328

The Effect of Non-Ionic Surfactants on Water Use and Plant Growth of *Chrysanthemum* x *morifolium* Ramat. 'Florida Marble'

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TABLE OF CONTENTS

LIST OF TABLES

LITERATURE REVIEW

A wetting agent is a compound that aids the adsorption of water or other liquids to the surface of solid materials. Since these compounds are 'surface active' they areoften called surfactants, a shortened version of surface-active agent. Surfactants, or wetting agents, are of four types; anionic, cationic, non-ionic, and ampholytic, according to the nature of their electrical charge. Due to the lack of ionization and probable inertness, non-ionic wetting agents are utilized for plant production (23).

Non-ionic wetting agents may vary considerably due to the presence of polymerized ethylene oxide groups, polyhydric alcohols, esters of polyhydric alcohols, polyether alcohols, or combinations thereof (25). Although the exact makeup of wetting agents if often unknown (or secret), one well-known brand, Aqua Gro, is 50% polyoxyethlene esther and 50% polyoxyethlene ether (21). Depending on their planned use, wetting agents are varied in composition - some of the components are more toxic to plants, others work better on clay soils, while others perform best on organic soils (9, 19, 25, 26).

EFFECTS AND ACTION IN SOIL

Although the exact mode of action is unknown, it is hypothesized that non-ionic wetting agents make water-repellent soil more wettable in the following manner: the wetting agent molecule is composed of two groups, one hydrophobic (repelling water) and the other hydrophilic (attracting water); the hydrophobic end of the molecule is adsorbed by the soil leaving the hydrophilic end exposed for water adsorption (25, 31). Wetting agents also have an effect on the water by reducing the surface tension (1, 9, 17). This can occur at very low wetting agent concentration while further additions may not lower surface tension more than the initial application (9, 22). The decrease in surface tension lowers the contact angle at the solid-liquid interface and enables water to 'spread' further and be held less tightly to soil particles (8, 29).

It has been suggested that the adsorption of a wetting agent is proportional to the surface area of the soil. Valoras et al (31) demonstrated that wetting agents have more of an effect in clay soils than sands. The application of wetting agents to peat conditioners for plant production has shown favorable results, particularly as an aid to rewetting. Wetting agents have proved more effective when applied to peat as compared to mineral soil materials (5, 12, 13, 18, 31).

In many studies wetting agents have been applied to two soil types, one hydrophobic and one hydrophilic. In most cases wetting agents are found to have no effect or a slight detrimental effect on soil structure in hydrophilic soils (15, 20, 21, 27). The detrimental effect on soil structure is due to destabilization of aggregates, which decreases hydraulic conductivity by blocking pores. However, wetting agents may improve aggregate stability in the long run and have been shown to decrease crust strength (9, 14, 15, 20). On hydrophobic soils wetting agents increase penetrability, diffusivity, infiltration, and percolation, while aggregate stability decreases (9, 19, 21, 27).

All wetting agents do not move through the soil at the same rate or depth due to differences in adsorption ability; this can be very important for avoiding phytotoxicity. Aqua Gro has been found to be highly adsorptive and resistant to leaching (14, 22, 31). In addition to soil type, soil moisture at application and concentration of the wetting agent are factors influencing the effectiveness of wetting agents (22).

Non-ionic wetting agents have been shown to retard evaporation by lowering the surface tension of water and causing a decline in capillary action. However, the effectiveness is highly dependent on soil type and texture (8, 16, 19, 24). Due to some of the benefits already discussed. wetting agents have been recommended as a means of reducing erosion and reducing water use for plant production (1, 18, 19, 23, 24).

EFFECT ON PLANTS

In general wetting agents have a detrimental effect on the growth of microorganisms and have been used for disease control in plants; the reduction of powdery mildew and pythiaceous disease has been shown (6, 7, 29).

The effects of wetting agents on higher plants are more variable. The a-thors of a study on the propagation of range plants stated that wetting agents are basically phytotoxic but can improve shoot emergence when applied to water repellent soils (17). Burridge (2) observed reduced seed germination and radicle growth, while Osborn et.al. (23) reported enhanced seed germination. Non-ionic wetting agents were found to have either a detrimental effect or no effect on rooting of cuttings (2).

Because of the variability of the wetting agents, their phytotoxicity differ, which may explain the mixed propagation results. Application method also affects results. When wetting agents are tested in solution culture phytotoxicity is often observed; however when applied to soils, the results are more varied with plant toxicity depending on soil type and concentration of the wetting agent. Wetting agents have been shown to increase root penetrability and development of some plant organs. More often, wetting agents lead to decreased root and overall plant growth, and may cause visual damage (2, 3, 5, 11, 25, 26, 32). Improved drought resistance was reported by Moore (25); however no data was presented.

Wetting agents are less toxic in soil than in solution culture because of adsorption to soil particles which alters the compound activity and soil properties. The reason for toxicity to plants has been suggested to be a result of affected cell membranes and/or a flooding of intercellular spaces (3, 11). Valoras et.al. (32) observed that wetting agent is taken up by the plant and toxicity increases with the concentration. Toxicity to roots has been demonstrated to increase with wetting agent concentration (11). However, since some of these results were derived after application of excessively high concentrations (beyond what would be needed for surface tension reduction) of the tested material, the validity of those results may be questionable.

SUMMARY

Previous work done on the effect of wetting agents on soils and plants is limited and many of the reports are simply ideas or opinions. Since these compounds are often recommended (or sold) for use with container grown plants, more work is needed to clarify physiological effects on plants. Also information concerning wetting agent influence on soil media used for containerized plants is needed.

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EFFECT OF NON-IONIC SURFACTANTS ON WATER USE AND GROWTH OF CHRYSANTHEMUM X MORIFOLIUM RAMAT. 'FLORIDA MARBLE'[1]

Abstract. To test claims of water-use reduction by non-ionic surfactant products, three wetting agent treatments (Aqua Gro, Surf Side, and a water control) were applied to two container soils (Choice Nursery Mix and a 1:1:1 mixture of peat, perlite, and composted pine bark) in three temperature regimes (18, 24, and 29°C.). Effects of the wetting agents on water use of *Chrysanthemum* x *morifolium* Ramat. 'Florida Marble' were dependent on temperature and soil mix. Transpiration was most affected by wetting agent treatment at 29°C. transpiration increased by 135 and 61% for Aqua Gro and Surf Side, respectively. Reduced transpiration occurred at 18°C. on the 1:1:1 soil for Surf Side and at 24°C. transpiration was reduced for both wetting agents in Choice Nursery Mix.

The partially hydrophobic 1:1:1 soil was most affected by wetting agent application; at 24°C. Aqua Gro increased evapotranspiration (ET) in the 1:1:1 and at 29°C. both wetting agents increased ET. Surf Side

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at 24^{o}C. in Choice Nursery Mix reduced ET. In the 1:1:1 soil mix at 24 and 29^{o}C. for Surf Side and at 24^{o}C. for Aqua Gro, evaporation increased. At 18^{o}C. wetting agents decreased evaporation in the Choice Nursery Mix.

At 18 and 24^{o}C. few plant growth responses were observed. Fresh and dry weight were increased by Aqua Gro in the 1:1:1 soil mix at 29^{o}C.

INTRODUCTION

Non-ionic surfactants (or wetting agents) have been used for many years as chemical amendments to aid rewetting of water-repellent soils. Some wetting agents are advertised as reducing water usage in container plant culture, which would result in savings of labor, water, and money. In Kansas, where rainfall and humidity are low, groundwater often scarse or heavily mineralized, and summer temperatures high, water-use savings could be particularly helpful. This research was conducted to test the effect on water use and plant growth of two wetting agents applied on two potting soils.

Wetting agents, by reducing the surface tension of water, can influence capillary forces in soils (4). A reduction of soil evaporation would result in total water-use savings, wetting agents have been shown to retard evaporation from soil soils (2, 4). If taken into plants, wetting agent action could possibly change internal water relations, perhaps effecting transpiration; plant water uptake could also be altered with soil water normally available to plants becoming available. However, wetting agents have in some instances shown detrimental effects on plant growth (1, 6) which might negate any benefit derived from water-use reduction.

MATERIALS AND METHODS

Three ambient temperatures were chosen as representative of temperatures found during the growing season in Kansas: 18, 24, and 29°C.[1] One of three similar growth chambers were set at each temperature. Light levels were similar and chambers were equipped with thermographs. Day and night temperatures were the same and photoperiod in all chambers was 14 hours.

Two soils were used: Choice Nursery Mix and 1:1:1 mixture of composted pine bark, peat, and perlite. The commercial soil (Choice Nursery Mix) was composed of 7 parts composted pine bark to 3 parts vermiculite (Table 1). The 1:1:1 mix was amended with lime to raise the pH of 4.0 to the 5.5 pH of the Choice Nursery Mix. The 1:1:1 mix was then moistened and allowed to set for a few days.

Three wetting agent treatments were applied to each soil at each temperature: non-ionic wetting agent Aqua Gro liquid; non-ionic wetting agent Surf Side 30 liquid; and water. Wetting agents were applied at recommended rate as a soil drench after potting. An equal amount of water was applied to pots not treated with wetting agent. In addition to applying treatments to pots containing plants, wetting agent was

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[1]Based on records of the last 30 years of the Kansas Agricultural Experiment Station: April, May, and June average mean temperature = 18°C.; July average mean temperature - 24°C; August and September average mean temperature = 29°C.

applied to pots containing only soil. For each soil-wetting agent-temperature, five pots with plants and two pots without plants were prepared for a total of 42 pots per growth chamber. Thus for each temperature the treatments were:

Mix	Wetting Agent	Rate: ml/ai/l	Number of Pots	
			With Plants	Without Plants
Choice	Aqua Gro	29.6/11.4	5	2
Choice	Surf Side	25.0/19.0	5	2
Choice	Water		5	2
1:1:1	Aqua Gro	29.6/11.4	5	2
1:1:1	Surf Side	25.0/19.0	5	2
1:1:1	Water		5	2

Rooted cuttings of Chrysanthemum x morifolium Ramat. cv. 'Florida Marble' were used. After wetting agent application the pots were allowed to equilibrate in a greenhouse overnight. The next day pots containing the 1:1:1 mix were fertilized with liquid fertilizer (20-20-20) to bring that soil up to the nutrient level of the Choice Nursery Mix. After three days in the greenhouse, pots were moved into the growth chambers.

To obtain water use data, the plants were observed daily. When any plants (regardless of treatment or temperature) wilted, all pots were removed from all chambers and weighed. After weighing pots were watered with equal amounts, allowed to drain briefly, then watered again; water use between each watering was then calculated. All plants were randomly replaced in their original chambers.

The experiment continued for 41 days and then terminated due to lack of plant response. When all the plants in one chamber appeared to wilt at the same time it was assumed that the wetting agent treatments had been degraded or leached.

After removal from the growth chambers, fresh and dry weights of the plants were determined. The chrysanthemums were clipped at the base and aerial parts weighed, dried at 65°C., and weighed again.

The two soils were tested for organic matter content by combusting air dried samples at 538°C. Samples were dry sieved to determine particle size distribution (Table 1).

PROBLEMS WITH PROCEDURES

This experiment was originally planned (and implemented) to be conducted three times in order to statistically compare temperature treatments. However mechanical failure of the growth chambers severely limited usefulness of the data for the first and third runs of the study.

There are problems with insects, particularly during the third trial; chemical control was only partially effective.

Another problem resulted from plants flowering in the first trial. In subsequent runs the day length was increased from 12 to 14 hours to retard flowering.

RESULTS

18°C. TEMPERATURE REGIME

Comparison of the water treatments (check) show that at 18°C. evaporation for both soils was similar. The 1:1:1 soil mix had a higher evapotranspiration (ET) rate as well, though not significant (Table 2). Fresh and dry weights were essentially the same for the two soils (Table 3).

In comparison to the water control, Aqua Gro treatment in the 1:1:1 soil mix did not result in any significant difference for evaporation, transpiration, or ET (Table 2). Aqua Gro applied to Choice Nursery Mix decreased evaporation by 19% while transpiration and evapotranspiration were unaffected. Surf Side applied to the Choice Nursery Mix exhibited a 15% reduction in evaporation; no other water use effects were observed in either soil.

Except for transpiration in the 1:1:1 soil mix, Aqua Gro and Surf Side responses for water use variables were essentially the same. Aqua Gro had a 37% higher transpiration rate than Surf Side in the 1:1:1 mix (Table 2).

Aqua Gro and Surf Side exhibited no effect on fresh weights in either soil; however the Aqua Gro treatment resulted in higher fresh weight than Surf Side (Table 3). There were no differences in dry weights between any of the three treatments in either soil.

$24^{o}C$. TEMPERATURE REGIME

At $24^{o}C$. evaporation, transpiration, and evapotranspiration were nearly identical for both mixes as demonstrated by the check treatments (Table 2). The water control fresh and dry weights were also similar (Table 3).

When applied to the 1:1:1 mix, Aqua Gro increased evaporation and ET, while in Choice Nursery Mix transpiration decreased by 30% (Table 2). Evaporation increased and transpiration and ET remained unchanged in the 1:1:1 soil mix for the Surf Side treatment; however in Choice Nursery Mix evapotranspiration and transpiration were reduced by 18 and 33%, respectively.

Compared to Surf Side, Aqua Gro exhibited greater evaporation and ET rates in the 1:1:1 soil mix (Table 2). For Choice Nursery Mix no differences were observed.

Fresh weight was greater for the Aqua Gro treatment than the water or Surf Side treatments in the 1:1:1 mix (Table 3). No other wetting agent affects were observed on plant growth at $24^{o}C$. Similar results were found for plant growth at the $18^{o}C$. temperature.

29^{o}C. TEMPERATURE REGIME

As indicated by the water control, evaporation, transpiration, and ET were different for both soils at 29^{o}C. (Table 2). Choice Nursery Mix exhibited 75 and 36% greater transpiration and ET rates, respectively. Choice Nursery Mix also had greater fresh (31%) and dry weights (10%) than the 1:1:1 soil mix.

Aqua Gro applied to the 1:1:1 mix resulted in increased transpiration and ET. In Choice Nursery Mix Aqua Gro demonstrated no influence on water parameters (Table 2). In the 1:1:1 soil Surf Side had higher evaporation, transpiration, and ET rates than the control. In Choice Nursery Mix no differences in water use for any variable were observed.

When applied to the 1:1:1 soil mix Aqua Gro increased transpiration and ET rates over those of Surf Side (Table 2). Similar responses were observed using Choice Nursery Mix.

Plant growth responses, due to wetting agent treatment were apparent at 29^{o}C., but only in the 1:1:1 soil mix (Table 3). Aqua Gro treatment increased fresh and dry shoot weight by 30.4 and 10.0%, respectively. Surf Side also increased fresh and dry shoot weights but to a lesser degree.

DISCUSSION

Plant water consumption (evapotranspiration) is a total of evaporation and transpiration. A reduction in either can result in a substantial water use savings. Higher plant water consumption necessitates more frequent irrigation, greater water use, and increased production costs. The reduction of water use while maintaining (or increasing) plant growth is the ideal sought from the addition of wetting agents.

WATER USE

At 18°C. neither soil mix nor wetting agent treatment affected evapotranspiration (ET). Effects on ET at 24°C. depended on the soil and treatment; Aqua Gro caused a 20% increase in ET in the 1:1:1 soil mix but had no influence when applied to Choice Nursery Mix. Surf Side reduced ET at 24°C. in Choice Nursery Mix but not in the 1:1:1 mix. At 29°C. in the 1:1:1 soil, both wetting agents had substantially higher evapotranspiration values than the water control. In Choice Nursery Mix no difference in ET was observed due to wetting agent action.

Transpiration was the component of evapotranspiration that appeared to be most affected by wetting agent; however the nature of the response was dependent on the soil and temperature. At 29°C. in the 1:1:1 soil mix, transpiration was increased by 135 and 61% for Aqua Gro and Surf

Side, respectively. Reduced transpiration occurred at 18°C. on the 1:1:1 soil for Surf Side and at 24°C. transpiration was reduced for both wetting agent treatments in Choice Nursery Mix.

The author found no reports in the literature concerning wetting agent affects on transpiration. Since wetting agents can influence capillary forces in soils (9), the energy status (water potential) of the water possibly was altered, which could affect plant water uptake. Also the plants in the 18°C. chamber were never under drought stress (as were plants in the 29°C. chamber) and these soils were not difficult to rewet with free water always available to all treatments. Perhaps because of this, affects of the wetting agents on plant water use and growth were not demonstrated. The plants in the 29°C. chamber were always first to wilt and toward the end of the experiment were often under drought stress, which in itself may have caused damage to the plants.

Law (8) observed a reduction in evaporation following wetting agent application. He attributed this to reduced interfacial tension which decreased capillary flow to the soil surface. In the present study, evaporation was decreased by wetting agents at 18°C. in Choice Nursery Mix; however increased evaporation occurred in the 1:1:1 soil mix at 24 and 29°C. for Surf Side and at 24°C. for Aqua Gro. The 1:1:1 mix was one third peat (the Choice mix contained no peat) and was more hydrophobic in nature than Choice Nursery Mix. Wetting agents have been shown to have little or no affect on evaporation in hydrophilic soils (16). Perhaps reduced interfacial tension in the partially hydrophobic 1:1:1 mix actually increased capillary flow to the surface, while in the more hydrophilic Choice Nursery Mix a net capillary flow reduction occurred. Also the shallow pots, relatively well drained mixes, and frequency of watering used in this study may have prevented the formation of a unique drying zone. That is, all pots were watered when plants in the 29°C. chamber wilted and there was probably not enough time for the surface evaporation necessary for a drying zone to form before the next watering of pots without plants (the measure of evaporation).

PLANT GROWTH

At 18°C. and 24°C. few plant growth responses were observed. The only significant differences were between Aqua Gro and Surf Side fresh weights in the 1:1:1 mix. Compared to Surf Side, Aqua Gro increased fresh weight by 16.6 and 7.6%, respectively, at 18 and 24°C. In the 1:1:1 mix at 29°C., the Aqua Gro treatment resulted in greater fresh and dry shoot weights than either the check or the Surf Side treatments. Surf Side also increased fresh and dry weights but not as much as Aqua Gro. No plant responses were apparent in the hydrophilic Choice Nursery Mix.

The plant growth response observed in this study were all on the partially hydrophobic 1:1:1 mix. The water use parameters were also most affected by wetting agent treatment in this soil. Since dry weight was only marginally influenced by wetting agent, the fresh weight increase would appear to be primarily water. For example, plant moisture contents for the control and Aqua Gro treatments were 45.6 and 54.1%, respectively, at 29^{o}C. in the 1:1:1 mix. Increased plant succulense would not necessarily be desirable since drought and heat hardiness could decrease.

Valoras et.al. (32) observed that wetting agent is taken up by plants and that toxicity increases with concentration. Several studies have shown a detrimental affect of wetting agents in solution culture on plant growth (24, 32). However Endo's work (3) demonstrated that low wetting agent concentration applied to soil actually increased shoot growth. The results of this study indicate that plant growth increases do occur in some instances. Concentrations used were similar to the rates Endo found could increase plant growth.

Since the energy status of water may have been altered by wetting agent application, ET may have been increased; however no data was found in the literature on changes in soil moisture retention resulting from additions of wetting agents. The results of this study do not clearly show that wetting agents decrease plant water use, neither do the results clearly show an increase. Rather the varying plant and soil response reflect the varying nature of non-ionic wetting agents and how differeing soils and environments may affect wetting agent action. Thus, blanket claims of water use reduction from wetting agent use do not appear to be valid.

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Table 1. Physical properties of the soil mixes.

Characteristic	Soil Mix	
	1:1:1	Choice
Particle Size Distribution:		
% greater than 5.00 mm in diameter...	5.6	8.3
% greater than 1.27 mm in diameter...	41.2	39.3
% greater than 0.40 mm in diameter...	43.0	39.9
% greater than 0.25 mm in diameter...	7.8	6.9
% less than 0.25 mm in diameter...	2.3	5.6
Percent Organic Matter:	31.3	34.9

Table 2. Evaporation (E), transpiration (T), and evapotranspiration (ET) rates in ml of water use per pot per day.

	Water Use Per Day					
Treatment	E		T		ET	
18°C Temperature Regime						
1:1:1 Mix						
Water (check)	15.2a	(100)[yz]	20.3ab	(100)	35.5a	(100)
Aqua Gro	15.3a	(101)	24.4a	(120)	39.6a	(112)
Surf Side	15.3a	(101)	17.8b	(88)	33.0a	(93)
Choice Mix						
Water (check)	16.2a	(100)	14.4a	(100)	30.6a	(100)
Aqua Gro	13.2b	(81)	18.6a	(129)	31.8a	(104)
Surf Side	13.8b	(85)	17.2a	(119)	30.9a	(101)
24°C Temperature Regime						
1:1:1 Mix						
Water (check)	19.2c	(100)[yz]	36.8a	(100)	56.0b	(100)
Aqua Gro	24.4a	(127)	43.1a	(125)	67.4a	(120)
Surf Side	21.4b	(111)	38.3a	(104)	59.7b	(107)
Choice Mix						
Water (check)	20.6a	(100)	36.7b	(100)	57.3a	(100)
Aqua Gro	25.3a	(123)	25.6a	(70)	50.9ab	(89)
Surf Side	22.3a	(108)	24.7a	(67)	46.9b	(82)
29°C Temperature Regime						
1:1:1 Mix						
Water (check)	35.6b	(100)[yz]	21.1c	(100)	56.7c	(100)
Aqua Gro	35.8ab	(101)	49.6a	(235)	85.4a	(151)
Surf Side	40.4a	(113)	33.9b	(161)	74.3b	(131)
Choice Mix						
Water (check)	39.9a	(100)	37.0a	(100)	76.9a	(100)
Aqua Gro	39.6	(99)	41.6a	(112)	80.6a	(105)
Surf Side	39.9a	(100)	38.6a	(104)	78.4a	(102)

[y] Percent of the water control.

[z] LSD (.05 level) between mixes is 2.44, 8.04, and 7.35 for evaporation, transpiration, and evapotranspiration, respectively.

Mean separation within soils by Duncan's Multiple Range Test, .05 level.

Temperatures cannot be compared statistically.

Table 3. Final fresh and dry shoot weights in gm per pot.

Treatment	Shoot Weight Fresh		Dry	
18°C Temperature Regime				
1:1:1 Mix				
Water (check)	64.0ab	(100)[y,z]	31.3a	(100)
Aqua Gro	70.4a	(110)	32.9a	(105)
Surf Side	60.4b	(94)	31.5a	(101)
Choice Mix				
Water (check)	63.3a	(100)	30.6a	(100)
Aqua Gro	70.4a	(111)	31.6a	(103)
Surf Side	68.0a	(107)	31.3a	(102)
24°C Temperature Regime				
1:1:1 Mix				
Water (check)	62.3b	(100)[y,z]	32.1a	(100)
Aqua Gro	66.8a	(107)	33.0a	(103)
Surf Side	62.1b	(100)	32.5a	(101)
Choice Mix				
Water (check)	60.3a	(100)	32.2a	(100)
Aqua Gro	55.5a	(92)	31.5a	(95)
Surf Side	58.4a	(97)	31.5a	(95)
29°C Temperature Regime				
1:1:1 Mix				
Water (check)	53.3c	(100)[y,z]	29.0c	(100)
Aqua Gro	69.5a	(130)	31.9a	(110)
Surf Side	63.4b	(119)	30.9b	(107)
Choice Mix				
Water (check)	69.8a	(100)	31.9a	(100)
Aqua Gro	66.2a	(95)	31.6a	(99)
Surf Side	65.5a	(94)	30.9a	(97)

[y] Percent of the water control.

[z] LSD (.05 level) between mixes is 5.62 and 1.22 for fresh and dry shoot weights respectively.

Mean separation within soils by Duncan's Multiple Range Test, .05 level. Temperatures cannot be compared statistically.

The Effect of Non-Ionic Surfactants on Water Use and Plant Growth of *Chrysanthemum* x *morifolium* Ramat, 'Florida Marble'

by

John Paul Bowles

B.S., Auburn University, 1976

AN ABSTRACT OF A MASTER'S THESIS

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To test claims of water-use reduction by non-ionic surfactant products, three wetting agent treatments (Aqua Gro, Surf Side, and a water control) were applied to two container soils (Choice Nursery Mix and a 1:1:1 mixture of peat, perlite, and composted pine bark) in three temperature regimes (18, 24, and 29°C.). Effects of the wetting agents on water use of Chrysanthemum x morifolium Ramat. 'Florida Marble' were dependent on temperature and soil mix. Transpiration was most affected by wetting agent treatment at 29°C. transpiration increased by 135 and 61% for Aqua Gro and Surf Side, respectively. Reduced transpiration occurred at 18°C. on the 1:1:1 soil for Surf Side and at 24°C. transpiration was reduced for both wetting agents in Choice Nursery Mix.

The partially hydrophobic 1:1:1 soil was most affected by wetting agent application; at 24°C. Aqua Gro increased evapotranspiration (ET) in the 1:1:1 and at 29°C. both wetting agents increased ET. Surf Side at 24°C. in Choice Nursery Mix reduced ET. In the 1:1:1 soil mix at 24 and 29°C. for Surf Side and at 24°C. for Aqua Gro, evaporation increased. At 18°C. wetting agents decreased evaporation in the Choice Nursery Mix.

At 18 and 24°C. few plant growth responses were observed. Fresh and dry weight were increased by Aqua Gro in the 1:1:1 soil mix at 29°C.