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Wetting Agent and Phosphorus for Quick Establishment of Kentucky Bluegrass

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ABSTRACT. Wetting agent is a substance that reduces the soil water repellency and causes a liquid to spread more easily into the soil. Wetting agents are well known as to improve irrigation efficiency. Phosphorus is one of the 17 essential nutrient elements and promote faster seed germination. The objective of this study was to evaluate wetting agent and P rates for fast germination and establishment of Kentucky bluegrass. Three levels of wetting agent which were 0.23, 0.46, and 0.92 ml m^{-2} were applied and the P treatments were 5, 10, and 15 g m^{-2}. The medium and high rate of wetting agent at the high P rate had the greatest turfgrass coverage and took 28 days to reach 50% turfgrass coverage regardless of P application. Based on this study, wetting agent is effective for fast germination and establishment of Kentucky bluegrass if sufficient phosphorus is applied.

***Key words*:** Establishment, Germination, Kentucky bluegrass, Phosphorus, Wetting agent

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Introduction

Quick establishment of turfgrass is often required in golf courses to recover area damaged by divot, disease, compaction, and physiological reasons. Fast germination of turfgrass seed is necessary for quick establishment. For appropriate seed germination, plant seeds require proper light intensity, optimum temperature, sufficient water content and suitable oxygen level (Bewley and Black, 1994). Among these factors to germinate plant seeds, soil water content is relatively manageable to increase germination speed and rates although the water requirements for seed germination are various based on plant species and soil types. Mantovani and Iglesias (2001) investigated seed germination of terrestrial bromeliads under water stress. They reported that no seed germination was found under water potentials lower than -0.14 MPa. Hensler et al. (2009) evaluated 6 cool-season grasses which were tall fescue [*Schedonorus phoenix* (Scop.) Holub], hard fescue (*Festuca brevipila* Tracey), red fescue (*Festuca rubra* L. ssp. *rubra*), chewings fescue [*Festuca rubra* L. ssp. fallax (Thuill.) Nyman], perennial ryegrass (*Lolium perenne* L.), and Kentucky bluegrass (*Poa pratensis* L.) with 4 osmotic potential treatments of 0.0, -0.4, -0.8, -1.2, and -1.6 MPa to investigate germination and morphological development. They found that perennial ryegrass had greater germination rates than all other species evaluated at all osmotic potentials. In addition to plant species, soil types and condition affect soil water content. Turfgrass grown on sandy soils should be irrigated more than silt and loamy soil resulted from losses of soil water content through leaching. If soil has a condition of water repellency, water use efficiency is affectedly reduced. Water repellent soil is often found in the upper 5cm of the soil which includes the zone of greatest root growth, organic matter accumulation and microorganism activity (Karnok and Tucker, 2003).

Wetting agent is a substance that reduces the soil water repellency and causes a liquid to spread more easily into the soil (Beard and Beand, 2005; Zontek and Kostka, 2012). Wetting agents are divided into four groups depending on their ionization which are anionic, cationic, nonionic, and amphoteric. Among these four groups, nonionic wetting agents have comparatively low toxicity to plant growth and are used in most turfgrass management in the present day (Karnok et al., 2004). Previous researches have reported the advantages of wetting agent. Karnok and Tucker (2001) found that wetting agent treatment during summer stress improved turfgrass color, quality and root growth of creeping bentgrass (*Agrostis stolonifera* L.). Wetting agents are effective to reduce

or remove localized dry spot caused by hydrophobic soils on putting greens (Karnok and Tucker, 1999). Cooper et al. (1987) found that wetting agent rates of 8.4 L ha^{-1} had greater turfgrass quality than untreated annual bluegrass (*Poa annua* L.) but did not affect seedhead inhibition of annual bluegrass. Leinauer et al. (2007) evaluated 10 wetting agents with different soil depth and season in sandy rootzone and found that water repellency was alleviated by wetting agent at the surface to 2.5 cm depth. Karnok and Tudcker (2008) examined wetting agents to improve irrigation efficiency and found irrigation rates required were decreased by wetting agent treatments resulted from increasing the uniformity of water infiltration. There are a few studies regarding wetting agent effects to seed germination although many researches have been reported for the benefits of wetting agents.

Phosphorus (P) effects to turfgrass is well known as one of the 17 essential nutrients.

Westfall and Simmons (1971) found P treatments increase seedling density on Kentucky bluegrass. Watschke et al. (1977) found that rooting of Kentucky bluegrass sod treated by P was increased. Nemitz et al. (2007) evaluated Kentucky bluegrass treated by 7 P rates on a calcareous soil and found turfgrass seed germinated more quickly at 45 mg kg^{-1} which is a higher P concentrations among treatments. Despite researches which report P effects to turfgrass growth, there are abundant researches that show minimal or no growth responses from P applications to turfgrass growth. Christians (1996) found that there were no significant turfgrass responses to P applications to Kentucky bluegrass grown on soil with P levels as low as 7 mg kg^{-1}. Lee (2009) found Kentucky bluegrass established from sod on soil of a low P level need no P for three years. Lee (2011) reported that Kentucky bluegrass established newly seeded had no P effect on growth and establishment for one year. These researches said that P application doesn't affect turfgrass growth in matured stage.

Although P application have little effects on matured turfgrass growth in recent researches, proper soil P is necessary for seed germination. Wetting agent is commonly used to improve water use efficiency, relieve localized dry spot, and improve drainage. Because water and P application are required for seed germination, it may be possible that wetting agents enhance germination rates and quick establishment of turfgrass with P treatments. The objective of this study was to evaluate wetting agent and P rates for fast germination and establishment of Kentucky bluegrass.

Materials and Methods

Research was initiated at the Hoseo Turfgrass Research Center on the campus of Hoseo University in Asan, Chungnam, Korea. Each plot size for the study was 0.4 by 0.4 m and Kentucky bluegrass (*Poa pratensis* L.) 'camas' was seeded on the plots at June 5 for the 1st and August 6, 2014 for the 2nd study, respectively. The study was conducted two times. For the wetting agent and P rate application, treatments were initiated on April 28 and June 29, 2014 for the 1st and 2nd study after seeding, respectively. The source of wetting agent was Hydro-Wet (KALO) which consist of 87.5% poloxanlene, 2-butoxyethanol. Three levels of wetting agent 0.23, 0.46, and 0.92 ml m^{-2} were applied as low, medium, and high, respectively. Fused phosphate fertilizer (0-20-0) (NH, a Farmers Cooperative) was used for the P applications. The P treatments were 5, 10, and 15 g m^{-2} for the low, medium, and high P rate treatments, respectively. Urea (46-0-0) of 5 g m^{-2} was applied to all plots for nitrogen application before the initiation of the study. All fertilizers were granular type. Irrigation at 1 cm depth was applied at three times a day (8:00 am) until germination and at one time a day (8:00 am) after germination. Additional water was applied if required depending on the symptom of soil surface. A watering plastic bottle was used for all of irrigation. Turf color ratings are a measure of overall plot color (NTEP, 2010). Turfgrass color was measured by an index of damage caused by disease or insect pests, nutrient deficiency or environmental stress. Turfgrass color was visually rated on a scale of 1 to 9 (1 = straw brown, 6 = acceptable, and 9 = dark green) every day after 50% germination. Turfgrass quality was measured by an index of turf density, leaf texture, disease resistance, mowing qualities, and stress tolerance including several stresses during winter (Beard, 1973; Turgeon, 1999). Turfgrass quality was visually rated on a scale of 1 to 9 (1 = poor, 6 = acceptable, and 9 = best) every day after 50% germination. Volumetric water content (%) in the soil was measured at the depth of 12 cm every day (5:00 pm) by Time Domain Reflectometry (Field Scout TDR-300, Spectrum Technologies). The experimental design was a randomized complete-block design with three replications. Analysis of variance (ANOVA) was performed on transformed data using Statistical Analysis Systems design (SAS Institute Inc., 2001). Treatment differences were analyzed by the Proc Mixed procedure. When appropriate, mean separations were performed by Fischer's protected least significant difference (LSD) at a 0.05 probability level. All statistical analyses were analyzed by SAS.

Results and Discussion

There was no significant wetting agent and P rates interaction for turfgrass color and quality throughout the 1st and 2nd study (data not shown). There were no significant wetting agent and P rates main effects for turfgrass color and quality for entire study period. Phosphorus seldom influences the color of turf unless there is extreme deficiency (Sheard, 1993). This is in agreement with results obtained by other researchers. Lee (2009) evaluated N and P rate on Kentucky

Table 1. Analysis of variance for coverage by germination of Kentucky bluegrass.

Source	df	9 DAT[a]	16 DAT	19 DAT	23 DAT	28 DAT	32 DAT	37 DAT	42 DAT
		---------- The 1st study ----------							
Wetting Agent (WA)	2	NS[b]	NS	NS	NS	NS	NS	NS	NS
Phosphorus Rate (PR)	2	NS	NS	NS	NS	NS	NS	NS	NS
WA × PR	4	NS	NS	NS	NS	NS	NS	NS	NS
		---------- The 2nd study ----------							
Wetting Agent (WA)	2	NS	*	NS	NS	NS	NS	NS	NS
Phosphorus Rate (PR)	2	NS	NS	NS	*	NS	NS	NS	NS
WA × PR	4	NS	**	**	**	**	**	**	**

*, ** indicates significance at $P = 0.05$ and $P = 0.01$, respectively.
[a]DAT means day after treatment.
[b]NS indicates not significant at $P = 0.05$.

bluegrass grown a P deficient soils and found P application had no effects on color and quality for three years. Christians (1996) reported there were no significant turfgrass responses to P applications to Kentucky bluegrass grown on soil with P levels as low as 7 mg kg^{-1}. Nus et al. (1993) found no significant P rate treatment effects on Kentucky bluegrass quality was found for five years regardless of the soil P level. Compared to N application, P treatment is unlikely to enhance turfgrass color and quality. No significant difference for interaction and main effects for turf coverage was found for the 1st study, but significant wetting agent and P rates interaction were found for throughout the 2nd study except 9 DAT (day after treatment) (Table 1). The daily average temperature range for the 1st study is from 11.4 to 25.2°C and 21.2 to 29.2°C for the 2nd study (data not shown). The temperature difference between the 1st and 2nd study was 4 to 9.8°C. These temperature differences may affect rates of seed germination treated by wetting agent and P rates application. Temperature as a factor affecting seed germination have been reported by Thomson and Grime (1983).

Significant wetting agent and P rates interaction were found for the 2nd study (Table 2). Turfgrass coverage by seed germination was increased as increasing rates of wetting agent application at medium P throughout the study. The low rate of wetting agent at the low p rate had the lowest or equal to the lowest turfgrass coverage during the 2nd study. At the low P

Table 2. Wetting agents and phosphorus rates interaction for turfgrass coverage by germination of Kentucky bluegrass.

Wetting Agent	July 8 (9 DAT[a])			July 15 (16 DAT)			July 18 (19 DAT)			July 22 (23 DAT)		
	Low P[b]	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P
Low[c]	3.7[d]	2.3	4.7	13.3 b[e]A[f]	10.7 bA	11.7 bA	23.3 bA	23.3 abA	23.3 bA	31.7 aA	30.0 abA	30.0 bA
Medium	2.3	4.3	3.0	13.3 bAB	10.0 bB	15.0 bA	26.7 abB	20.0 bB	36.7 aA	33.3 aA	23.3 bB	35.0 abA
High	2.3	2.3	3.7	18.3 aA	18.3 aA	20.0 aA	35.0 aA	31.7 aA	30.0 abA	35.0 aA	36.7 aA	40.0 aA
LSD (P=0.05)		NS			4.39			9.12			6.77	
Wetting Agent	July 27 (28 DAT)			July 31 (32 DAT)			Aug. 5 (37 DAT)			Aug. 10 (42 DAT)		
	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P
Low	36.7 bA	28.3 bA	36.3 bA	41.7 bA	35.0 bA	36.7 bA	48.3 aA	36.7 bA	38.3 bA	48.3 bA	43.3 bA	40.0 bA
Medium	41.7 abA	28.3 bB	43.3 abA	43.3 bAB	33.3 bB	50.0 aA	55.0 aA	35.0 bB	55.0 abA	55.0 abA	38.3 bB	56.7 aA
High	50.0 aA	50.0 aA	50.0 aA	56.7 aA	58.3 aA	53.3 aA	60.0 aA	70.0 aA	66.7 aA	61.7 aA	66.7 aA	68.3 aA
LSD (P=0.05)		11.92			11.66			13.97			11.66	

[a]DAT means day after treatment.
[b]Low, medium, and high rate of P application are 5, 10 and 15 g m^{-2}, respectively.
[c]Low, medium, and high level of wetting agent are 0.04, 0.08, and 0.16 ml m^{-2}, respectively.
[d]The units of turfgrass coverage are percent (%).
[e]Mean with the same upper case letters is not significantly different among P rate treatments.
[f]Mean with the same lower case letters is not significantly different among wetting agent treatments.

Table 3. Analysis of variance for soil water content.

Source	The 1st study								
	df	30 DAT[a]	32 DAT	48 DAT	50 DAT	51 DAT	53 DAT	54 DAT	56 DAT
Wetting Agent (WA)	2	NS[b]	NS	NS	NS	NS	NS	NS	NS
Phosphorus Rate (PR)	2	NS	NS	NS	NS	NS	NS	NS	NS
WA × PR	4	*	NS	NS	NS	*	NS	**	**
Source	The 2nd study								
	df	9 DAT	16 DAT	19 DAT	22 DAT	28 DAT	32 DAT	37 DAT	42 DAT
Wetting Agent (WA)	2	NS[b]	*	NS	NS	NS	NS	NS	NS
Phosphorus Rate (PR)	2	NS	NS	NS	*	NS	NS	NS	NS
WA × PR	4	NS	**	**	**	**	**	**	**

*, ** indicates significance at $P = 0.05$ and $P = 0.01$, respectively.
[a]DAT means day after treatment.
[b]NS indicates not significant at $P = 0.05$.

rate, the medium and the high rate of wetting agent had no differences except 16 and 32 DAT. The high rate of wetting agent at the medium rate of P application had the greatest or equal to the greatest turfgrass coverage. The high rate of wetting agent at the medium P rate had 54.0 to 76.7% more coverage than the low and medium rate of wetting agent. At the high P rate, there were no significant differences between the medium and high rate of wetting agent except 16 DAT. At the low and medium P rate, the high rate of wetting agent had the greatest turfgrass coverage, but no differences between the medium and high rate of wetting agent at the high P rate were found in 32 DAT. The low rate of wetting agent at the low p rate had the lowest or equal to the lowest turfgrass coverage. At the low and high rate of wetting agent, the P rate had no effects on turfgrass coverage. Although the P rate effects at the medium rate of wetting agent were found, the results on turfgrass coverage was inconsistent. The low and high P rate had greater turfgrass coverage than the medium P rate on 4 of 8 rating dates. It is not clear about P application to seed germination based on interaction of wetting agent and P rates. Inconsistent results with different P rates to seed germination were found from Zuk and Li (2011). They evaluated 5 species and 10 cultivars treated by 6 different P rates and found that P decrease the period to germinate seeds at 15 mg P Kg^{-1} but

Table 4. Wetting agents and phosphorus rates interaction for soil water content from the 1st study.

Wetting Agent	May 28 (30 DAT[a])			May 30 (32 DAT)			June 15 (48 DAT)			June 17 (50 DAT)		
	Low P[b]	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P
Low[c]	38.5[d] ab[e]B[f]	44.5 aA	36.7 bB	31.3	28.8	29.2	36.2	36.7	36.3	26.5	26.6	21.0
Medium	39.5 aA	30.6 bB	40.8 aA	27.9	31.4	27.3	38.1	33.2	35.5	25.1	27.5	31.6
High	35.9 bB	44.9 aA	43.1 aA	29.4	28.2	26.8	32.6	36.8	35.1	31.5	33.6	34.1
LSD ($P = 0.05$)	3.14			NS			NS			NS		
Wetting Agent	June 18 (51 DAT)			June 31 (53 DAT)			June 21 (54 DAT)			June 23 (56 DAT)		
	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P
Low	40.8 aA	40.3 aA	33.7 bB	34.1	34.3	26.7	34.0 aA	36.8 aA	28.0 bB	26.9 aA	26.8 aA	22.0 bA
Medium	40.0 aA	37.2 aA	39.3 aA	33.6	27.7	34.4	37.0 aA	29.5 bB	39.3 aA	24.3 aA	17.1 bB	28.1 aA
High	39.0 aA	38.7 aA	40.6 aA	35.0	35.7	34.1	38.2 aA	37.3 aA	37.3 aA	27.0 aA	27.9 aA	26.3 abA
LSD ($P = 0.05$)	4.42			NS			6.41			4.86		

[a]DAT means day after treatment.
[b]Low, medium, and high rate of P application are 5, 10 and 15 g m^{-2}, respectively.
[c]Low, medium, and high level of wetting agent are 0.04, 0.08, and 0.16 ml m^{-2}, respectively.
[d]The units of soil water content are percent (%).
[e]Mean with the same upper case letters is not significantly different among P rate treatments.
[f]Mean with the same lower case letters is not significantly different among wetting agent treatments.

Table 5. Wetting agents and phosphorus rates interaction for soil water content from the 2nd study.

Wetting Agent	July 8 (9 DAT[a])			July 15 (16 DAT)			July 18 (19 DAT)			July 22 (23 DAT)		
	Low P[b]	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P
Low[c]	20.5[d]	12.1	13.8	29.2 a[e]A[f]	27.5 aA	20.5 bB	36.2 abA	36.7 aA	36.3 aA	26.5 bA	26.6 bA	21.0 bB
Medium	16.1	24.2	26.1	21.1 bB	15.9 bC	28.8 aA	38.1 aA	33.2 aB	35.5 aAB	25.1 bB	27.5bB	31.6 aA
High	20.5	20.0	21.7	29.4 aA	28.2 aA	26.8 aA	32.6 bA	36.8 aA	35.1 aA	31.5 aB	33.6 aA	34.1 aA
LSD ($P = 0.05$)		NS			5.17			4.83			3.53	
Wetting Agent	July 27 (28 DAT)			July 31 (32 DAT)			Aug. 5 (37 DAT)			Aug. 10 (42 DAT)		
	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P	Low P	Medium P	High P
Low	41.4 abA	40.9 aA	38.8 bA	31.6 aAB	35.4 aA	27.7 bB	36.3 aA	38.8 aA	35.2 aA	39.0 aA	38.8 aA	34.5 bB
Medium	39.5 bB	36.1 bC	42.8 aA	33.4 aA	20.8 bB	34.4 aA	37.6 aA	31.1 bB	37.5 aA	39.0 aA	35.7 bB	41.2 aA
High	43.4 aA	41.1 aAB	39.8 abB	36.9 aA	32.1 aAB	29.3 abB	39.8 aA	38.0 aA	33.4 aB	41.1 aA	39.5 aAB	36.8 bB
LSD ($P = 0.05$)		3.25			6.36			4.93			3.87	

[a]DAT means day after treatment.
[b]Low, medium, and high rate of P application are 5, 10 and 15 g m^{-2}, respectively.
[c]Low, medium, and high level of wetting agent are 0.04, 0.08, and 0.16 ml m^{-2}, respectively.
[d]The units of soil water content are percent (%).
[e]Mean with the same upper case letters is not significantly different among P rate treatments.
[f]Mean with the same lower case letters is not significantly different among wetting agent treatments.

delayed as P levels increased for most species. Similar results was shown in the study. At the medium rate of wetting agent, the low P had the greatest or equal to the greatest turfgrass coverage, but the medium P rate had lower turfgrass coverage than the low P rate in 37 DAT.

There were significant wetting agent and P rates interaction on soil water content for the 1st and 2nd study (Table 3). In the 1st study, the low rate of wetting agent had the lowest or equal to the lowest level of soil water content (Table 4). No differences between the medium and high rate of wetting agent at the high P rate were found. These results were also found for turfgrass coverage. For the turfgrass coverage, the medium and high rate of wetting agent had greater turfgrass coverage than the low rate at the high P rate on 6 of 8 rating dates. At the high P rate, the medium and high rate of wetting agent influenced to soil water content resulted in greater turfgrass coverage from seeded Kentucky bluegrass. But no relation between soil water content and turfgrass coverage by wetting agent at the low P rate was found. In the 2nd study, the medium and high rate of wetting agent at the high P rate had greater soil water content than the low rate of wetting agent on 4 of 8 rating dates. At the medium P rate, the low and high rate of wetting agent had greater soil water content than the medium rate on 5 of 8 rating dates. At the low P rate, inconsistent results on soil water contents was shown regardless of rates of wetting agent.

Kentucky bluegrass treated by the high rate of wetting agent reached 50% turfgrass coverage regardless of the P rates in 28 DAT. It is faster than common lawn establishment. Seeded lawns may require up to 60 days to become fully established (Stier, 2000). Sheard (1993) reported that high level of P in the soil is required for rapid germination and growth which occurs immediately following germination of the seed. However, the P rate had no main effects on turfgrass coverage due to interaction of wetting agent and the P rate in the study. Overall, the medium and high rate of wetting agent at the high P rate had the greatest turfgrass coverage and took 28 days to reach 50% turfgrass coverage regardless of the P rate. However, it is still not clear the reason why interaction of wetting agent and the P application was not shown at the temperature range from 11.4 to 25.2°C. Further study would be required. Based on this study, wetting agent may be an assistant material for fast germination and establishment if high P level is applied and temperature range is high enough (>11.4 to 25.2°C).

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