negatively the flowering process and the inflorescence in buckwheat (*Fagopyrum esculentum*) plants, by reducing the fertility of newly formed flowers (Slawinska and Obendorf, 2001); (Delperee, *et al.* 2003). Reductions in nutrient uptake and content within plant tissues under water deficit conditions have been reported by other investigators, (Taiz and Zeiger, 2002). It was reported that actively growing plants would transpire a weight of water equal to their fresh leaf weight each hour, under conditions of arid and semi-arid regions, if water were adequately supplied (Moftah, 1997). This scary figure has made it necessary to find ways by which available water can be economically utilized. One way to achieve this goal is by reducing the transpiration rate, so that the amount of irrigation water can be minimized.

Certain chemicals with certain biological activities can be used to reduce the transpiration rate, and mitigate plant water stress, by increasing the leaf resistance to the diffusion of water vapor. Based on their mechanism of action, such anti-transpirants (ATs) have been grouped into three categories, (Prakash and Ramachandran, 2000), namely;

- **(a)** Film-forming types (which coat leaf surfaces with films that are impervious to water vapor).
- **(b)** Reflecting materials (which reflect back a portion of the incident radiation falling on the upper surface of the leaves)
- **(c)** Stomatal closing types (which affect the metabolic processes in leaf tissues).

Film forming and reflecting (ATs) are not toxic, and have longer periods of effectiveness than metabolic types (Al-Humaid and Moftah, 2004).

The pinolene-base, Vapor Gard (VG), has not been reported to reduce the photosynthetic rate, and it dries on plants to form a clear, glossy film, which retards normal moisture loss without interfering with plant growth, or normal respiration. Moreover, the reflective Kaolin spray was found to decrease leaf temperature, by increasing leaf reflectance, and to reduce the transpiration rate, more than photosynthesis, in many plant species grown at high solar radiation levels (Nakano and Uehara, 1996). Early studies demonstrated, that the reflective Kaolin improved the water status and growth of water stressed tomato plants (Glenn, *et al.* 2003).

Tuberose *(Polianthes tuberosa L.)* cv. Double, is one of the most popular odorous flowering ornamentals, and it is an excellent summer flowering bulb, suitable for summer marketing. It is commercially grown for its attractive and alluring cut flowers, and also for the production of bulbs. Floral arrangements are made from its flowers, and also used for floral bouquets and for table decorations, because the flowers remain effectively fresh and attractive for many days. Tuberose usually blooms during summer and fall months, producing a showy conspicuous fragrant yield of cut flowers of high marketable value, due to the lack of other flowering bulbs in summer and autumn (El-Naggar, 1998).

(Al-Humaid and Moftah, 2004) found that Vapor Gard (VG), and Kaolin sprays reduced transpiration, and improved photosynthesis and water use efficiency in water stressed tuberose. The present study was undertaken to determine and compare the effects of Vapor Gard (VG), emulsion film *(polyterpene material)* and Kaolin particle film *(a reflecting material)* on vegetative and reproductive growth, nutrient uptake, soluble sugars and total carbohydrate content of tuberose *(Polianthes tuberosa L.)* cv. Double plants grown under different water regimes to select the most suitable antitranspirat (AT), to regulate the irrigation of ornamental plants in the arid regions of Saudi Arabia.

Materials and Methods

Tuberose *(Polianthes tuberosa L.)* cv. Double bulbs of about 4-5cm in diameter were planted on April 7th, 2002, in 30cm plastic pots each filled with 10kg air dried sandy soil (Table 1). Pots were placed in a greenhouse and plants were allowed to grow for four weeks at 30°C/20°C day/night temperature, 400μmol $m^{-2}s^{-1}$ photosynthetic active radiation (PAR), enhanced by high pressure sodium lamps supplement from (5 to 21hr). Before planting, the first of three equal doses of Sangral (William Sinclair Horticulture Ltd, England), compound fertilizer (20N-20P-20K, plus micronutrients), was applied to the soil (6gm pot^{-1}). In the greenhouse, all pots were irrigated to the field capacity. The field capacity of the soil was (14.50% ± 0.3%) (mean of six replications ± SE), measured with the pressure plate apparatus. Chemical and physical properties of the soil are shown in (Table 1).

Pots were transferred to open field conditions, and plants, were irrigated to field capacity, for another four weeks, to prevent water stress, to ensure the establishment of seedlings, and to allow adaptation to the field conditions before drought treatments were imposed. The second remaining two doses of fertilizer were added fortnightly antitranspirants (ATs) (i.e. 70 and 84 days after planting, DAP). Eight weeks after planting, water stress was imposed by withholding irrigation for a

Table 1. Chemical and Physical Analyses of the Soil.

Chemical properties	Physical properties
pH*: 8.20	Fractions (%):
ECe (ms)**: 2.06	Sand: 95.30
Soluble cations (meq.L-1):	Silt: 3.60
	Clay: 1.10
Na^+ 11.00	
Ca^{2+} 4.35	
Mg^{2+} 2.50	
Soluble anions (meq.L-1):	Texture: Sandy Soil
CO_3^{2-} + HCO_3- 2.99	
SO_4^{2-} 11.70	
Cl^- 7.60	
$CaCO_3$ 4.00%	
O.M. 0.23%	

* pH of H_2O (soil : water = 2.5 : 1)
** ECe = Electric conductivity of the extract.

period of three days, during which (ATs), were applied and watering of pots, as assigned to the required water stress levels, was resumed on the 4th day of water withholding.

● Antitranspirant Treatments

Depending on a preliminary experiment, and recommendations of earlier studies on different crop species (Moftah, 1997); (Martinez, *et al.* 2001); (Nakano and Uehara, 1996), the pinolene-base Vapor Gard (VG), (Miller Chemical & Fertilizer Corp., Hannover, PA, USA) was applied at 2% (v/v), and Surround wetable powder (WP), (Engelhard Corp., Iselin, NJ, USA), a hydrophilic Kaolin particle film, with wetting and sticking agent *(Triton B),* was applied at 3% (w/v) . The treatments of both (ATs) were prepared, using only water, (Sutherland and Walters, 2001); (Glenn, *et al.* 2003). Thus (AT) treatments were:

I) 0 (control),
II) 3% VG emulsion film, and
III) 3% Kaolin particle film.

Tuberose plants were sprayed three times in two week intervals, with a fine mist of the (AT) solutions, starting 59 DAP, using a hand pressure-sprayer, until run-off from the whole plant. Water was sprayed as a control treatment.

● Irrigation Procedure

At the beginning of water stress treatments (60 DAP), the evapo-transpiration (ET) was determined gravimetrically, (weighing pots with plants), and the amount of water lost during the three days, through which, water was withheld, was recovered completely by irrigation for control pots only. Other pots received either 80% or 60% of the water added to control plants. Thus, throughout the course of the experiment, the amount of water applied at each irrigation event was equal to the net evapo-transpiration (ET) between each two successive irrigation events.

In order to determine the amount of water evaporating from soil surfaces, three pots filled with the same amount of soil were watered to 100%, 80%, and 60% of the field capacity. The loss in pot weights represented the amount of water lost by evaporation.

● Experimental Design

The experimental layout was a randomized complete block design, replicated three times. Beside the three pots for the evaporation measurements, each block included seven treatments:

1, 2 & 3: 100%, and 80%, and 60% evapo-transpiration (ET) watering
4, & 5: 80%, and 60%, evapo-transpiration (+) Vapor Gard [(ET + (VG)]
6, & 7: 80%, and 60%, evapo-transpiration (+) surroundwebable power. [ET) (+) surround, WP)]

● Vegetative Growth

The number of leaves per flowering stalk, number of basal leaves, total leaf area, and shoot dry weight per plant (after drying at 70°C until steady weight) were determined.

● Flowering and Inflorescence Characteristics

Flowering time, flowering stalk length and diameter, spike length, number of flowers per spike, and fresh weight of flowering stalk were determined.

● Bulb yield

At harvest time, when basal leaves dried out, bulbs were gently dug out from the soil with the whole root system, and were cleaned using weak streams of water. The number, the diameter, and the bulb dry weight per plant (after drying at 70°C until steady weight) were measured.

- Flower Quality Rating

The quality rating was based on a scale of 1-10 (El-Naggar, 1998);

(**a**) 1-3 = poor quality (short stem, slender, small spike and poor appearance),
(**b**) 3-7 = good quality (average specification and appearance),
(**c**) 7-10 = excellent quality (highly marketable and superior quality of strong, healthy showy and alluring flowering stalk).

- Ion Analysis

At the end of the harvest, total (N) was determined using the Kjeldahl method. Phosphorus concentration was measured using a colorimetric assay, while (K) and (Ca) were measured by atomic absorption spectrophotometry (Walinga, *et al.* 1995).

- Soluble Sugars

Soluble sugar content was determined following the method described by, (Buysse and Merckx, 1993). Briefly, fifty milligrams of dry leaf powder were extracted with 80% (v/v) ethanol, for three times (20mL). The total volume of the combined and filtered extracts, was adjusted to (100mL), using deionized water. One milliliter of the samples was transferred into a glass tube, and (1mL) 18% (w/v) phenol solution was then added. Immediately afterwards, (5mL) of concentrated sulphuric acid was added, and the solution in the tube was mixed using a vortex mixer. The tubes were allowed to stand for 20min, and cooled to room temperature, before absorbance was measured with a spectrophotometer at 490nm (Genesys, Spectronic Instruments, Inc., Rochester, NY, USA).

- Total Carbohydrates

The acid digestion extracts of fifty milligrams of dry leaf powder were adjusted to (100mL) using deionized water. Total carbohydrate was determined, spectrophotometrically, using the phenol/sulphuric acid method, as described by (Buysse and Merckx, 1993). All chemical measurements were made in dry ground materials, from fully expanded leaves of nine plants per treatment (3 plants/block).

- Statistical Analysis

All data were, statistically, analyzed according to (Snedecor and Cochran, 1980) with the aid of the *COSTAT* computer program for statistics. Differences among treatments were tested with *LSD* at 5% level of significance.

Results and Discussion

(**1**) Growth Parameters

The number of leaves, leaf area, and shoot dry weight of tuberose, were significantly reduced by water deficit treatments, particularly the 60% (ET) regime as compared with the control (Table 2). The decrease in the number of basal leaves was about 27% and 54% of control at 80% and 60%, (ET), respectively, while the number of leaves on the flowering stalk was reduced by 20%, and 48%, respectively. The corresponding decrease in area reached 13% and 31%, respectively, compared to the control. Thus, shoot biomass (dry wt) was reduced by about 17%, at moderate water deficit, while severe stress (60% (ET)) caused a 39% decrease in shoot dry weight per plant.

Table 2. Effects of Vapor Gard (VG) and Kaolin sprays on the vegetative growth parameters of tuberose plants grown under different irrigation regimes. 'Each value represents the mean of three replicates.'

Water regime Evapotranspiration (ET)%	Anti-transpirant spray (AT)	No. leaves /flowering stalk	No. basal leaves /plant	Total leaf area/plant (cm2)	Shoot dry wt (g/plant)
Control	00	6.23a*	22.14a	986a	16.22a
80%ET	00	5.00b	16.07b	862b	13.45b
+	VG	6.06a	19.15a	904b	13.86b
+	Kaolin	6.14a	20.90a	935a	14.58b
60%ET	00	3.24c	10.13c	674c	9.88d
+	VG	4.20	15.03b	687c	10.16c
+	Kaolin	4.28b	15.04b	714c	10.82c

(ET) = Evapotranspiration. (AT) = Antitranspirant.
*Similar letters in the same column indicate no significant differences between values at L.S.D. (0.05).

The results are in agreement with (Younis, *et al.* 2000) who found that, the water deficit on plants inhibited leaf expansion, and stem, and root elongation. Therefore, a small decrease in plant water content, and turgor, can slow down or fully stop growth, (Taiz and Zeiger, 2002).

The 20% reduction in available soil water did not adversely affect plant growth when sprayed with antitranspirants (ATs), especially Kaolin, which had more pronounced effects on growth parameters, than Vapor Gard, (VG) (See, Table 2). The insignificant differences between (AT-treated) plants and the 80% (ET), may be attributed to the increased turgor and water use efficiency in the former, compared, to untreated water-stressed tuberose plants. Since water consumption was less for the (AT-treated) plants, the biomass-to-water ratio was expected to be significantly better in these plants, compared, to unsprayed ones. This result may indicate also that (ATs) have the potential to help plants form a well-developed root system for vegetative and reproductive growth, as it was reported by (Liang, *et al.* 2002).

(2) Reproductive Parameters

Naturally, when a plant experiences unfavorable conditions, inflorescence and seed production are often accelerated. The present study shows that, tuberose plants tended to flower early as they were subjected to water deficit. Thus, 60% (ET-treated) plants had a significantly shorter flowering period, flowering nearly a week earlier and producing fewer flowers than the control (Table 3). No significant differences in days to flower were recorded between a 80% (ET) treatment and the control. Vapor Gard (VG), spray shortened the flowering period by about 2 to 5 days while Kaolin spray accelerated flowering by about 4 to 5 days at 80% and 60% (ET), respectively, as compared with control.

All elements of the marketable inflorescences were reduced significantly in plants grown under water deficit conditions. Even at mild water deficit (80% (ET)), flowering stalk length, flowering spike length, and the number of flowers, per inflorescence, were significantly reduced by about 15%, 23%, and 29%, respectively, as compared to the control plants. Similarly, the number of bulbs per plant, the dry weight of bulbs per plant, and the daughter bulb diameter were decreased by about 19%, 14%, and 4%, respectively. The decrease in floral and bulbous variables was more severe at 60% (ET) with or without (AT) applications. Such a decrease is not considered economically acceptable (Table 4).

The results were in agreement with those of (Jaimez, *et al.,* 2000) and (Bissuel-Belaygue, *et al.,* 2002), who found that the water deficit had significant effect on number of aborted flowers, bulb size, inflorescences and floral buds and number of flowers per plant. According to the present study and earlier work by (Al-Humaid and Moftah, 2004); it could be speculated that water deficit and high evapo-transpiration (ET) rates during dry warm periods (flowering stage) in this region significantly reduced, both flower production and inflorescence formation. They also lowered leaf water potential that caused stomatal closure which, in turn, reduced the photosynthetic rate and decreased the photosynthates transported to the produced bulbs. Thus, bulb production and quality were lower than the control. This conclusion is in harmony with that reported by (Jaimez, *et al.,* 2000).

Recorded data clearly show that (VG) or Kaolin sprays were beneficial only for plants grown under 80% (ET) irrigation regime, while at 60% (ET) neither (ATs) compensated for the harmful effect on flowering and bulb production resulting from the water deficit. Flowering stalk length and diameter of (AT) treated-plants grown at 80% (ET) and the control were comparable, while spike length, number of flowers per plant, and flowering stalk weight of the corresponding treatments were significantly different. Although both materials are considered economically acceptable for plants grown under 80% (ET) water supply, plants showed a better response to Kaolin than to (VG) treatments as flowering, and bulb parameters were substantially improved under the former, compared to the latter material (See, Table 4). The distinct effect of Kaolin might be due to its ability to reflect

Table 3. Effects of Vapor Gard (VG) and Kaolin sprays on the flowering and inflorescence characteristics of tuberose plants grown under different irrigation regimes. Each value represents the mean of three replicates.

Water regime (ET)%	(AT) spray	Days to flowering	Flowering stalk length (cm)	Flowering stalk diam. (cm)	Spike length (cm)	No. of flowers /spike	Flowering stalk wt (g)	Quality rating
Control	00	135.9a*	58.54a	0.78a	23.50a	14.22a	52.41a	8.1a
80%ET	00	133.2a	49.66b	0.75a	18.12b	10.12c	42.17c	6.5b
+	VG	134.3a	52.12a	0.75a	19.66b	12.34b	47.20b	6.9b
+	Kaolin	31.6b	56.14a	0.73a	22.11a	12.85b	50.66a	7.8a
60%ET	00	128.4c	35.15d	0.64c	12.10c	7.06d	30.42e	2.1c
+	VG	131.3b	42.10c	0.68b	19.74b	10.62c	39.11d	2.5c
+	Kaolin	130.5b	40.22c	0.69b	18.85b	9.33d	38.72d	2.8c

(ET) = Evapotranspiration. (AT) = Antitranspirant.

* Similar letters in the same column indicate no significant differences between values at L.S.D. (0.05).

most of the solar radiation falling on the plant leaves. The reflection causes better cooling for the leaf tissues under water stress conditions, and warm climate prevailing in the region. This leads to enhancement of the photosynthetic rate, the water status, the carbohydrate metabolism, and the elemental uptake under water deficit conditions. Such improvement was found to mitigate the detrimental effect of water deficit on the partitioning of assimilates during the period of flowering bud initiation. Thus, this mitigation improved flower formation and bulb production (Jaimez, *et al.* 2000). Data showed that, Kaolin also increased leaf area per plant as compared with 80% (ET). That increase has been positively and significantly correlated with improvement of the reproductive organs (Kisman and Sudarmawan, 2002).

Table 4. Effects of Vapor Gard (VG) and Kaolin sprays on bulb yields and bulb characteristics of tuberose plants grown under different irrigation regimes. Each value represents the mean of three replicates.

Water regime (ET)%	spray (AT)	No. of bulbs /plant	Dry wt of bulbs (g/plant)	Diameter of daughter bulb (cm)
Control	00	22.24a*	6.82a	3.11a
80%ET	00	18.12b	5.85b	3.00b
+	VG	20.40a	6.72a	3.10a
+	Kaolin	21.05a	6.77a	3.19a
60%ET	00	10.03d	5.41c	2.08c
+	VG	14.30c	5.65b	2.86b
+	Kaolin	14.90c	5.73b	2.97b

(ET) = Evapotranspiration. (AT) = Antitranspirant.
*Similar letters in the same column indicate no significant differences between values at L.S.D. (0.05).

(3) Leaf Mineral Concentration

As expected, concentrations of (N, P, K, and Ca) in tuberose leaves, were substantially decreased by severe water deficit conditions (60% (ET) treatment). However, there were significant differences between 80% (ET) stressed plants and the control in their nutrient contents (Table 5). Kaolin significantly increased nutrient contents (N, K, and Ca) at 80% (ET) relative to 80% (ET) treatment. Kaolin had a pronounced effect on ion content compared to (VG). Because long distance movement from roots to the above ground parts occurs in the transpiration stream, a reduction in the rate of ion transport might occur in severely stressed plants, to reduce transpiration. Moreover, efficiency of nutrient absorption, and transport within the plant, may be reduced, because the movement of minerals is slow in drying soil. Also root extension is decreased, and suberization reduced root permeability (Nilsen and Orcutt, 1966).

Table 5. Effects of Vapor Gard (VG) and Kaolin sprays on nutrient element concentration in leaves of tuberose plants grown under different irrigation regimes. Each value represents the mean of three replicates.

Water regime (ET)%	(AT) spray	N%	P%	K%	Ca%
Control	00	2.45a*	0.35a	2.65a	2.15b
80%ET	00	2.12b	0.28b	2.04b	2.02c
+	VG	2.24b	0.29b	2.10b	2.11b
+	Kaolin	2.35a	0.30b	2.48a	3.08a
60%ET	00	1.86c	0.18c	1.56c	1.74d
+	VG	1.99c	0.21b	1.98c	1.92c
+	Kaolin	2.00c	0.23b	2.02b	2.01c

ET = Evapotranspiration. AT = Antitranspirant.
*Similar letters in the same column indicate no significant differences between values at L.S.D. (0.05).

Phosphorus values were significantly decreased in (AT) treatedplants, because of the low transpiration rate (Moftah, 1997). On the other hand, (K and Ca) levels were improved in sprayed plants (by Kaolin) under the 80% (ET) regime, because the availability of soil water that was developed by (ATs) may enhance the active transport of these elements. Nitrate reductase in tuberose roots may also be enhanced by the improved water level in the soil, leading to an increase in (N) uptake and content in plant leaves. The positive effect of (AT) (Kaolin) on nutrient uptake was also reported by (Martinez, *et al.*, 2001). The increased (K and Ca) concentrations in plant tissues, suggests that these ions may play a fundamental role in facilitating high turgor maintenance under water deficit conditions. This conclusion is in agreement with (De-Pascale, *et al.*, 2003) on pepper plants grown under drought stress.

(4) Soluble Sugars and Total Carbohydrates

It is obvious that water deficit decreased both soluble sugars, and total carbohydrate contents in tuberose leaves (Table 6). The decrease in soluble sugars was almost 19% and 21% at 80% and 60% (ET) treatments, respectively, while the corresponding values for total carbohydrates were 16% and 37%, respectively. This means that, total carbohydrates were more sensitive to water deficit, and thus, decreased more than soluble sugars. Interestingly, the ratio of soluble sugars to total carbohydrates increased as water deficit, became more severe. This ratio was about 51% at 80% (ET), while at 60% (ET) the ratio was almost 65%, as compared with 52% for the control (Table 6). The increase in soluble sugars with Kaolin treatments was observed at the 80% or 60% (ET) regimes, as compared with 80% or 60% (ET) alone.

Soluble sugars and total carbohydrates were significantly lower in 80% and 60% (ET) treated plants, either with, or without (AT) treatments, than in the control. However, soluble and total sugars were significantly higher in Kaolin than in (VG-treated) plants. (Barathi, *et al.,* 2001) found that, soluble sugar content was affected by water stress, and this effect was accompanied by a decrease in starch content, indicating drought injury signs. In the present study, decreases in soluble sugar content occurred after soil water was nearly depleted. This was coincident with the decrease in vegetative growth and flowering quality, indicating that the reduction in soluble sugars could be associated with cell damage and leaf senescence. These findings are in harmony with; (Wang, *et al.,* 2003). The superior effect of Kaolin over (VG) on enhancing formation of soluble sugars and total carbohydrates in water stressed-tuberose leaves, may reflect the role of Kaolin in reducing leaf temperature during the warm period of tuberose production. Therefore, photosynthesis and water status were improved in Kaolin treated-plants under water deficit conditions.

Table 6. Effects of *Vapor Gard (VG)* and *Kaolin* sprays on soluble sugars and total carbohydrate content in leaves of tuberose plants grown under different irrigation regimes. Each value represents the mean of three replicates.

Water regime (ET)%	(AT) spray	Soluble sugars (%)	Carbohydrates (total %)	SS/TC** ratio
Control	00	12.62a*	24.14a	0.52
80%ET	00	10.20c	20.16b	0.51
+	VG	10.32c	21.45b	0.48
+	Kaolin	11.20b	23.65a	0.47
60%ET	00	10.00c	15.29d	0.65
+	VG	9.13d	18.18c	0.50
+	Kaolin	11.14b	20.20b	0.55

(ET) = Evapotranspiration.
(AT) = Antitranspirant.
(TC) = Total carbohydrates
*Similar letters in the same column indicate no significant differences between
values at L.S.D. (0.05).
**SS = Soluble sugars.

Conclusion

It could be concluded that water deficit, in arid and semi-arid regions, negatively affects vegetative growth, and flowering parameters, the quality of the marketable inflorescences, and the bulb production of tuberose plants. Applications of emulsion film type Vapor Gard (VG), and particle film type Kaolin were found to enhance most parameters, in plants subjected to mild water stress. While at severe water stress, plants were not able to reach the economical level, even when they were sprayed with the antitranspirants. Under these conditions of water deficit, and heat stress with high evaporative demands, such as that prevailing in most arid and semi-arid regions, Kaolin sprayed-plants performed better than (VG-sprayed) plants, due to Kaolin's ability to reflect most of the solar radiation falling on leaves, and thus to reduce leaf temperature, to improve plant functions, to increase nutrient content, and carbohydrate formation, and, therefore, to enhance growth and productivity of tuberose plants.

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