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The Effects of Three Antitranspirants on Yield and Transpiration of Potato Cultivars

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ABSTRACT. Under greenhouse conditions, antitranspirant chemicals wilt pruf, folicote and vapor guard, reduced transpiration rate of potato plants under study by 38 to 50%. Significant differences among chemical treatments as well as among potato cultivars were found.

Plant height, dry matter, and yield, were increased by antitranspirant treatments. There are significant differences among chemical treatments as well as among potato cultivars. No significant differences among treatments for plant height was found but there were significant differences among cultivars.

The effect of antitranspirant on number of leaves, number of leaflets, and leaftlet size was insignificant. Wilting degree was significantly reduced by antitranspirant chemicals.

It appears that no economical profit was found by using two applications of chemicals compared to one application.

Introduction

Environmental factors such as high light intensity, high temperature, salinity and drought stress affect vegetable crops in Saudi Arabia, such as potato. Little attention has been given to heat and drought tolerance in potatoes; possibly because centers of potato production and research are mostly located in temperature zones with reasonable rainfall (Harris 1978). In Saudi Arabia and many other countries, potatoes are grown in hot semi-arid regions. Although they are irrigated during most of the growing season. Nevertheless, they are exposed to various degrees of water stress result-

ing from high ambient temperatures and low humidity, a combination which is very common during spring and summer seasons.

The present study was conducted to evaluate the effect of three antitranspirant chemicals on plant growth, yield, transpiration rate, and heat induced drought responses of potato cultivars.

Transpiration is the loss of water in the form of vapor from the stem and leaves of the living plant. The loss of water from the plant to atmosphere occurs by gaseous diffusion through the leaf stomata. The gaseous diffusion of water vapor is directly controlled by the regulation of stomatal aperture. The stomatal movement is controlled by plant and atmospheric factors (Kramer 1969).

Artificial controls of transpiration have been developed and tested for a decade. The major types of materials used were, film forming substances that block water vapor diffusion from the leaf (Slatyer and Bierhuizen 1964); chemicals that increase resistance to the diffusion of water vapor by inducing stomatal closure (Waggoner and Zelitch 1965); and reflectant materials that decrease the evaporative energy to the plant (Aboukhaled 1970).

The reduction of transpiration by using antitranspirants based on the assumption that an increase in resistance at the leaf surface will decrease transpiration more than it will decrease CO_2 uptake (Kramer 1983). Fuehring and Finkner (1983) reported that antitranspirant affect water loss more than carbon dioxide exchange in leaves. Antitranspirants have shown to reduce transpiration (Davenport and Hagan 1973; Gale and Hagan 1966; Susan 1990; and Wendt 1978). Wendt (1973) obtained slight increases in yield of potatoes by use of antitranspirants.

Ziv and Hagiladi (1983) found that antitranspirants chemicals (vapor guard and wilt pruf) effectively controlled powdery mildew. The use of non-toxic antitranspirants as disease control agents in pot plants contributes to improve plant quality and reduce water loss under moisture stress conditions during transplanting, shipment and handling (Martin 1974).

Material and Methods

Four cultivars of potato, Norchip, Norgold, Red Norland and Monona were selected for greenhouse study. Day temperatures were at 22-30°C and night temperatures were at 13-19°C. Relative humidity varied from 50-70%.

The following procedures were common to all experiments.

1. Potato tubers were cut and planted in plastic flats, in a mixture of soil sphagnum peat, vermiculite and sand 1:1:1 ratio.
2. Seedlings were transplanted into one gallon plastic pots containing the same soil mixture as above.
3. Pesticides were sprayed weekly on potato plants. The following chemicals were used, Pratt Dx (Pyrethrum and Rotenone), Thiodan, and Insecticidal soap.
4. The plants were fertilized every two weeks with one tablespoon/gallon of rapid

grow 20-20-20 fertilizer.

5. Antitranspirant chemicals were diluted in water wilt pruf (1:10 water dilution), Folicote (1:20 water dilution), and vapor guard (1:40 water dilution).
6. The plants of each cultivar were sprayed with hand sprayer.
7. Drip irrigation system was used in watering the plants.

Experiment I

Nine plants of each cultivar and treatment were exposed to heat induced drought stress in a heat chamber. Two weeks after the application of the antitranspirants, the stress conditions in the chamber were 120°F (48.9°C) and 60-70% relative humidity for 5 hours. The plants were sprayed with the three antitranspirants at the post-bloom stage when tubers were developing at seven weeks from emergence. The fourth treatment consisted of nine control plants.

Each plant was measured both before and after chemicals were applied at six and eight weeks after emergence. Measurement taken included plant height (from soil line to main growing point), number of leaves per plant and leaflet size (length × width) of a fully expanded leaf on each plant. These were measured in centimeters. Degree of wilting in the heat chamber was determined on 1 to 10 scale. Wilt ratings of 1 to 4 involved wilting of 10 to 40% of the leaves; rating of 5 to 10 involved wilting of stem and leaves (50 to 100 per cent).

The plants were harvested when they were mature and tuber counts and weights were determined from which average tuber sizes (gm) were calculated.

Experiment II

Four plants of each cultivar and treatment were planted. The plants were sprayed twice with antitranspirants after 4 weeks and 8 weeks from emergence, and two weeks after applying the chemicals, all plants were tested in the heat machine. Degree of wilting and plant damage were estimated. Tuber number and weight were established at harvest.

Experiment III

1. The Weighing Method

Transpiration was determined by the pot weight method with four plants of each cultivar and treatment. The mix media was saturated with water, and was left for 15-30 minutes to let the free water drop and then weighed the plant and the container. The pots were sealed from the top by aluminum foil. The plants were weighed again after 48 hours. This process was repeated three times at two days intervals. Transpiration was recorded as the difference between the 0 and 48 hour weight in grams. Measurement time was at 1:00-3:00 p.m.

2. The Cobalt Chloride Method

The same plants were used to measure transpiration by the cobalt chloride paper. The cobalt chloride paper was placed in the desiccator for 48 hours until the color be-

came clearly blue. The paper removed and sealed the bottle and protected from moisture and light. The dry blue paper was placed upon the leaf and covered with microscopic slide and held firmly by a small tweezers. The time required to change the color from blue to violet (red or pink) was recorded. The starting point and ending point of color change were standardized. Transpiration rate was measured from upper and lower surface of the leaf. Measurement time at 1:00-3:00 p.m. The calculation method described by Curtis and Clark (1950) was used.

On the date of termination of the experiment, all plants of each cultivar and treatment were cut off from the base and the fresh and dry weights of vegetative growth were determined.

Results and Discussion

Antitranspirants have been shown to play an important role in regulating plant responses to heat and drought. Antitranspirants reduced transpiration of potato plants (Table 1, 2) by an estimated 50.3, 42.0, and 38.12% by folicote, wilt-pruf and vapor guard treatments respectively using the weighing method. Similar results were obtained by using cobalt paper, but wilt pruf treatment had higher value than folicote treatment. Significant differences among chemical treatments as well as cultivars

TABLE 1. Mean squares for the effect of three antitranspirants on transpiration by weighing method, transpiration by cobalt paper and dry matter of four potato cultivars grown under greenhouse conditions.

Source of variation	df	Transpiration by weighing method	Transpiration by cobalt paper	Dry matter (g)
Treatment (Trt)	3	0.470**	0.0500**	87.63**
Rep	1	0.001	0.0001	5.10
Trt × rep	3	0.016	0.0002	11.10
Cultivars	3	0.223	0.0330	23.96
Trt × cultivars	9	0.040	0.0096	21.11
Rep × cultivars (Trt)	12	0.014	0.0010	7.22

** Statistically significant at 0.01 levels of probability.

TABLE 2. Treatment comparisons of three antitranspirants for the transpiration by weighing method, transpiration by cobalt paper, and dry matter of four potato cultivars grown under greenhouse conditions.

Treatment	Transpiration by weighing method	Transpiration by cobalt paper	Dry matter (g)
1. Vapor guard	2.* 0.381 A	3. 0.243 A	1. 38.19 A
2. Folicote	3. 0.444 A	2. 0.249 A	2. 35.31 BA
3. Wilt-pruf	1. 0.474 A	1. 0.287 B	3. 34.75 BA
4. Check	4. 0.766 B	4. 0.363 C	4. 32.50 B

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Treatment number.

were found (Tables 2 and 3). The greatest reduction in transpiration occurred with chemicals folicote and wilt pruf and the potato cultivar, Norgold. The lowest reduction was in Red Norland while Norchip and Monona were intermediate. The response of the cultivars to the chemical treatments was variable.

TABLE 3. Means for the effect of three antitranspirants on transpiration by weighing method, transpiration by cobalt paper, and dry matter of four potato cultivars grown under greenhouse conditions.

Cultivars	Transpiration by weighing method	Transpiration by cobalt paper	Dry matter (g)
1. Norgold	1.* 0.363 A	1. 0.241 A	4. 36.25 A
2. Monona	4. 0.505 B	4. 0.263 A	2. 36.00 A
3. Red Norland	3. 0.552 B	2. 0.293 B	1. 34.94 BA
4. Norchip	2. 0.645 B	3. 0.346 C	3. 33.56 B

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Variety number.

Antitranspirants increased yield of potato cultivars and tuber size (Table 4). Differences among chemical treatments as well as among potato cultivars were significant (Tables 4 and 5). Chemical treatments and potato cultivars interaction were significant (Table 6) for yield and tuber size. No significant differences among treatments and cultivars for tuber number were found. Similar results were obtained by Davenport and Hagan (1973), and Wendt (1973).

TABLE 4. Treatment comparisons of three antitranspirants for the number of tubers, tuber yield, tuber mean weight, and wilting degrees of four potato cultivars grown under greenhouse conditions.

Treatment	Number of tubers	Tuber yield (kg)	Tuber mean weight (kg)	Wilting degrees
1. Vapor guard	1.*2.360 A	1. 0.626 A	1. 0.279 A	1. 2.138 A
2. Folicote	2. 2.050 B	3. 0.480 B	3. 0.258 BA	3. 2.388 A
3. Wilt-pruf	3. 1.972 B	2. 0.465 B	2. 0.252 B	2. 2.388 A
4. Check	4. 1.916 B	4. 0.343 C	4. 0.180 C	4. 4.111 B

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Treatment number.

TABLE 5. Means for the effect of three antitranspirants on the number of tubers, tuber yield, tuber mean weight, and wilting degrees of four potato cultivars grown under greenhouse conditions.

Cultivars	Number of tubers	Tuber yield (kg)	Tuber mean weight (kg)	Wilting degrees
1. Norgold	4.* 2.972 A	4. 0.677 A	3. 0.255 A	2. 2.31 A
2. Monona	3. 2.055 B	3. 0.503 B	3. 0.253 A	3. 2.75 A
3. Red Norland	2. 1.750 CB	1. 0.371 C	4. 0.232 A	1. 2.97 A
4. Norchip	1. 1.530 C	2. 0.365 C	2. 0.231 A	4. 3.00 A

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Variety number.

TABLE 6. Mean squares for the effect of three antitranspirants on the number of tubers, tuber yield, tuber mean weight, and wilting degrees of four potato cultivars grown under greenhouse conditions.

Source of variation	df	Number of tubers	Tuber yield (kg)	Tuber mean weight (kg)	Wilting degrees
Treatment (Trt)	3	1.410	0.4800**	0.0670**	29.84**
Rep	2	4.690	0.0100	0.0100	6.67
Trt × rep	6	0.074	0.0020	0.0020	2.56
Cultivars	3	14.530**	0.0100	0.0100	3.71
Trt × cultivars	9	1.960	0.0200**	0.0200**	3.27
Rep × cultivars (Trt)	24	1.100	0.0034	0.0034	4.18

** Statistically significant at 0.01 levels of probability.

Lipe and Wendt (1978) obtained an increase in yield by use of antitranspirants and also indicated that there was no response to the antitranspirant achieved on clay loam soils with frequent irrigation (4-5 days). This was expected as stress periods would be unlikely under such conditions.

Number of tubers among cultivars varied significantly (Table 7). This was possibly due to different genotypes. No significant differences among treatment for the number of tubers and tuber yield were found (Table 8) when two applications of antitranspirants were sprayed. But there was a significant difference among treatments for the tuber mean weight. The average tuber weight (gm) was increased by all treatments (Table 8). The greatest increase in average tuber size was with cultivar Norgold and vapor guard treatment (Tables 8 and 9). Yield increases that resulted from treatment with antitranspirants when plants were subjected to heat and drought stress were possibly due to reduction in transpiration more than CO_2 uptake (Kramer 1983). Consequently, photosynthesis per unit of leaf surface will increase and the translocation of carbohydrate into the tubers will increase as well as the dry matter (Table 1). Untreated plants (check treatment) photosynthesis rate will be low due to the drought injury results because of pronounced increases in transpiration rate as temperature increases. There are two reasons may explain this sharp rise: (a) the direct effect of temperature on the diffusion constant of water; and (b) a steepening of the vapor pressure gradient between the leaf and external atmosphere.

Antitranspirants increased the dry matter of all potato cultivars significantly (Tables 1 and 3). Significant differences among cultivars as well as among treatments were found (Tables 2 and 3). The greatest increase in dry matter was found in Norchip with vapor guard treatment. The increase of dry matter by all treatments ranged from 6.5 to 15.9% (Table 8).

The effect of antitranspirants on plant wilting in the heat chamber was pronounced. The average degree of wilting was reduced by 25.1 to 60% (Table 8) with two applications of chemicals. In one application, as an experiment on the average degree of wilting was 42 to 48% (Table 4). Vapor guard was the most effective chemical in both experiments I and II, 42 and 60% respectively, followed by wilt-pruf 42 and 48% and folicote 42 and 25%. Cultivars responded differently for first and second application of chemicals (Tables 5 and 9). Significant differences among treat-

ments were found and no significant differences were found among potato cultivars (Tables 4 and 5).

TABLE 7. Mean squares for the effect of two applications of three antitranspirants on the number of tubers, tuber yield, tuber mean weight, and wilting degrees of four potato cultivars grown under greenhouse conditions.

Source of variation	df	Number of tubers	Tuber yield (kg)	Tuber mean weight (kg)	Wilting degrees
Treatment (Trt)	3	1.52	0.140*	0.0140**	15.88**
Rep	1	0.77	0.030	0.0013	7.56
Trt × rep	3	1.36	0.050	0.0010	0.85
Cultivars	3	4.89**	0.163*	0.0020	3.04
Trt × cultivars	9	0.84	0.053	0.0050*	3.14
Rep × cultivars (Trt)	12	0.62	0.010	0.0030	1.57

*, ** Statistically significant at 0.05 and 0.01 levels of probability, respectively.

TABLE 8. Treatment comparisons with two applications of chemicals for the number of tubers, tuber yield, tuber mean weight, and wilting degrees of four potato cultivars grown under greenhouse conditions.

Treatment	Number of tubers	Tuber yield (kg)	Tuber mean weight (kg)	Wilting degrees
1. Vapor guard	1.* 2.500 A	3. 0.559 A	3. 0.250 A	1. 1.50 A
2. Folicote	2. 2.375 A	2. 0.493 A	2. 0.210 BA	3. 1.94 BA
3. Wilt-pruf	3. 2.375 A	1. 0.472 A	1. 0.202 BA	2. 2.81 BC
4. Check	4. 1.813 A	4. 0.341 A	4. 0.191 B	4. 3.75 C

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Treatment number.

TABLE 9. Means for the effect of two applications of three antitranspirants on the number of tubers, tuber yield, tuber mean weight, and wilting degrees of four potato cultivars grown under greenhouse conditions.

Cultivars	Number of tubers	Tuber yield (kg)	Tuber mean weight (kg)	Wilting degrees
1. Norgold	4.* 2.813 A	3. 0.541 A	3. 0.226 A	2. 2.0625 A
2. Monona	3. 2.440 A	4. 0.531 A	1. 0.220 A	3. 2.1880 A
3. Red Norland	2. 2.313 A	2. 0.471 A	2. 0.215 A	4. 2.8750 A
4. Norchip	1. 1.500 B	1. 0.322 B	4. 0.201 A	1. 2.8750 A

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Variety number.

Plant height was increased (4.7 to 7.2%) by antitranspirants. No significant difference among chemical treatments was found, but there was a significant difference among potato cultivars (Tables 10 and 11). The effect was greatest with Red Norland and Norchip and least with Monona. The effect of antitranspirants on leaf number and leaflet number was insignificant (Table 10). Potato cultivars varied in plant height, number of leaves and number of leaflets. Treatment of cultivars interaction for plant height was insignificant, but treatment by cultivars interaction for number

of leaves and number of leaflets was significant (Table 12). The chemical treatments increased average leaflet size by 1.2 to 5.6% (Table 10). No significant difference among chemical treatment was found but there was a significant difference among cultivars (Tables 10 and 11). Treatment by cultivars interaction for leaflet size was significant (Table 12). In conclusion, these results indicate that potato cultivars vary greatly in their responses to antitranspirant treatments under stress conditions. Yield, dry matter, plant height were generally increased by all treatments. Antitranspirant reduced transpiration of all potato cultivars and reduced wilting degree of plant under stress conditions. The commercial use of antitranspirant in the agroecosystem seems economical, because of increasing yield and reducing water consumption.

TABLE 10. Treatment comparisons of three antitranspirants for plant height, number of leaves, number of leaflets, and leaflet area of four potato cultivars grown under greenhouse conditions.

Treatment	Plant height (cm)	Number of leaves	Number of leaflets	Leaflet area (cm^2)
1. Vapor guard	1.* 85.69 A	3. 16.55 A	4. 8.22 A	1. 16.49 A
2. Folicote	2. 84.81 A	1. 16.44 A	3. 8.11 A	3. 16.32 A
3. Wilt pruf	3. 83.50 A	2. 15.97 A	1. 8.05 A	2. 15.75 A
4. Check	4. 79.55 A	4. 15.86 A	2. 7.94 A	4. 15.56 A

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Treatment number.

TABLE 11. Means for the effect of three antitranspirants on plant height, number of leaves, number of leaflets, and leaflet area of four potato cultivars grown under greenhouse conditions.

Cultivars	Plant height (cm)	Number of leaves	Number of leaflets	Leaflet area (cm^2)
1. Norgold	3.* 88.11 A	4. 16.86 A	1. 8.83 A	3. 18.5 A
2. Monona	4. 85.25 BA	3. 16.86 A	3. 8.55 A	4. 13.3 B
3. Red Norland	1. 82.44 B	1. 16.11 A	4. 8.38 A	1. 12.83 B
4. Norchip	2. 77.75 C	2. 15.00 B	2. 6.55 B	2. 12.09 B

Means within columns followed by the same letter are not significantly different at 0.05 (Duncan's Multiple Range test).

* Cultivar number.

TABLE 12. Mean squares for the effect of three antitranspirants on plant height, number of leaves, number of leaflets and leaflet area of four potato cultivars grown under greenhouse conditions.

Source of variation	df	Plant height (cm)	Number of leaves	Number of leaflets	Leaflet area (cm^2)
Treatment (Trt)	3	264.35	4.230	0.48	7.19
Rep	2	50.19	2.146	0.33	37.70
Trt × rep	6	184.13	5.520	0.26	20.65
Cultivars	3	701.43**	27.860	38.60**	268.31**
Trt × cultivars	9	90.54	6.040*	3.57**	63.10**
Rep × cultivars (Trt)	24	45.48	3.490**	0.76	15.26**

*, ** Statistically significant at 0.05 and 0.01 levels of probability, respectively.

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تأثـير ثلاث من مقـللات النتح على المحصـول وكميـة النتح لأصناف البطاطس

صالح حسين بياري
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المستخلص . تحت ظروف البيوت المحمية مقللات النتح ولت بروف wilt pruf وفولي كوت folicote وفيبرقـارد vapor guard خفضت نسبة النتح من نباتات البطاطس تحت الدراسة بحوالي ٣٨-٥٠٪ . ولقد وجدت فروق معنوية بين المعاملات الكيميائية وكذلك بين أصناف البطاطس لنسبة النتح .

المعاملات الكيميائية زادت كمية المحصول والوزن الجاف وأطوال النباتات . وكانت استجـابـة النباتات لهذه المعاملات متباينة . وكانت هناك فروق معنوية بين الكيماويات وكذلك بين استجابة أصناف البطاطس للمحصول والوزن الجاف ، ولم يكن هناك فروق معنوية بالنسبة لأطوال النباتات واستخدام الكيماويات ولكن الفروق المعنوية كانت بين الأصناف .

ولقـد كان تأثـير الكيماويات على عدد الأوراق والـوريقـات ومسـاحـة الوريقات غير معنوي . كما أدى استخدام مقللات النتح إلى تقليل درجة ذبول النباتات .

وتبين من التجارب أنه لايوجد أي عائد اقتصادي من إضافة المواد الكيميائية مرتين بدلاً من مرة واحدة .