SUBSURFACE FERTILIZATION WITH HIGH PRESSURE WATER INJECTION

C.M. Miller and P.E. Rieke
Crop and Soil Sciences
Michigan State University
East Lansing, Michigan

Recent studies have shown the Hydroject, a tool developed by the Toro Company that utilizes high pressure pulses of water to cultivate the soil, has promise in temporarily relieving soil compaction. Water injection cultivation (WIC) with this tool imparts less damage to the turfgrass plant and the playing surface than hollow tine cultivation. This makes cultivation by the turf manager more feasible during periods of high use and stress conditions. Since the Hydroject utilizes water it seems reasonable to assume the Hydroject could be used for injection of fertilizer nutrients. Injection of potassium, phosphorus, and nitrogen has been compared to surface (foliar) applications and will be summarized in this discussion. This research is being conducted at the hancock Turfgrass Research Center at Michigan State University.

POTASSIUM INJECTION

Potassium treatments were initiated in early August for 1990 and were designed to evaluate potassium fertilization of an annual bluegrass (Poa annua L.) fairway turf grown on a sandy loam soil. Annual treatments were split into two separate applications, half applied in mid-July to late August and half applied in early September, (see Table 1): 1) control; 2) Hydroject aerification alone; 3) surface application of 3 lbs. K_2O per 1000 sq. ft. The potassium source used was potassium chloride. Soil samples taken in mid July and late October of each year were analyzed using the neutral normal ammonium acetate extraction process. On the basis of soil tests of the check plots. Michigan State Soil Testing Laboratory recommendations suggest an annual application of 3.5 lbs K_2O per 1000 sq. ft. Each treatment was replicated four times. Plot size was 7 feet by 10 feet.

Results of soil tests after four years of treatments in October, 1993 are shown in Table 1. It should be noted that these tests were taken after 4 years of fertilization treatments, and effectively reflect the pattern seen in previous tests throughout the experiment. Plots receiving no potassium fertilization had lower available potassium values at each soil depth, as expected. These values, however, are still in the adequate range and would need to be less than 50 lbs available K/acre to be considered deficient. in the upper soil (0-3"), no significant differences in available potassium content were evident between method of application at either rate of fertilization. Moving downward in the soil profile, only at the high rate of fertilization did injection significantly increase available potassium content of the soil over surface fertilization. It is evident that potassium applied to the surface is saturating the exchange sites of the surface soil and is moving downward in the soil profile.

Several tests involving turf response were also evaluated. Injection of potassium did not significantly alter the color or quality of turf compared to turf receiving no potassium fertilization or turf receiving surface applied potassium fertilization. No significant differences in clipping yields were found among treatments as well.

Clippings were also analyzed for potassium content. On several of the nine dates clippings were analyzed, clippings taken from plots receiving no potassium fertilization had significantly lower potassium contents. Although they were significantly lower, the values were still considered adequate and are well above values found in turf considered to be potassium deficient. On no dates were there significant differences in potassium content in clippings from plots receiving potassium fertilization, regardless of the rate or method of application. Average potassium content of clippings taken from non fertilized plots was approximately 23 g K per kg tissue and 26 g K per kg tissue for clippings taken from fertilized plots. Based on the lack of color or growth response from the application of additional potassium, regardless of method or rate of application, it is evident that there is sufficient potassium available in this sandy loam soil.

Table 1. Available soil potassium levels as affected by K fertilization. Sampled 12 Oct., after 1993 applications.[y] Study was initiated August, 1990.

	lbs. available K/Acre		
Annual treatment	0-3" zone	3-6" zone	6-9" zone
(lbs K20/1000 sq. ft.)			
check	96 c[x]	60 d	64 d
water injection	111 c	75 d	77 cd
3 lb surface	212 b	126 c	105 bc
3 lb inject	205 b	146 bc	112 bc
6 lb surface	292 a	181 b	126 b
6 lb inject	300 a	242 a	190 a

[x]Numbers in columns followed by the same letter are not significantly different at the 0.95 level of probability using Fisher's PLSD test.
dates of potassium fertilization treatments: August 21, September 18, 1993.

PHOSPHORUS INJECTION

A similar study was designed to evaluate phosphorus fertilization of a Penncross creeping bentgrass (*Argrostis palustris* Huds.) putting green grown on a modified loamy sand soil. The thatch layer of this stand was approximately 3/4 inches thick. Annual treatments were split into two separate applications, half applied in early August and half applied in late September (see Table 2): 1) control: 2) Hydroject aerification alone; 3) surface application of 2.5 lbs P_2O_5 per 1000 square feet; 4) subsurface injection of 2.5 lbs P_2O_5 per 1000 square feet; and 5) subsurface injection of 5.0 lbs P_2O_5 per 1000 square feet. Soil samples taken in early August and early November of each year were analyzed using the Olsen soil test procedure. Based on soil tests of the check plots, Michigan State Soil Testing Laboratory recommends an annual application of 3.0 lbs. P_2O_5 per 1000 square feet. Each treatment was replicated four times. Plot size was 8 feet by 10 feet. The phosphorus source for the 1990 and 1991 applications was calcium monophosphate, however, due to major difficulties dissolving this source into solution, 1992 and 1993 fertilization treatments were applied using phosphoric acid.

Results of Olsen soil tests taken after annual fertilization treatments in November 1993 are shown in Table 2. As with Table 1, the numbers shown are after 4 years of fertilization treatments and reflect the pattern seen in prior tests. Plots receiving no phosphorus fertilization had much lower soil phosphorus levels, especially in the upper levels of the soil profile due to mining or extraction by the turfgrass root system. These numbers are approaching those found in phosphorus levels in the thatch layer (approximately 3/4" thick) and upper soil (0-3"). Deeper in the soil profile in these plots. Phosphorus contents are much lower and are equal to plots receiving no phosphorus fertilization. Even after 4 years of phosphorus treatments, phosphorus applied to the surface still has not penetrated past the upper 3 inches of the soil profile. Clearly, injection of phosphorus is an effective method of increasing phosphorus levels deeper in the soil profile.

Turf response in this study was also evaluated using several different tests. Differences in root weights were found among fertilization treatments in the upper soil (0-3 inch zone) on several dates. Plots receiving surface phosphorus fertilization had higher root weights than did plots receiving injection fertilization. These differences may be attributed to salt injury of the roots from the injected phosphorus source (phosphoric acid). No differences in root weights were found among plots receiving surface phosphorus and plots receiving no phosphorus fertilization (check and WIC only plots). It should be noted that in this turf stand, 90% of the root mass was found to be in the upper 3 inches of the soil. No consistent differences in root mass were found among treatments in either the 3 to 6 inch depth zone or the 6 to 9 inch depth zone.

Injection of phosphorus at either rate did not significantly alter the color of the turf compared to surface application. Check plots consistently showed lower color ratings than plots receiving phosphorus fertilization due to a slight purple color which was more intense in the spring when soil temperatures were lower. The purple color indicates the turf is beginning to suffer from phosphorus deficiency. It is interesting to note that on several dates plots receiving water injection alone had significantly higher color ratings than check plots. No consistent differences in turf quality or clipping yields were seen among treatments.

Table 2. Soil phosphorus (Olsen) levels at different depths after 4 years of treatments, 4 Nov. 1993. Study was initiated in August, 1990.

	Available P, lbs /Acre			
Annual treatment	**Thatch Layer**	**0-3" zone**	**3-6" zone**	**6-9" zone**
(lbs P_2O_5/1000 sq. ft.)				
check	22 d[x]	23 c	39 c	51 b
water injection	22 d	21 c	37 c	50 b
surface 2.5	191 a	121 b	49 c	51 b
inject 2.5	88 c	117 b	138 b	91 a
inject 5.0	133 b	158 a	183 a	100 a

[x]Numbers in columns followed by the same letter are not significantly different at the 0.95 level of probability using Fisher's PLSD test.
1993 dates of phosphorus fertilization: August 12, September 22.

Clippings were also analyzed for phosphorus content. Clippings taken from plots receiving no phosphorus fertilization consistently had lower phosphorus contents than those taken from plots receiving surface or injected phosphorus. Comparison of clippings among fertilization treatments revealed consistent differences between surface and injection treatments at the low rate of phosphorus fertilization, with the clippings taken from the surface fertilized plots having significantly higher phosphorus contents. A possible explanation for this higher P content may be the differences between the two treatments in the root weight density in the upper 3 inches of the soil, where significantly higher root weights were found in plots receiving surface fertilization. It is questionable whether the difference in phosphorus content of the clippings are meaningful however, as the phosphorus contents of both sets of clippings are in the adequate range and no differences were evident on the surface in terms of color or quality. No differences in phosphorus content were seen between clippings taken from plots receiving surface phosphorus and plots receiving the high rate of phosphorus injection fertilization. Average phosphorus content of clippings taken from non-fertilized plots was approximately 21.0 g P per kg tissue. Clippings taken from plots treated with both the surface application and the high rate of injected phosphorus fertilization had and average of 4.5 g P per kg tissue while clippings taken from plots receiving the low rate of injection fertilization averaged approximately 3.5 g P per kg tissue.

NITROGEN INJECTION

A small study was initiated in June 1992 to investigate the effects of injection of nitrogen and how it compares to traditional surface fertilization. Due to its high degree of water solubility, urea was chosen as the nitrogen source for this study. The study was conducted on a Penncross creeping bentgrass putting green grown on a modified loamy sand soil. The stand had not received nitrogen fertilization the previous year.

Initial injection applications of nitrogen in 1992 revealed a localized green up response around the holes where the injection jets containing the urea solution penetrated the soil. This gave the turf a striped appearance which lasted 2 to 3 weeks. The response to the surface applications was a uniform green appearance. The striped appearance of the turf receiving injection application gave it significantly lower color and quality ratings than turf receiving surface applications. In 1993, the localized green response around the injection holes was not as dramatic and minimal striping of the turf was seen. Thus, no consistent differences between injected and surface treated turf were seen for color or quality.

Clippings were on several dates in 1992 and 1993 for growth and chemical analysis. In 1992, despite having lower color and quality ratings than plots receiving surface treatments plots receiving injection application of nitrogen had significantly higher clipping yields. One possible explanation could be decreased loss of nitrogen from volatilization and denitrification when it is injected. Similar results were found on several dates in 1993. Clippings had not been analyzed for nitrogen content at the time of publication.

Based on this research, high pressure water injection of potassium has the potential for increasing the levels of this nutrient deeper in the profile in soils where its limited availability may be affecting plant growth. This may be especially true in finer textured soils where the downward movement of potassium is more limited.

In sandy soils having adequate levels of potassium, the advantages of injection of potassium over traditional surface fertilization are less obvious.

Injection of phosphorus into finer textured soils may also have potential benefits. Limited downward movement of phosphorus in these soils will concentrate the phosphorus in the surface layer. Deeper roots can mine the phosphorus was seen after applications to the surface, however, an increase in deeper rooting from the injection of phosphorus was not seen, possibly due to the phosphorus source used. Phosphoric acid may have caused significant injury to the roots of turf receiving injection fertilization. Ammonium phosphate is a possible alternative source, although phosphorus rates would need to be adjusted to prevent ammonia toxicity to the turf.

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