The Effects of Vapor Gard on some Physiological Traits of Durum Wheat and Barley Leaves under Water Stress

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Summary

The use of antitranspirants is one method of mitigating water while increasing the yield of cereal crops. Experiments were carried out on a durum wheat (*Triticum durum* L.) variety (Karim) and a barley (*Hordeum vulgare* L.) variety (Rihane) to study the effects of Vapor Gard (VG; di-1-p-menthene), an antitranspirant, on two physiological traits at two different growth stages. The study was conducted in a glasshouse under water stress and VG was sprayed twice at three concentrations (5, 7, and 10%) at tillering and stem elongation stages. VG spray reduced the effect of water stress on durum wheat and barley varieties. Leaf water potential (LWP) was significantly increased, albeit at different rates, for the two cereal species. However, no significant change was observed for photosynthetic rate (PR). These results favor the use of VG although more studies are recommended on other physiological traits to strongly support the application of this antitranspirant.

Key words

antitranspirant, barley, durum wheat, plant physiology, Vapor Gard

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Introduction

Most of the global food supply, which is derived from cereal crops in rainfed agriculture, is highly vulnerable to drought. Grain yield loss from drought can be ascertained by comparing rainfed and irrigated yields; in developing countries rainfed cereal yield is less than half the yield of irrigated cereals (Hazell and Wood, 2008).

The ability to improve crop water productivity (i.e., yield per unit of water used) will be an important component of the response to future global pressures on food supply, such as population growth and climate change. Drought stress is currently one of the major problems in agriculture at a global scale (Hasanuzzaman et al., 2012). Because of the shortage of rainfall and availability of water sources, many new methods to enhance plant tolerance to drought stress, such as metabolomics, have been suggested (Ruan and Teixeira da Silva, 2011). The application of antitranspirants is another method of mitigating water and salinity stress while increasing the yield of cereal crops, such as wheat (Nasraoui, 1993; Shaffer and White, 1985). As most water absorbed by plants is lost through transpiration, reducing plant transpiration could conserve irrigation water and minimize plant stress. The use of antitranspirants, therefore, may be important to reduce water loss. Polymers are less permeable to CO_2 than to water, and films that close stomata also inhibit photosynthesis as much as transpiration. Research on the use of antitranspirants is quite limited (Plaut et al., 2004). Typically, an antitranspirant film mechanically reduces stomatal and cuticle transpiration (i.e., water loss) as well as gaseous exchange (Osswald et al., 1984), although such a reduction in photosynthetic activity and transpiration is generally perceived to be accompanied by lower yield (Carbonnier et al., 1986). It is also impossible to reduce evapotranspiration without influencing gaseous exchange. Thus, the relationship between water and CO_2 rate could determine the efficacy and applicability of such an antitranspirant film.

Vapor Gard (VG; di-1-*p*-menthene) is a water-emulsifiable organic compound for use on plants to reduce water transpiration. This antitranspirant reduces plant transpiration and also improves the color of mango fruit and some of its biochemical features, such as polygalacturonase activity (Lazan et al., 1990). To offer a theoretical basis for the development and application of thin-film plant antitranspirants in China, the main components in VG made in the USA were analyzed by gas chromatography, infrared spectra and other fine-scale analytical techniques (Bi et al., 2008). Their analyses indicated that VG contained water-soluble mineral oil, a terpene resin, Span-60, Tween-60 and OP-10 and that no metal elements, halogens, nitrogen elements or ions could be detected, making it a safe and eco-friendly antitranspirant for use on horticultural and field crops. When VG at 2% was used as an antitranspirant on *Fraxinus americana* and *Malus domestica* ('Golden Delicious') in a glasshouse, apple scab (*Venturia inaequalis* (Cooke) G. Wint.) was effectively controlled (Shaffer and White, 1985). When VG was mixed with folicote (an antitranspirant) at 2% and sprayed onto *Solanum tuberosum* plants in the field, the number of tubers and yield increased relative to treatments aimed at increasing soil moisture (Lipe and Thomas, 1990). Treatment of bread wheat (*Triticum aestivum* L. 'Sakha 93' and 'Giza 168') with a reflectant increased water status, chlorophyll content, biological yield and harvest index, whereas water potential and transpiration rate decreased (El-Kholy and Gaballah, 2005). A 1% solution of VG significantly improved several photosynthetic parameters of various genotypes of *Actinidia arguta* plants even though visually plants did not appear to be significantly different (Latocha et al., 2009). The application of VG decreased the evaporation of mulberry (*Morus alba* L.) plants (Misra et al., 2009) and *Phaseolus vulgaris* plants, observed through thermal imaging (Ludwig et al., 2010). Another antitranspirant (WE-426A03), when diluted with distilled water in a ratio of 1:30, was successfully used to prolong the vase life of *Rosa hybrida* (Song et al., 2011). Compared with the control, spraying antitranspirant alone could reduce the degree of fresh weight loss, delay flower opening, slow down the rate of stomatal conductance, decrease water loss during transpiration, maintain the integrity of cell membranes, and reduce the accumulation of malondialdehyde in *Phaseolus vulgaris* ('Pinto') plants (Francini et al., 2011). The application of VG at 1 and 2% on barley (*Hordeum vulgare* L.) and apple (*Malus* x *domestica*) plants, respectively increased the chlorophyll content in leaves at the beginning of experiments and enhanced the efficiency of the photosynthetic apparatus during almost the entire experimental period (Sutherland and Walters, 2002; Percival and Boyle, 2009). Since VG has never been tested on durum wheat or only once in barley with the objective of reducing the incidence of disease, the aim of this study was to determine the effect of its application on two cereals, *Tritium durum* (var. 'Karim') and *Hordeum vulgare* (var. 'Rihane'), by measuring the physiological response as leaf water potential and photosynthetic rate under water stress conditions.

Materials and methods

Experimental conditions

Experiments were carried out in a glasshouse with an additional 4 h supplementing natural daylight (natural light supported by artificial light using Powerstar Osram lamps; 150 W, 3000 lux). Temperature was 25 and 16°C during the day and night, respectively. Durum wheat and barley seeds were sown in a 0.5-L pot, containing a 2:1 mixture of loamy soil substrate amended with pure sand, at a rate of five certified seeds/pot, and at a spacing of 2 cm. Seeds were watered every 48 h at maximum field capacity (FC) for one week.

All leaves of plants were sprayed with VG at the tillering (Z 30; Z=Zadok) and stem elongation stages (Z 37). A total of 24 plants in each block were sprayed using a hand pump in the morning and each plant received between 5 and 10 ml of VG. Liquid VG solution consisted of resin (96% di-1-*p*-menthene + 4% emulsifier) that was applied at three concentrations [5, 7, 10%, v/v] at 100, 75, 50 and 25% of soil FC. The solvent was water.

Experimental design

Separate experiments were established for durum wheat and barley. The experimental design was a split-plot with two factors (water regime=main factor, VG concentration=sub-factor) and four replications. Control plants were sprayed with tap water. Every two days, pots were weighed to restore the soil moisture for each level of FC. For all treatments, plant weight was not included.

Measurements

At the tillering and stem elongation stages, and two weeks after VG had been sprayed on experimental units, leaf water potential (LWP) was measured with a room pressure gauge (Scholander Room) between 12.00 AM (i.e., noon) and 14.00 PM. Photosynthetic rate (PR) and gas exchange were measured with a portable photosynthesis system (LICOR 1600 LCA 4 portable photosynthesis system; Licor Inc., Lincoln, NE, USA). All measurements were made using fully expanded young leaves.

Data analysis

All data were subjected to an analysis of variance using SAS package (SAS Institute Inc., 1985). To test for significance between treatments, means were separated using the least significant difference (LSD) test at the 5% level of probability.

Results

Tillering stage

Leaf water potential

Generally, water deficit induced a decrease in LWP. However, at 25% FC, VG spray increased LWP of wheat significantly compared with the control, regardless of the VG concentration. For barley, a significant difference in LWP was noted after VG spray at 25% FC. At 7% and 10% VG, LWP was least affected by water stress (Fig. 1). The best LWP was obtained at 50% FC with 7% VG. In the same FC, plants sprayed with antitranspirants had a better LWP than control plants but the 10% VG treatment had a negative effect on the LWP of plants at 100 and 75% FC.

Photosynthetic rate

Generally, no significant differences were found in the PR of wheat and barley following VG spray compared with the control. However, for wheat, VG spray improved PR over controls, but only at 100% FC (for all VG concentration) and 25% FC when sprayed with 5 and 7% of VG (Fig. 2). At 75 and 100% FC, only a slight decrease in PR was observed for leaves sprayed with 5, 7 and 10% VG.

Stem elongation stage

Leaf water potential

A significant increase in the LWP of wheat was observed after a VG spray (all three concentrations) at 25% FC compared to the control. For barley, VG spray improved LWP compared with the control, regardless of its concentration, except for 100% FC treatment (Fig. 3). LWP was not affected by VG sprays at 75% FC. A gain in water content was observed for plants treated with 7% and 10% VG. Compared to plants of 75% FC, the leaves of those at 25% FC and sprayed with VG at 5% and 7%, had the same LWP.

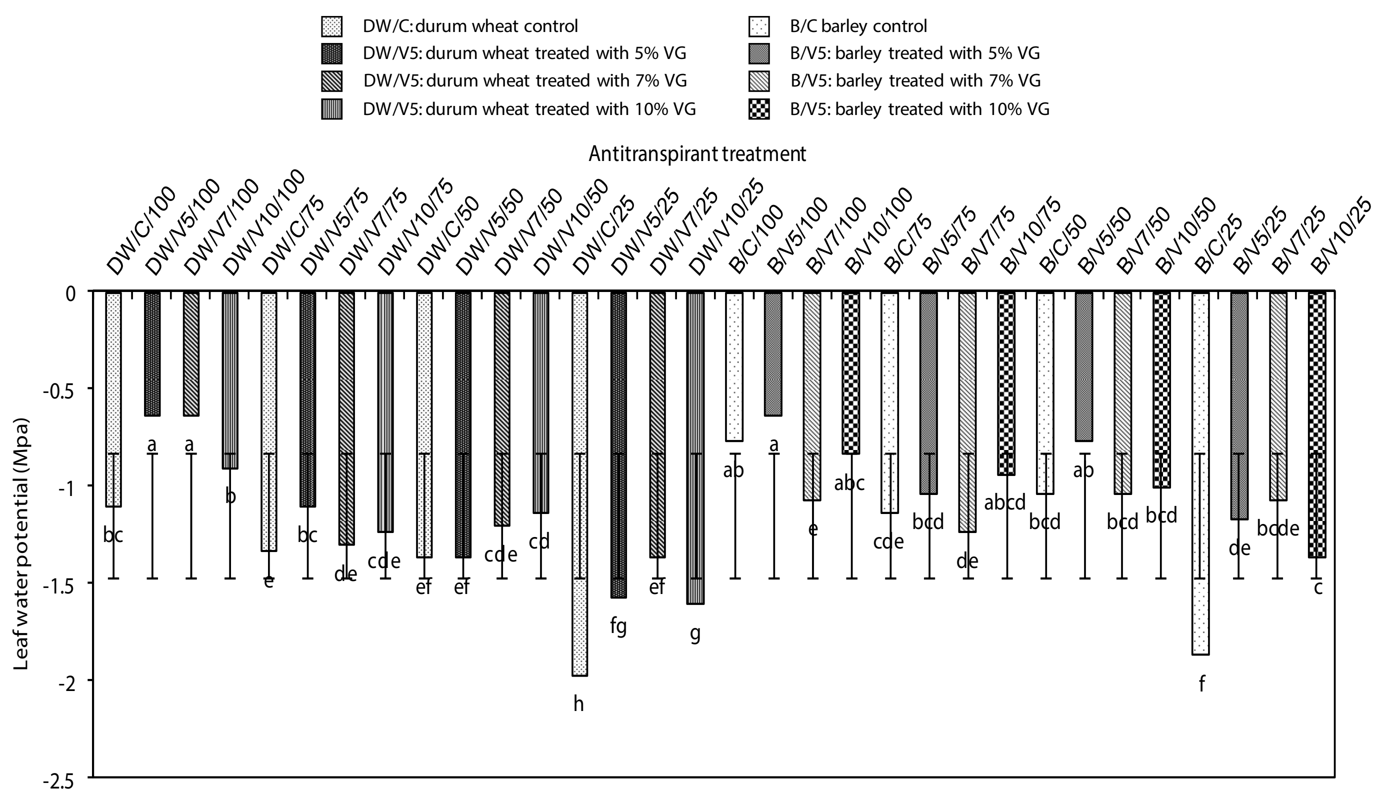

Figure 1. Effects of antitranspirant foliar treatment with Vapor Gard on the leaf water potential (LWP) of durum wheat ($LSD_{5\%}$=0.28) and barley ($LSD_{5\%}$=0.41), at the tillering stage under four water regimes: 25, 50, 75, 100% of field capacity in a glasshouse. B=barley; C=control; DW=durum wheat; V=Vapor Gard at 5%, 7% or 10% (V5, V7, V10).

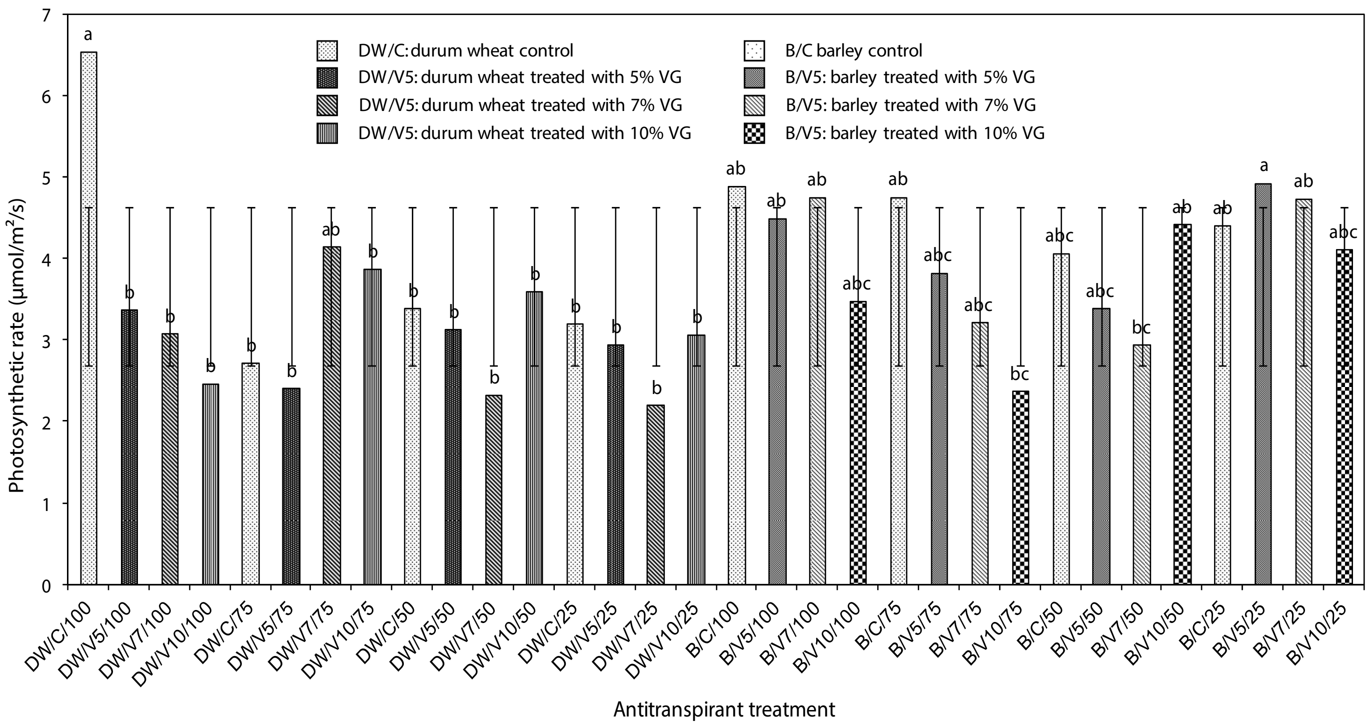

Figure 2. Effect of antitranspirant foliar treatments with Vapor Gard on the photosynthetic rate (PR) of durum wheat ($LSD_{5\%}$=3.28) and barley ($LSD_{5\%}$=1.28) at the tillering stage under four water regimes: 25, 50, 75, 100% of field capacity in a glasshouse. B=barley; C=control; DW=durum wheat; V=Vapor Gard at 5%, 7% or 10% (V5, V7, V10).

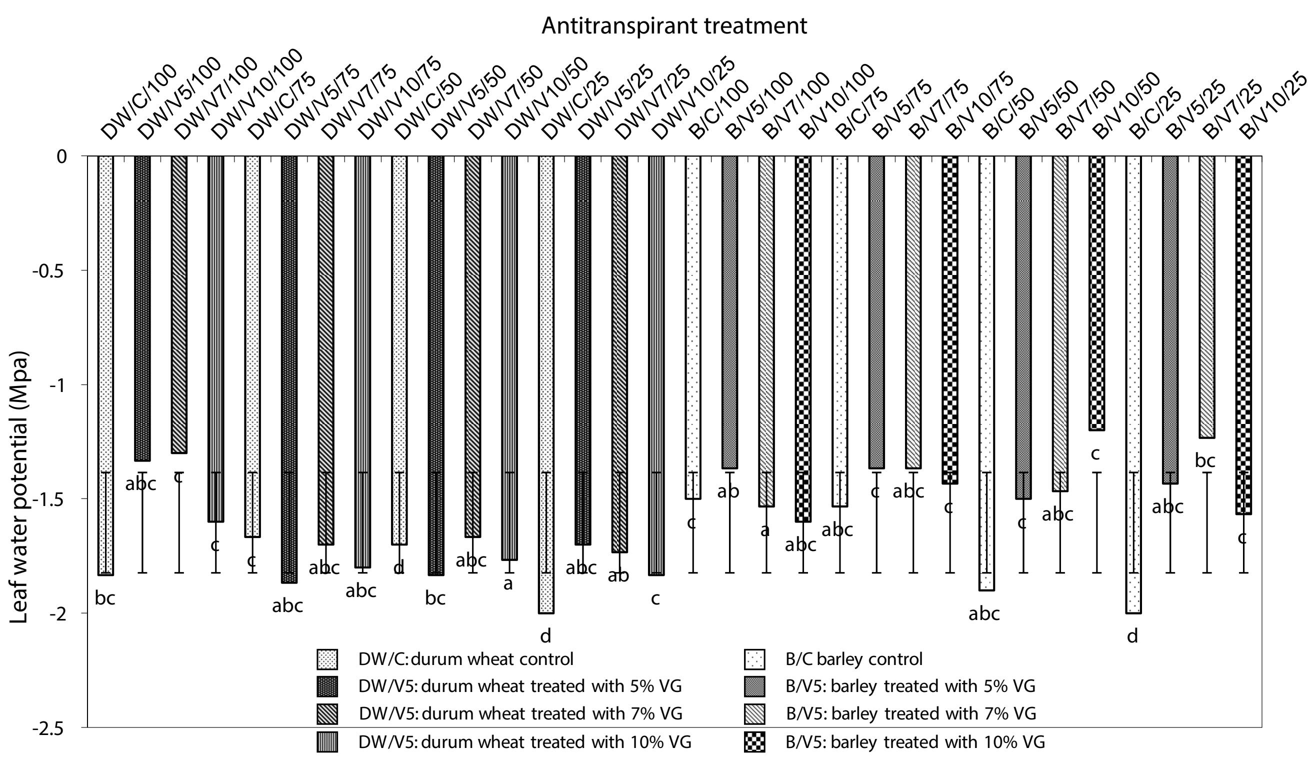

Figure 3. Effects of antitranspirant foliar treatments with Vapor Gard on the leaf water potential (LWP) of durum wheat ($LSD_{5\%}$=0.22) and barley ($LSD_{5\%}$=0.30), at the stem elongation stage under 4 water regimes: 25, 50, 75, 100% of field capacity in a glasshouse. B=barley; C=control; DW=durum wheat; V=Vapor Gard at 5%, 7% or 10% (V5, V7, V10).

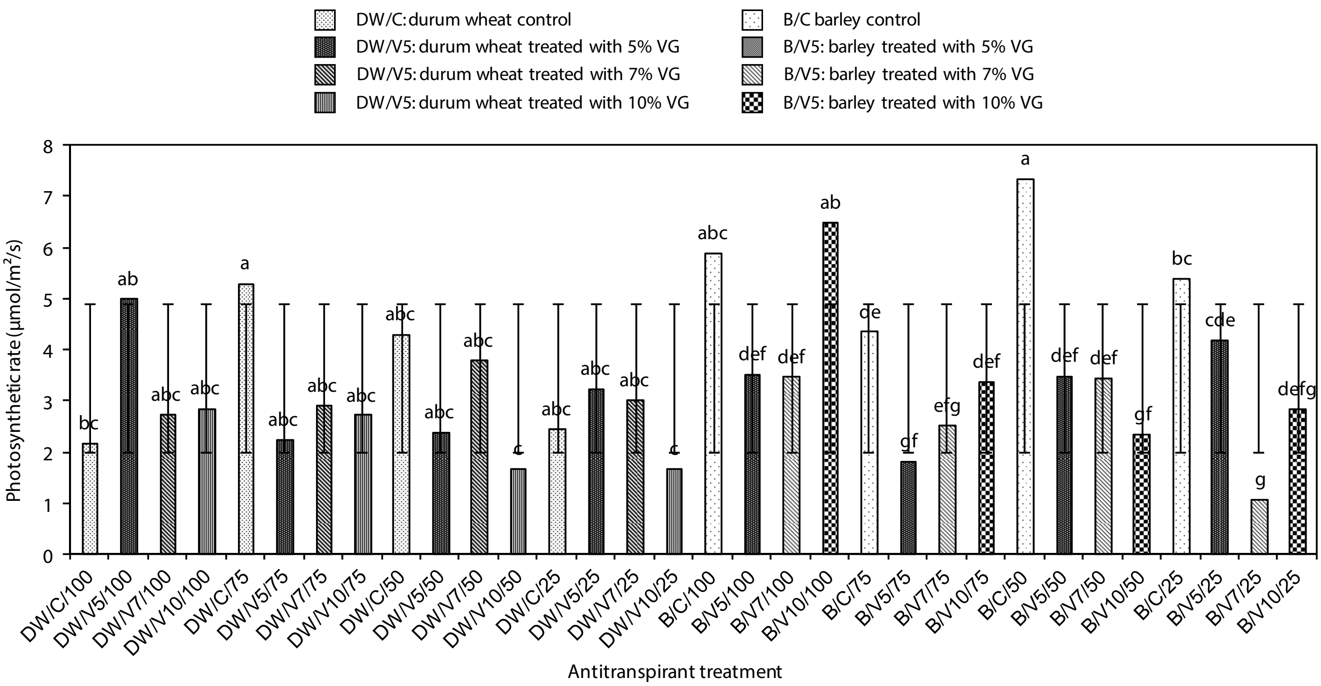

Figure 4. Effect of antitranspirant foliar treatments with Vapor Gard on the photosynthetic rate (PR) of durum wheat ($LSD_{5\%}$=2.53) and barley ($LSD_{5\%}$=1.70), at the tillering stage under four water regimes: 25, 50, 75, 100% of field capacity in a glasshouse. B=barley; C=control; DW=durum wheat; V=Vapor Gard at 5%, 7% or 10% (V5, V7, V10).

Photosynthetic rate

In durum wheat, a reduction in FC from 75% to 25% significantly reduced PR. VG spray did not alleviate the effect of water stress on PR. The PR of barley was higher than that of durum wheat in all equivalent treatments. As for durum wheat, VG was unable to alleviate the negative impacts of reduced FC on PR, independent of the level of FC and the concentration of VG applied (Fig. 4).

Discussion

Antitranspirants are commonly used to reduce leaf water loss. They increased the relative water content of *Morus alba* leaves at different irrigation levels (Misra et al. 2009). The efficacy of antitranspirant films (a few days – a few weeks) depends on economic parameters and also on the number of new leaves formed after treatments. Generally, antitranspirants can be efficient up to one month (Plaut et al., 2004). They may allow a reduction in water transpiration without greatly affecting photosynthetic activity (Glenn et al., 2001). In addition to the beneficial effect of elevated CO_2 concentration on drought stress, antitranspirants can significantly improve drought tolerance (Del Amor et al., 2010).

Under water stress conditions, the use of Triadimefon as an antitranspirant mixed with a fungicide on *Phaseolus vulgaris* reduced water loss from leaves without decreasing photosynthetic activity or stomatal regulation (Mokhtari et al., 2006). Another study dealing with Triadimefon spray showed a decrease in transpiration, allowing bean plants to withstand drought. Leaf diffusive resistance increased, indicating partial stomatal closure, and treated plants maintained water potential while control leaves did not. Chlorophyll and carotenoid contents increased in the treated leaves. However, there was no effect on protein synthesis (Asare-Boamah et al., 1986). When *Solanum melongena* plants were treated with three antitranspirants (cycocel, limewash, potassium chloride) and water stressed at three growth stages, a decrease in chlorophyll content, soluble protein and PR occurred (Prakash and Ramachandran, 2000). *Zinnia elegans* plants sprayed with Cloud Cover showed a significant difference in growth, fresh weight and longevity in the flowering period and in the control of powdery mildew (Kamp, 1985).

Other results related to yield physiology of wheat indicated that, irrespective of reduced assimilate availability from photosynthesis, the most drought-sensitive stage of grain formation may respond positively to antitranspirant application. Field experiments over three years, in which di-1-*p*-menthene (i.e., VG) was sprayed at five growth stages and 10 soil moisture deficits levels, showed a reduction in grain yield of wheat when the antitranspirant was applied between inflorescence and anthesis. However, grain yield increased when the antitranspirant was applied at the flag leaf stage, which is generally highly sensitive (Kettlewell et al., 2010). Moreover, antitranspirants are usually biodegradable, cost-efficient and stable at high temperature, humidity and light intensity. Studies on the effect of folicote showed an improvement of vegetative growth, fruit yield and fruit quality of *Ficus carica* (Al-Desouki et al., 2009).

Antitranspirant treatments significantly decreased leaf weight which might be reflected by a decrease in transpiration rate (Shanan and Shalaby, 2011). This effect was associated with improved plant water relations, increased cell membrane stability, reduced leaf abscission, and a transient reduction in plant growth rates (Goreta et al., 2007).

In an experiment with several species, an antitranspirant (pinolene) spray affected yield as well as the rate of CO_2 emission. The antitranspirant did not affect dry weight accumulation in the leaves, stems, roots, total plant leaf area, and leaf dry weight percentage. Even though CO_2 assimilation was not impaired by the antitranspirant, water uptake was significantly reduced, regardless of the nutrient growth solution used (Del Amore and Rubio, 2009). The leaves of sesame plants appeared to express a defense mechanism, especially at 25% FC, if sprayed by kaolin, $CaCO_3$ and paraffin (Gaballah et al., 2007). Consequently, VG efficiency was observed immediately after application and the effect of water stress was reduced, as shown by Mokhtari et al. (2006), due partially at least to the relative stability of the photosynthetic rate of durum wheat and barley. Spray interval seems to play a major role (Glenn et al., 2001). Three antitranspirants, including VG, were unable to mitigate drought stress in artichoke (Shinohara and Leskovar, 2014). VG delayed grape ripening and reduce sugar accumulation in the berries of *Vitis vinifera* L. (Palliotti et al., 2013). The use of kaolin, an antitranspirant, on olive trees, increased chlorophyll content, changed the fatty acid composition and improved the oxidative stability of the essential oil (Khaleghi et al., 2015).

In addition to these positive water stress-mitigating benefits, the leaf surface-protecting property of sufactants may aid in protection against diseases (Walters, 2009).

Conclusions

This study was carried out to investigate the effect of VG spray on leaf water potential and photosynthetic rate of durum wheat and barley under water stress. Results showed that, overall, VG spray increased LWP of durum wheat and barley without any significant change in the PR compared to controls, but only under select treatments. This improvement of LWP in durum wheat and barley may be attributed to better water status of plants, possibly by means of a reduction in transpiration. In this study, water deficit was reduced by VG spray, but only for a short period of time, and more investigations are needed to evaluate the relationship between the number of sprays and the duration of the antitranspirant film at the leaf surface. More studies should be carried out on other physiological traits to implement the use of an antitranspirant such as VG to alleviate water deficit effect on cereal yield, especially under rain-fed conditions in a semi-arid climate.

References

AL-DESOUKI, M.I., I.E. ABD EL-RAHMAN, AND SAHAR A.F. (2009) Effect of some antitranspirants and supplementary irrigation on growth, yield and fruit quality of Sultani fig (*Ficus carica*) grown in the Egyptian western coastal zone under rain fed conditions. Res J Agric Biol Sci 5: 899-908

ASARE-BOAMAH, N.K., G. HOFSTRA, R.A. FLETCHER AND DUMBROFF E.B. (1986) Triadimefon protects bean plants from water stress through its effects on abscisic acid. *Plant Cell Physiol.* 27:383-390.

BI, H-T., J-D. LI, Y-X. WU, J-C. FENG, AND ZHANG, Z-Y. (2008) Component analysis of thin film plant antitranspirant Vapor Gard. *Nonwood For. Res. 04* (in Chinese with English abstract)

CARBONNIER, J., E. ATCHO, AND JOSSANG P., 1986. Antitranspirants végétaux et régulateurs stomatiques: objets et limites. 75-111. In: Recherches et applications dans le domaine des antitranspirants stomatiques (J. Carbonnier, D. Laffray et ACTT, eds.) France.

DEL AMORE, F.M. AND RUBIO J.S. (2009) Effects of antitranspirant spray and potassium: calcium: magnesium ratio on photosynthesis, nutrient and water uptake, growth, and yield of sweet pepper. *J. Plant Nutr.* 32: 97-111.

DEL AMOR, F.M., P. CUADRA-CRESPO, D.J. WALKER, J.M. CÁMARA, AND MADRID R. (2010) Effect of foliar application of antitranspirant on photosynthesis and water relations of pepper plants under different levels of CO_2 and water stress. *J. Plant Physiol.* 167: 1232-1238.

EL-KHOLY, M.A. AND GABALLAH M.S. (2005) Productivity of wheat cultivars as affected by seeding methods and reflectant application under water stress condition. *J. Agron.* 4: 23-30.

FRANCINI, A., G. LORENZI, AND NALI C. (2011) The antitranspirant di-1-*p*-menthene, a potential chemical protectant of ozone damage to plants. *Water, Air, Soil Poll.*219: 459-472.

GABALLAH, M.S., B. ABOU LEILA, H.A. EL-ZEINY, AND KHALIL S. (2007) Estimating the performance of salt-stressed sesame plant treated with antitranspirants. *J. Appl. Sci. Res.* 9: 811-817.

GLENN, D.M., T. VAN DER ZWET, G. PUTERKA, P. GUNDRUM, AND BROWN E. (2001) Efficacy of kaolin-based particle films to control apple diseases. Online. Plant Health Progress doi:10.1094/PHP-2001-0823-01-RS. http://www.plantmanagementnetwork.org.

GORETA, S., D.I. LESKOVAR AND JIFON J.L. (2007) Gas exchange, water status, and growth of pepper seedlings exposed to transient water deficit stress are differentially altered by antitranspirants. *J. Amer. Soc. Hortic. Sci.* 132: 603-610.

HASANUZZAMAN, M., M.A. HOSSAIN, J.A. TEIXEIRA DA SILVA, AND FUJITA M. (2012) Plant response and tolerance to abiotic oxidative stress: antioxidant defense is a key factor. In: *Crop Stress and its Management: Perspectives and Strategies*. Bandi, V., A.K. Shanker, C. Shanker, and M. Mandapaka, (Eds.). Springer, The Netherlands. Chapter 8: 261-315.

HAZELL, P. AND WOOD S. (2008) Drivers of change in global agriculture. *Philos. Trans R. Soc. B.* 363: 495-515.

KAMP, M. (1985) Control of *Erysiphe cichoracearum* on *Zinnia elegans*, with a polymer- based antitranspirant. *HortScience* 20: 879-881.

KETTLEWELL, P.S., HEATH W.L., AND HAIGH I.M. (2010) Yield enhancement of droughted wheat by film antitranspirant application: rationale and evidence. *Agri. Sci.* 1: 143-147

KHALEGHI, E., ARZANI, K., MOALLEMI, N., BARZEGAR M. (2015) The efficacy of kaolin particle film on oil quality indices of olive trees (*Olea europaea* L.) cv 'Zard' grown under warm and semi-arid region of Iran. *Food Chem.* 166: 35-41

LATOCHA, P., M. CIECHCINSKA, S.P. PIETKIEWICZ, AND KALAJ M.H. (2009) Preliminary assessment of antitranspirant Vapor Gard influence on *Actinidia arguta* growing under drought stress conditions. *Ann. Warsaw Univ. Life Sc-. – SGGW, Horticult. Landsc. Architect.* 30: 149-159

LAZAN, H., Z.M. ALI, AND SANI H.A. (1990) Effects of Vapor Gard on polygalacturonase, malic enzyme and ripening of *Harumanis* mango. *Acta Hortic.* 269: 359-366.

LIPE, N.W, AND THOMAS G.D. (1990) Effect of antitranspirants on yield of Norgold Russel potatoes under greenhouse and field conditions. *Amer. J. Potato Res.* 67: 267-273.

LUDWIG, N., R. CABRINI, D.F. FAORO, M. GARGANO, S. GOMARASCA, D.M. IRITI, V. PICCHI, AND SOAVE C. (2010) Reduction of evaporative flux in bean leaves due to chitosan treatment assessed by infrared thermography. *Infrared Physics Technol.* 53: 65-70.

MISRA, A.K., B.K. DAS, J.K. DATTA, AND DE G.C. (2009) Effect of antitranspirants on water status and growth pattern of mulberry (*Morus alba* L.) under two levels of irrigation. *Indian J. Agri. Res.* 43: 144-147.

MOKHTARI, F., K. ELBADAOUI, AND PAUL R. (2006) Association between productivity, water use efficiency and gas exchange in a water-limited environment. *J. Food, Agriculture Environ.* 4: 288-294.

NASRAOUI, B. (1993) Role of antitranspirant films in protecting plants against fungal diseases. Annals de l'Institut National de la Recherche Agronomique de Tunisie. 66: 125-135.

OSSWALD, W., M. NIEHUSS, W. HUBER, AND ELSTNER E.F. (1984) Support of non-host resistance by artificial leaf coating. *J. Plant Dis. Prot.* 91: 338-344.

PALLIOTTI, A., F. PANARA, F. FAMIANI, P. SABBATINI, G. S. HOWELL, O. SILVESTRONI, AND PONI, S. (2013) Postveraison application of antitranspirant di-1-*p*-menthene to control sugar accumulation in Sangiovese grapevines. *Amer. J. Enology Viticulture* 64: 378-385

PERCIVAL, G.C. AND BOYLE S. (2009) Evaluation of film forming polymers to control apple scab (*Venturia inaequalis* (Cooke) G. Wint.) under laboratory and field conditions. *Crop Prot.* 28, 30-35.

PLAUT, Z., Y. MAGRIL, AND KEDEM U. (2004) A new film forming material which reduces water vapour conductance more than CO_2 fixation in several horticultural crops. *J. Hortic. Sci. Biotech.* 4: 528-532.

PRAKASH, M., AND RAMACHANDRAN K. (2000) Effects of moisture stress and anti-transpirants on leaf chlorophyll. *J. Agron. Crop Sci.* 184:153-156.

RUAN, C-J. AND TEIXEIRA DA SILVA J.A. (2011) Metabolomics: Creating new potentials for unraveling mechanisms in response to salt and drought stress and for biotechnological improvement of xero-halophytes. *Crit. Rev. Biotech.* 31: 152-168.

SAS INSTITUTE INC. (1985) SAS/STAT User's guide. 6. Edition. Cary, NC, SAS institute Inc. USA.

SHAFFER, W.H. AND J.A. WHITE. (1985) Polymer films: a new approach of controlling apple scab, in greenhouse studies. *Phythopathology* 75: 966.

SHANAN, N.T. AND SHALABY E.A. (2011) Influence of some chemical compounds as antitranspirant agents on vase life of *Monstera deliciosa* leaves. *African J. Agric. Res.* 6: 132-139.

SHINOHARA, T., LESKOVAR, D.I. (2014) Effects of ABA, antitranspirants, heat and drought stress on plant growth, physiology and water status of artichoke transplants. *Sci. Hortic.* 165: 225-234

SONG, X., W-S. WANG, C. ZHANG, M. QIANG, AND LI Y-F. (2011) Postharvest physiochemical responses of cut rose (*Rosa hybrida* L.) to antitranspirant and vacuum cooling. Philippine Agric. Scientist 94: 368-374

SUTHERLAND, F. AND WALTERS D.R. (2002) Effect of film-forming polymers on infection of barley with the powdery mildew fungus *Blumeria graminis* f. sp. Hordei. *Eur. J. Plant Pathol.* 108: 385-389.

WALTERS, D. (2009) Control of plant disease by disguising the leaf surface. In: Walters, D. (Ed.) *Disease Control in Crops: Biological and Environmentally Friendly Approaches*. Blackwell Publishing Ltd., UK, pp. 237-245

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