Soil Wetting Agents: Tools for Every Superintendent’s Arsenal
An Objective and In-Depth Review of Over Five Decades of Research

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The Editorial Staff and members of the MGCSA would like to recognize Dr. Brian Horgan and Mr. Sam Bauer for their contribution of relevant material published in the Hole Notes magazine. This extensive compendium of wetting solution science articles and published papers is a result of the Member Driven Research project initiated by the Research Committee and directed by you, the membership.

A quick search on the topic of “wetting agent” on Michigan State’s Turfgrass Information File brings up 1044 articles dating back to a 1946 article written by the USGA Green Section. In this Timely Turf Topic article, the authors discuss wetting agents mixed with DDT to improve dispersion aimed at controlling cutworms, ants, mole crickets, and other insects on golf courses (Grau, 1946). While the use of wetting agents in this case was more for the emulsifying and spreading properties provided, it was around this time that the talk of using wetting agents for soil improvement surfaced.

The research surrounding soil wetting agent use follows a long history of University and industry trials dating back to the mid-1950s when the pioneer Bob Moore of Aquatrols Corp. marketed the first commercially available wetting agent “AquaGro” (Hiscock, 2010). This review focuses on the research surrounding wetting agent use in the turfgrass industry from Bob Moore’s 1950 introduction until today. Much study has been conducted in this area, and many superintendents rely on this research and their personal experience to justify incorporating wetting agents into their turfgrass management program. History can provide valuable insight on where we are today with wetting agent use, and it’s important to take an objective look at the facts surrounding what these products can provide for your soil and turfgrass.

1955 to 1964

The initial discussion of wetting agent use surrounded the idea that "plain water" could be improved upon, and "making water wetter" would produce a better turf. In fact, in one of the first articles written on the use of wetting agents, Bob Moore mentions "we have been governed by the physical limitations of plain water" (Moore, 1957). Just as today, the primary wetting agents being used to improve soil conditions sixty years ago were non-ionic wetting agents, or those wetting agents lacking an ionic charge. These products were thought to be less injurious to plant tissue, consistent, and more effective.

Around this time the talk of soil moisture tension surfaced. Soil moisture tension is the tendency of water to cling to soil particles. Water with a lower tension has a greater ability to move and replace moisture withdrawn by turfgrass roots. Figure 1 is a graph from Moore, 1957 showing a close relationship between soil moisture tension and root elongation. While this graph looks too perfect and we all know that 100 percent soil moisture is never good for root growth, it puts perspective on an idea that we don't consider much these days, that is, allowing water to move more freely in our root zones, not just curing hydrophobicity. Reported benefits of lowering soil moisture tension included 1) increase in the availability of water and nutrient solutions, 2) freer movement of water and nutrient solutions, and 3) greater root growth (Moore, 1959). At this point in time, there was little turfgrass research to support these claims.

One of the first wetting agent studies in a turfgrass setting was published by the Soil Science Society of America. Researchers evaluated infiltration rate differences of three commercially available wetting agents when applied to quartz sand (Pelishek et al., 1962). The focus of this study was on the contact angle present between sand columns and the water solution applied to the columns. Pelishek et al. concluded that wetting agents can increase infiltration rates on hydrophobic soils, and there is a beneficial residual effect of wetting agents.

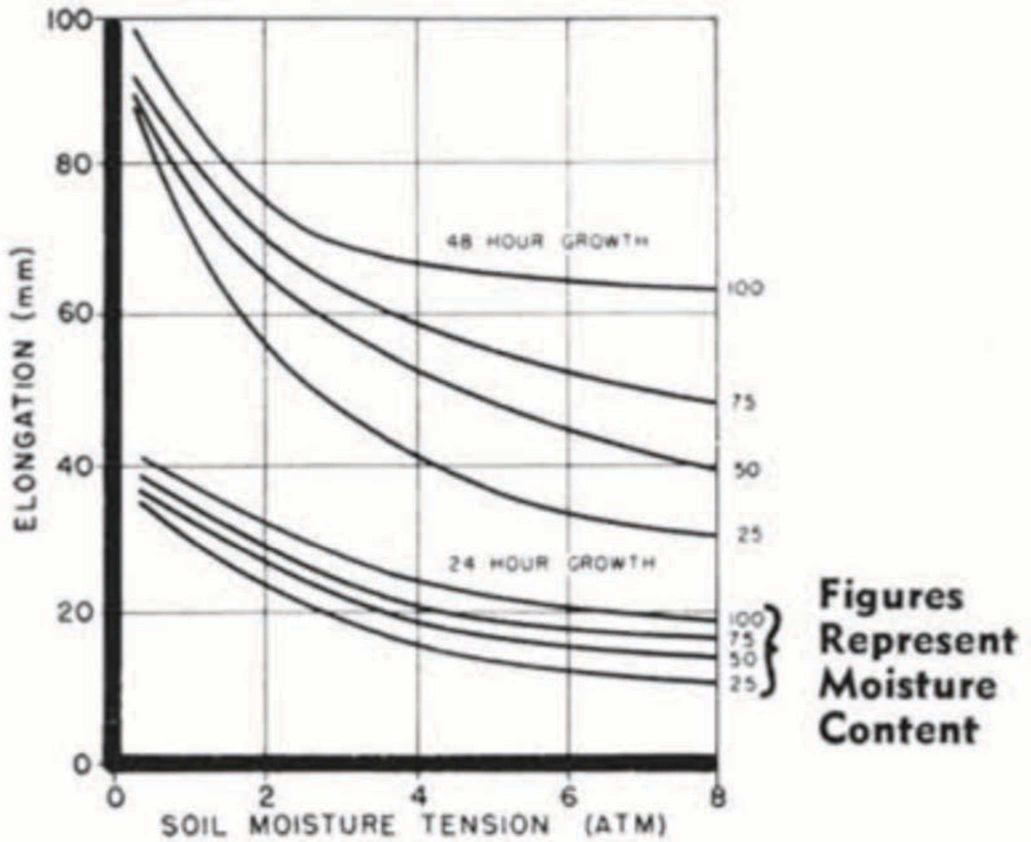


Figure No. 5. Elongation of roots as effected by soil-moisture tensions. Deeper roots are developed under low soil moisture tensions.

(Figure 1. Reference: Moore 1957)

1965-1974

Around the mid-1960s wetting agents were starting to become common tools used by golf course superintendents. Not surprisingly, this is when researchers began to evaluate their effectiveness and place in turfgrass management programs. Roberts (1966) studied the effects of four wetting agents applied monthly to creeping bentgrass, colonial bentgrass, and Kentucky bluegrass, grown both in the field and in a greenhouse at Iowa State University. The “old chemistry” wetting agents used in this study had no effect on turfgrass quality or moisture relations under field conditions. In the greenhouse, turf grown hydroponically in a wetting agent and nutrient solution showed chlorosis and reduced growth. In this case, increasing surfactant level in the solution caused an increase in toxic levels of copper and zinc concentrations in the turf tissue causing phytotoxicity. It appeared that the soil in the field study was able to bind the wetting agent, in which case no injury was apparent. During this period, the non-ionic surfactants were only considered of value in hydrophobic or difficult to wet soils.

In a three part study conducted by researchers at the University of California-Riverside, soil wetting agents were evaluated with various levels of compaction, irrigation, and soil amendments on common bermudagrass grown in a greenhouse. While this study was fairly complex, strong correlations were made with the addition of wetting agent on improving infiltration of sandy loam soils (40% greater infiltration rates), but not sandy loams modified with 33% either peat, lignified redwood, or calcined clay. Overall infiltration rates on these modified soils were significantly greater than on sandy loam alone, which explains the lack of response from wetting agent additions. Other responses evaluated in this study included compactability, evapotranspiration, top growth, salinity, tissue mineral content, oxygen diffusion rate, and top growth; wetting agent treatments showed little effect on these responses (Morgan et al., 1966; Letey et al., 1966; Valoras et al., 1966).

These same researchers studied the effects of AquaGro and Soil Penetrant 3685 (both polyoxyethylene based) on seed germination, shoot growth, and root growth of creeping bentgrass, Kentucky bluegrass, bermudagrass, annual ryegrass, tall fescue, and barley. This was one of the first studies that demonstrated differences in phytoxocicity among similar wetting agent chemistries. Both root and shoot growth reductions were associated with higher wetting agent application rates, and Soil Penetrant 3685 treated plants were suppressed more than those treated with AquaGro; this was attributed to the higher soil retention of AquaGro and therefore less product present in soil solution (Endo et al., 1969), similar to the idea from Roberts (1966).

1975-84

In an eight year study, Murray and Juska (1977) studied the effects of several management practices, including wetting agent applications, on thatch accumulation, turfgrass quality, and leaf spot development in Kentucky bluegrass turf established in Maryland. These researchers hypothesized that the wetting agent treatment (AquaGro) would increase thatch moisture levels and therefore increase the rate of thatch decomposition. Over the duration of the study, wetting agent applications had little effect on thatch accumulation or turfgrass quality compared to the untreated control, however leaf spot damage was reduced in plots that were treated with a wetting agent. Leaf spot severity is increased in high moisture environments; therefore the wetting agent's ability to increase soil and canopy dry time, as well as reduce the formation of dew, is most likely the reason for the reduced leaf spot severity. However, Vargas and Detweiler (1980) failed to show this same relationship with leaf spot and AquaGro on 'Pennlawn' creeping red fescue. Also, Otto and Vargas (1984) saw no effect of wetting agent applications on leaf spot or dollar spot severity on Kentucky bluegrass.

After experiencing severely hydrophobic conditions on a newly seeded 'Penncross' creeping bentgrass sand-based experimental putting green, researchers at Ohio State University studied the influence of three commercially available wetting agents (Hydro-Wet, AquaGro, and Grozyme) with or without core aeration on improving soil moisture retention. The hydrophobicity was attributed to an organic coating on the soil particles. Treatments consisting of aeration plus Hydro-Wet or AquaGro performed the best at reducing the severity of the localized dry spot, and these two wetting agents applied without aeration also helped to alleviate the symptoms. Grozyme treatments showed no effect on reducing turf injury caused by hydrophobic soils (Wilkinson and Miller, 1978).

Numerous studies on the use of wetting agents were being conducted during this time period by institutions such as Michigan State University and University of California-Riverside. While these studies were published in field day or conference reports and not peer-reviewed journals, much of our knowledge on the use of wetting agents was developed from these types of investigations. For example, Rieke (1974) demonstrated up to a 73% soil moisture increase one month after wetting agent applications on a hydrophobic fairway. This moisture increase resulted in a significant improvement in turfgrass quality for approximately two months after treatment in Michigan. The residual effects of AquaGro and Hydro-Wet were evaluated one year later. All of the wetting agent treated plots continued to hold more water than the untreated check, with the best treatment (Hydro-Wet applied at 32oz/1000ft2) holding 74% more water over one year after a single application in July. Turfgrass quality ratings closely reflected the increase in soil moisture content. Interestingly, soil cultivation treatments that were conducted on the same date one year prior showed no improvement in soil moisture or turfgrass quality.

This point validates the thought by many researchers at this time that coring and wetting agents should be used in combination for correcting hydrophobic soils. Soil moisture increases from the wetting agent applications were no longer evident after two years. In 1974, seven wetting agent treatments were added to a new study on the same site. AquaGro and Hydro-Wet treated plots exhibited the highest turfgrass quality ratings of all products tested (Rieke and Bay, 1975). While no phytotoxicity was witnessed during these studies, a follow up study was initiated to determine the phytotoxicity potential of the two best performing products, AquaGro and Hydro-Wet. Both products demonstrated some phytotoxic effects, although these effects were reduced as irrigation increased following application (Rieke and Bay, 1976).

Kaufmann and Jackson (1978) were some of the first researchers to study turfgrass water use rates as affected by wetting agents. This study was conducted on Kentucky bluegrass in-vitro by submerging the plants in solutions of either Hydro-Wet or AquaGro at 0, 200, 1000, or 5000 ppm dilution rates. At four and eight hours following submersion, water use rates were reduced in the wetting agent treated samples by 12-16% depending on treatment. Higher dilution rates did not increase this effect. These researchers conclude that water use rates can be reduced by as much as 10% with the use of wetting agents, but it is unclear whether or not this is desirable for the turfgrass being grown. Further investigation lead Kauffman (1980) to discover that transpiration is reduced in Kentucky bluegrass plants when the soil is treated with wetting agents or certain fungicides, and this closely resembles the relationship these compounds have on the stomatal conductance tested in this study. Figure 2 is a table from Kauffman's paper showing stomatal conductance, transpiration, and photosynthesis based on chemical treatment. Clearly, while low stomatal conductance reduces transpiration, it also has an effect on CO2 exchange, and therefore reduces photosynthesis. No turfgrass injury was observed in this study, but reducing photosynthesis should not be perceived as a positive attribute.

Table 1. The effect of four turfgrass chemicals on transpiration, photosynthesis and stomatal conductance of Merion Kentucky bluegrass

	(percent of untreated check)		
Chemical	conductance	transpiration	photosynthesis
Aquagro	62	68	87
Hydrowet	28	36	46
Tersan 1991	21	34	31
Chipco 26019	49	58	76
Check	100	100	100

(Figure 2. Reference: Kauffman 1980)

1985 to 1994

Wetting agent use was becoming so common by the mid-1980s that researcher's efforts were focused on finding secondary applications for these tools. Researchers at Cornell University studied annual bluegrass seed head suppression on a golf course fairway with several products, including the plant growth regulators mefluidide and amidochlor, and the wetting agents AquaGro, Hydro-Wet, Basic H, Amway Spray Adjuvant. All products were applied alone and not watered in. Surprisingly, over a three year period, spring AquaGro treatments reduced seed head production and yield from 26 to 77%; this treatment provided comparable suppression to the mefluidide treatment. Other wetting agents had no influence on seed head formation. Visual quality was slightly reduced with the highest AquaGro treatment from one to two weeks following application, however these effects were not present at three weeks after treatment. Clipping yields were not reduced with AquaGro.

The authors concluded that AquaGro apparently has some growth regulating properties because of the level of seed head suppression in the study, although there was no research to support this at the time (Petrovic et al., 1985). Certainly, timing of application and lack of post-application irrigation play some role here. A similar study was conducted by Cooper et al. (1987) evaluating the effects of mefluidide and AquaGro on root growth, seed head production, and quality of annual bluegrass maintained at fairway height in Ohio. During the peak seed head production time, April to May, mefluidide and AquaGro suppressed seed head density by 76 and 20%, respectively. However, only mefluidide consistently suppressed seed head production throughout the study; it also effectively prevented summer root die back as compared to the control and AquaGro treatment.

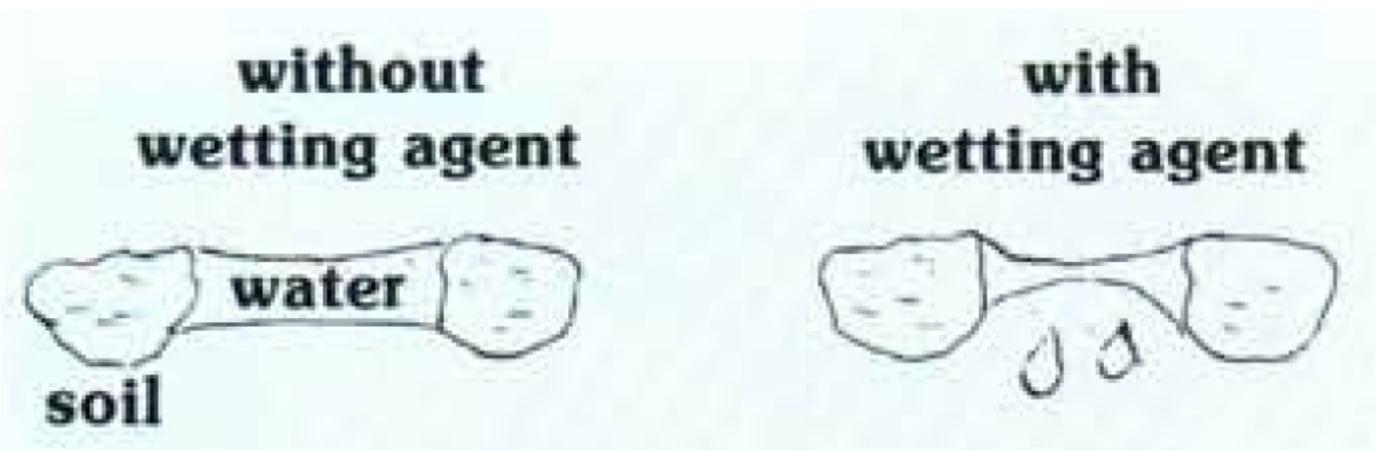
The stimpmeter had become an important tool around this time period. With that, researchers began to evaluate practices that would have an effect on green speed. Langlois (1985) studied the influence of Surf Side wetting agent on the green speed of 'Penneagle' creeping bentgrass in Pennsylvania. Measurements taken for five consecutive days following the wetting agent application showed no significant change in the green speed as measured with a stimpmeter.

Few additional peer-reviewed wetting agent studies were published from 1985-1994, which is surprising. By now, many superintendents and researchers knew the benefits and potential drawbacks that wetting agents had to offer them. Some of the most interesting and informational trade articles being written at this time were from Golf Course Management Magazine (GCM). In a 1985 GCM

article by Bruce Williams (former superintendent at Bob O'Link Golf Club), his success with using wetting agents on fairways to improve moisture distribution and retention was described, citing a 30 percent reduction in total water use since beginning the program six years prior.

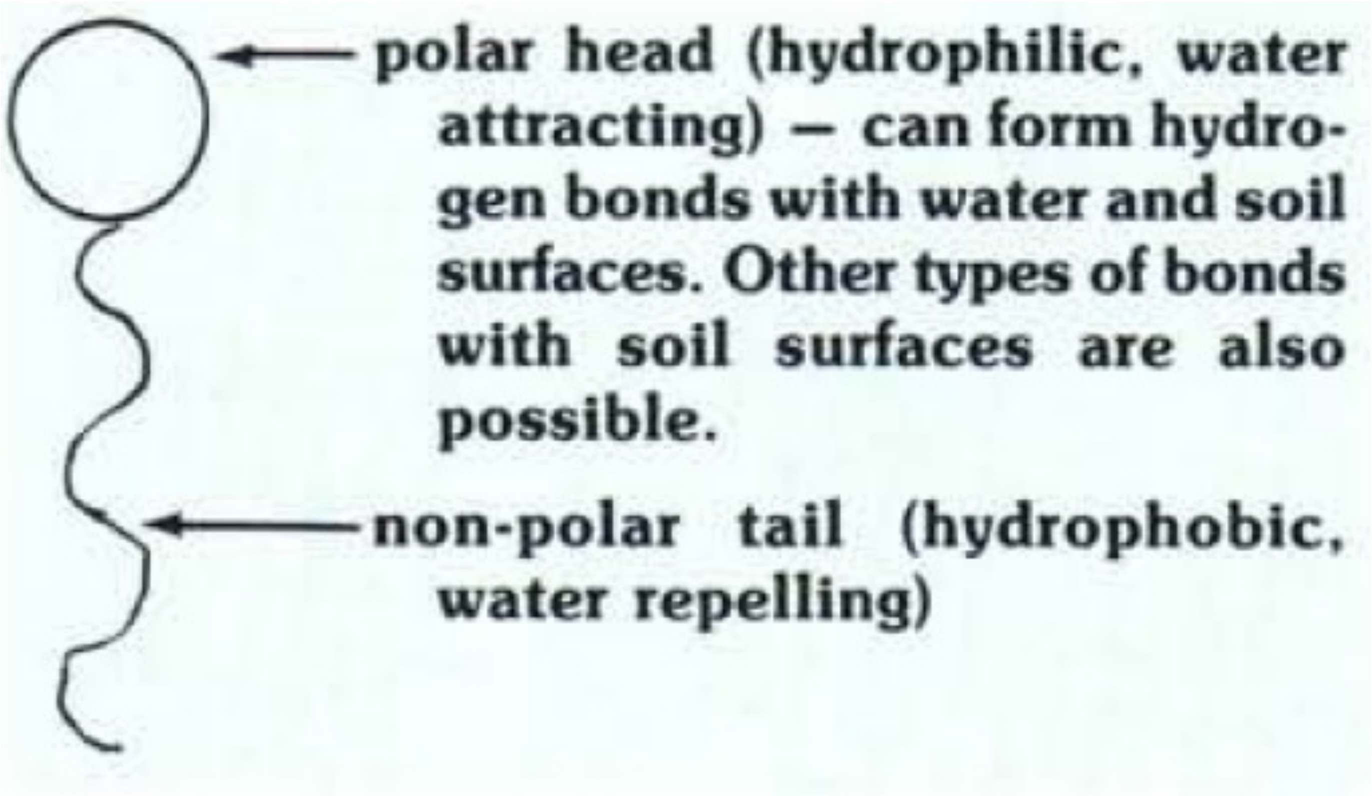
Another main benefit Bruce saw from wetting agent use was an elimination of wet areas that were favoring annual bluegrass (Williams, 1985). At a time when wetting agent benefits were primarily defined on hydrophobic soils, Dr. Bob Carrow (1989) discussed how wetting agents could be used to improve hydrophilic (wettable) soils in a GCM article titled "Understanding wetting agents: A look at how they influence soils can help superintendents better predict the results of treatment." Most turfgrass soils are in fact hydrophilic. In these situations, greater drainage could occur with the addition of a wetting agent due to decreased surface tension of the soil water. For this to happen, two factors need to be in place. First, the wetting agent must be present in sufficient quantities in the soil. Second, the soil must be able to drain, meaning no layers or extensive compaction present.

Figure 3 is a diagram of wetting agent interaction on hydrophilic soils from Dr.



(Figure 3. Reference: Carrow 1989)

Carrow's article. In addition to describing the wetting agents in hydrophilic situations, Dr. Carrow also discussed the mode of action of most wetting agents and how they behaved when in contact with hydrophobic soils. Non-ionic wetting agents have a polar (hydrophilic) head and a non-polar (hydrophobic) tail (Figure 4). As you would imagine, the tail attaches itself to the soil and the head attaches to



water, holding water in place for plant uptake.

(Figure 4. Reference: Carrow 1989)

Quinn (1993) described in a GCM article the "Special applications for wetting agents"; ranging from seed head reduction to overall water savings, however, much of this was still up for debate. At this time there were several proven products that were able to back up their claim of improving soil wettability or making "wetter water." Those products included: AquaGro (Aquatrols), Aqua-Aid (Aqua-Aid), Hydraflo (Grace-Sierra), Hydro-Wet (Kalo), Surf Side (Montco Products), Naiad (Naiad Co), Paragon (Precision Labs), and NOBURN (ROOTS).

Quinn also mentioned superintendent’s successes injecting wetting agent through Toro’s water aerator, the HydroJect. This process had been approved by the Toro Co. one year prior (Phillips, 1992). It was also in 1993 that the International Turfgrass Society Research Journal published a method for an individual to determine initial and residual effects of the wetting agents that they were using. The simple procedure involved filling a clear drinking straw with hydrophobic soil and measuring infiltration rates with different wetting agent concentrations (Mane, 1993). Even today, this simple procedure could be useful for a superintendent trying to justify the cost of wetting agents to his greens committee or membership.

1995 to 2004

By 1995, wetting agents were no longer considered out of the norm of basic agronomics, but research results were inconsistent and it was hard to identify the benefits that products could consistently produce on individual properties. In a study looking at three different wetting agents and their influence on alleviating soil water repellency of a ‘Tifdwarf’ bermudagrass stand, Cisar et al (1997) found that applications of Primer or Aqueduct provided significantly better turfgrass quality and reduced localized dry spot as compared to AquaGro and an untreated control. Combination treatments of Primer/Aqueduct or Primer/AquaGro did not provide higher turf quality ratings or fewer localized dry spots than the treatments applied alone. Also studying Primer, a researcher in Massachusetts evaluated the amelioration of water repellency on 100 percent sand-based creeping bentgrass tees using two rates of Primer (125ml and 185ml per 100m2) compared to an untreated control. After two applications, turfgrass quality improved, and localized dry spots and afternoon wilting were nearly eliminated. Kostka (2000) cited four benefits of the Primer application: 1) reduced soil water repellency, 2) enhanced turfgrass performance, 3) improved uniformity of turf, 4) increased available soil moisture. At Michigan State, researchers studied the effects of Primer and Midorich wetting agents on water retention and distribution in sand and loamy sand with no turf cover. While not significant, Midorich increased the water retention in the upper two inches of the sand system, whereas Primer significantly increased retention at six and ten inches. This data suggests that these two wetting agents react differently

in the soil, specifically Midorich remains in the upper profile and Primer moves more rapidly to greater depths. Trends were similar in the loamy sand root zone (Leinauer et al., 2001).

Karnok and Tucker (2001) evaluated the color, quality, and root growth effects of the wetting agent Tilwa applied to ‘Penncross’ creeping bentgrass grown on hydrophobic soil. Only a single application of wetting agent was made. Ratings were taken up to 18 weeks after treatment and the single wetting agent application improved turfgrass color and quality 78 percent of the time. Overall root length at the 0 to 8 cm was increased by 27 percent with the wetting agent application; this and the increase in turf quality can be attributed to the six percent increase in volumetric water content (VWC) of the hydrophobic soil over the duration of the study. Consider that field capacity of a sand-based system is 10-15 percent; an increase in six percent VWC can have profound effects on the turf plant.

At this time we still questioned the effectiveness of wetting agents in reducing seed head production of annual bluegrass. Researchers from the Chicago District Golf Association studied the effectiveness of AquaGro, as well as a newer wetting agent, Cascade, at inhibiting seed head production compared to several standard plant growth regulators. After three years, mefluidide and ethephon provided the most consistent suppression of annual bluegrass seed heads on putting green and fairway turf; suppression reached 95 percent, but phytotoxicity was concerning. While inconsistent, the wetting agent treatments provided up to 50 percent suppression of seed heads (Kane and Miller, 2003).

In addition to alleviating localized dry spot, wetting agents have been evaluated for their effectiveness at controlling fairy ring, a basidiomycete fungi implicated at causing soil hydrophobicity. Gelernter and Stowell (1997, 1998) evaluated the wetting agents Primer (alone) or Respond (alone or combined with azoxystrobin or flutolanil). Both Respond and Primer were effective at reducing localized dry spot (type C fairy ring), but not at reducing type B fairy ring which is a more progressed form of the fungus. The fungicides azoxystrobin and flutolanil were most effective at suppressing the symptoms of type B fairy ring when

Respond or Primer were added. Based on these studies, Gelernter and Stowell (1999) developed new management approaches for both fairy ring and localized dry spot. These approaches included five basic steps: 1) maintain thatch thickness below ½ inch, 2) use wetting agents to alleviate localized dry spot, 3) use fungicides flutolanil or azoxystrobin to control associated fungi, 4) implement a spring cultivation program, 5) hand water hydrophobic soils thoroughly. In a similar study aiming to control localized dry spot symptoms with flutolanil and wetting agents, Karnok and Tucker (2001) demonstrated that flutolanil alone, while effective in preventing localized dry spot, will not control the symptoms once they have developed. Wetting agents are required to cure the hydrophobicity of the soil.

2005 to present

The most comprehensive research on wetting agent use was completed in 2005 by the Golf Course Superintendent's Association of America and the United States Golf Association. A total of nine sites across the United States were chosen to conduct this research on ten commercially available and popular wetting agents. Research objectives included an evaluation of five characteristics: 1) turfgrass phytotoxicity, 2) turfgrass color and quality responses, 3) impact on soil hydrophobicity, 4) dew formation, and 5) pest damage. All wetting agent treatments were applied per label instructions according to the highest rate recommended to cure hydrophobic soils. This study was conducted for four months in 2003 and 2004 corresponding to the peak stress period at each location. Figure 5 shows a table with all wetting agents and application rates and timings. Results varied based on region, turfgrass species, and degree of soil hydrophobicity. In Michigan, turfgrass quality ratings were consistent among treatments from 2003 to 2004, and all wetting agents tested (except for Naiad) significantly improved turfgrass quality over the control. This is not consistent with the turfgrass color ratings seen in Missouri, where Cascade Plus produced the lowest color ratings in 2003; there was no statistical color difference between these treatments in 2004. The water droplet penetration test (WDPT) was used at each location to determine wetting agent effects on soil hydrophobicity. This test involves removing ¾ inch cores from each plot, placing a droplet of distilled water at various depths on each core, and determining the time that it takes for each droplet to penetrate the core. Surprisingly, in Missouri the wetting agents that were most effective in curing hydrophobicity also reduced turfgrass color; this contradicts Michigan data. It appears that the Missouri sand rootzone was drastically less hydrophobic (WDPT = 18 seconds) than the sands in Michigan (WDPT = 322 to 340 seconds). This implies that the Missouri plots had less to benefit from the wetting agent applications. In Michigan, WDPT closely reflected turfgrass quality; Naiad and control plots had the longest time for water penetration and also the lowest turfgrass quality ratings. Observations from these two states indicate that the wetting agents Aquaduct, Brilliance, Cascade Plus, Hydro-Wet, LescoFlo, Primer Select, and TriCure all have the ability to reduce soil hydrophobicity, but produce inconsistent results in turfgrass color and quality (Throssell, 2005). For a detailed explanation regarding questions about this research, visit Karnok (2005). It's important to note that newer wetting agent chemistries have been released since this study, such as Aquatrols Revolution (Pioppi, 2005).

WETTING AGENTS AND RATES

Product/rate (ounces)*	Timing	Spray volume (gallons/1,000 sq. ft.)†	Watering in
Aqueduct			
8	first application	1	irrigate before next mowing
8	1 week after first application	1	irrigate before next mowing
8	once every four weeks after second application	1	irrigate before next mowing
Brilliance			
8	first application	2	immediately after application
8	10 days after first application	2	immediately after application
8	12 weeks after second application	2	immediately after application
Cascade Plus			
8	first application	2	immediately after application
8	10 days after first application	2	immediately after application
Hydro-Wet			
8	first application	10	immediately after application
8	two weeks after first application	10	immediately after application
2	every two weeks after second application	5	immediately after application
LescoFlo			
8	first application	10	immediately water in
8	two weeks after first application	10	immediately water in
Naiad			
8	first application	10	immediately after application
8	two weeks after first application	10	immediately after application
6	once every four weeks after second application	10	immediately after application
Primer Select			
6	first application	2	irrigate before next mowing
6	every four weeks following first application	2	irrigate before next mowing
Respond 2			
10	first application	8	immediately after application
10	8 weeks after first application	8	immediately after application
Surfside 37			
32	first application	10	immediately after application
4	every two weeks after first application	10	immediately after application
TriCure			
6	first application	2	immediately water in
6	every four weeks following first application	2	immediately water in

*2, 4, 6, 8, 10 and 32 ounces = 59.1 milliliters, 0.12 liter, 0.17 liter, 0.24 liter, 0.30 liter and 0.94 liter, respectively.
†1, 2, 5, 8, and 10 gallons/1,000 square feet = 40.7, 81.5, 203.7, 326 and 407.5 liters/1,000 square meters, respectively.

Table 1. Wetting agents, rates of application in fluid ounces, timing of application, spray volume and post-application watering instructions used in the GCSAA/USGA wetting agent evaluation. The first application of all wetting agents was made on the same date and before the appearance of any symptoms of localized dry spots.

(Figure 5. Left. Reference: Throssell, 2005)

More regional specific studies have been conducted in recent years by the University of Minnesota-Twin Cities and the University of Wisconsin-Madison. These studies have been published in Hole Notes and The Grass Roots. One study included in the June 2011 issue of Hole Notes, "2010 Wetting Agent Study Update", evaluated the effects of six wetting agents that were currently being used by twelve golf courses in Minnesota.

Through GPS mapping of TDR data, these researchers were able to track changes in soil moisture levels and uniformity following a wetting agent application. In this study, block polymer and modified block polymer wetting agents (TriCure, Revolution) increased soil moisture and uniformity distribution by an average of 4.7 and 4.8 percent, respectively. Gluco ether block polymer wetting agents (Tournament Ready, Dispatch) reduced soil moisture by 2.7 percent, while decreasing uniformity by 3.9 percent. This study is a good demonstration of the differences between the water-holding and soil-penetrating chemistries of wetting agents (Johnsen and Horgan, 2011).

A follow up study was conducted in 2011 on the same golf courses with a modified treatment list. Wetting agent chemistry differences continued to be apparent based on soil moisture and uniformity. TriCure, Revolution, Immerse GT, Magnus, and Performa Gold treatments increased soil moisture by an average of 4.4 percent. Dispatch decreased soil moisture by 4.7 percent. TriCure, Magnus, and Revolution increased uniformity by 6.5 percent, while Dispatch and Tournament Ready reduced uniformity by 4.5 percent (Johnsen et al., 2012). These results are fairly consistent with the data collected in 2010. For a detailed explanation of the various wetting agent chemistries, read the article published by Zontek and Kostka (2012). Karnok published a recent article in GCM (2013) and laments the difficulties of understanding the chemistry of wetting agents and states: "who cares about the chemistry".

Dr. Doug Soldat addressed the question of how wetting agents perform in wet (or hydrophilic) soils in a two-year study conducted in Madison, Wisconsin. Six wetting agents were evaluated for their ability to reduce VWC in high moisture conditions on a one-year-old ‘Penn A4’ creeping bentgrass USGA spec putting green. During the 2009 study year, all wetting agent treatments had consistently lower VWC levels than the untreated control, with Revolution reducing VWC the most (> 4 %). Treatments of Tournament Ready, Sixteen90, and two experimental products from Aquatrols all demonstrated similar VWC values, which were consistently 2 percent drier than the control. Revolution was tested alone in 2010 and resulted in a less dramatic reduction in VWC compared to the control on the same putting green. Moving the treatments to an eight-year-old putting green with approximately 4 percent organic matter resulted in little VWC statistical difference between Revolution and the control (Soldat, 2010).

This data further validates that the benefits of wetting agents differ by soils; that these wetting agents have the ability to improve the wetting of hydrophobic soils and will reduce soil moisture in wet conditions. Soldat et al. (2010) also evaluated wetting agent effects on localized dry spot development, turfgrass quality, moisture uniformity, and moisture content on a ‘Penncross’ creeping bentgrass green. Two control plots (replacement of 100 or 30 percent evapotranspiration, ET) were compared with the wetting agents Aquaduct, Primer 604, and Revolution water at a replacement 30 percent of ET. Control plots irrigated with 100 percent replacement of ET demonstrated the highest turfgrass quality and least amount of localized dry spot, whereas the 30 percent ET control plots were below acceptable levels for most of the study. All wetting agent treatments provided acceptable turfgrass quality for most of the study with only 30 percent ET replacement. Soil moisture uniformity was the highest in all wetting agent treatments. Soil moisture content in wetting agent plots reflected changes in weather patterns; wetting agents improved the moisture content under dry conditions and reduced the moisture content under wet conditions. Remember this was reinforced by Carrow (1989).

Conclusion

The breadth of information presented throughout this review demonstrates where our knowledge has originated related to wetting agents. Much like winter injury studies in turfgrass, wetting agent research can vary greatly by location, soil type, irrigation practices, species, product, season, etc. There are no clear cut recommendations on how to effectively utilize wetting agents at your property. Please use the research cited in this article in conjunction with your local knowledge and experience. We've all read the purported benefits of the so-called wetting agent that will cure every problem under the sun. But we've also acknowledged the fact that a single wetting agent can both increase VWC and decrease VWC of a rootzone, improving uniformity. These products are tools that, when used wisely, can make a nice complement to your turfgrass management arsenal.

Opportunities for future research on wetting agents might involve their impact on surface firmness or winter survivability. We anticipate this information to be available in the years to come. For more background on wetting agent basics, we suggest reading the highlighted articles in the references section.

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