annually) resulted in higher quality ratings than the lower N rate (3 pounds). The non-topdressed plots (check) ranked significantly lower than where topdressing treatments were applied. The check plots have developed a significant thatch layer which results in a lower quality turf. Using the surface hardness tester developed by John N. Rogers, III at Pennsylvania State University with Don Waddington, the non-topdressed plots were found to be considerably harder than where topdressing was applied. The impact readings were in the range of 71-74 on topdressed plots compared to an average value of 86 on the check plots. In spite of the thatch layer on non-topdressed plots, the soil below the thatch has become highly compacted while topdressed plots exhibit more resilience.

After three years of topdressing with sand or sand mixes it has become apparent that putting green turf quality ratings are improved after topdressing (Table 12). Peak turf quality occurs on plots topdressed in spring and fall after these treatments have been applied while those plots topdressed every 3 weeks tend to have a more consistent quality throughout the growing season. On a few dates topdressing with sand mixes (80% sand, 20% peat or 60% sand, 20% peat, 20% loam topsoil) turf quality ranked better than when sand was used alone. All topdressed plots consistently ranked better than non-topdressed plots.

Applying Sand Aid with sand when topdressing on a Penncross bentgrass putting green resulted in improved turf quality on certain dates during the growing season. Data are given in Tables 13 and 14 for studies established in 1985 on a modified loamy sand and dune sand, respectively. This was particularly evident on the green growing on sand. Interestingly, plots which were cored had less dew on October 17 than plots which were sand topdressed or not treated. This rating was taken during a period of frequent rainfall and low evapotranspiration so differential soil moisture was not considered a factor in the differential in dew formation.

SOIL TEST RESPONSES TO PHOSPHATE AND POTASH

Ongoing studies on Penncross bentgrass putting greens have been continued in 1988. Phosphorus and potassium applications outlined in Tables 15 and 16 have been applied since 1982. On the soil green (loamy texture) in Table 15 it is apparent that 2 pounds of P per 1000 sq ft annually are needed to increase P soil test over the check on this soil that had a very high P level at the beginning of the study in 1982. At such high P levels (375 pounds per acre) it is apparent that P has moved down into the 2-4 inch depth (194 pounds per acre) compared to lower P levels applied. Potassium also accumulates in this loamy soil as indicated by the K soil tests in Table 15.

On the green established on a 80% sand, 20% peat mixture (Table 16) there is some residual potassium in the 0-2 inch depth from applications made during establishment. Some potash has accumulated in the 0-2 inch depth but only at the higher rates of application has much potassium moved into the 2-4 inch depth.

Phosphorus applied to a Penncross creeping bentgrass growing on sand (Table 17) corrected a phosphorus deficiency with as little as 1 pound P applied annually. However, the P soil test of 11 pounds per acre is still considered deficient for good stress tolerance of the turf. It is clear that phosphorus does leach in the sand which has no organic matter added other than what the turf contributes. Regular, light application of phosphorus should

Table 15. Effects of phosphorus and potassium treatments on soil tests of soil based Penncross creeping bentgrass green at 0-2 and 2-4 inch depths. Hancock Turfgrass Research Center. Nutrients expressed as lbs per acre. Treatments initiated 1982. Samples collected August, 1988.

Treatment lbs P and K per 1000 sq ft	0-2 inch depth				2-4 inch depth			
	P	K	Ca	Mg	P	K	Cu	Mg
0	141b*	140c	2109a	373b	157b	67b	1813a	345b
0.5	159b	157bc	2109a	416a	153b	95b	1761a	348ab
1	213b	197b	2063a	420a	163b	90b	1761a	356ab
2	375a	298a	2147a	435a	194a	160a	1762a	371a

* Means followed by same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

Table 16. Effects of phosphorus and potassium treatments on soil tests of a sand/peat based Penncross creeping bentgrass green at 0-2 and 2-4 inch depths. Hancock Turfgrass Research Center. Nutrients expressed as lbs per acre. Initiated 1982. Samples collected August, 1988.

Treatment lbs P and K per 1000 sq ft	0-2 inch depth				2-4 inch depth			
	P	K	Ca	Mg	P	K	Cu	Mg
0	11d	107b	4925a	717a	5a	28d	3733a	370a
0.5	50c	162a	4894a	780a	16c	48c	3986a	438a
1	97b	176a	3668a	793a	31b	82b	4379a	521a
2	215a	170a	4491a	722a	82a	107a	3568a	430a

* Means followed by same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

Table 17. Effects of phosphorus treatments on soil tests of a sand based Penncross creeping bentgrass green at 0-2 and 2-4 inch depths. Hancock Turfgrass Research Center. Nutrients expressed as lbs per acre. Treatments initiated 1983. Samples collected August, 1988.

Treatment P	0-2 inch depth P	K	Ca	Mg	2-4 inch depth P	K	Cu	Mg
0	7c	34a	335a	63a	8c	17a	234a	37a
1 spring 1 fall	29b	36a	337a	63a	28b	20a	234a	37a
1 spring	11c	48a	396a	68a	9c	17a	211a	27a
2 spring 2 fall	63a	56a	526a	81a	43a	20a	290a	40a

* Means followed by same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

probably be used on sand greens. Although greens represent a small area of the golf course, use care to prevent loss of phosphorus by leaching when greens are adjacent to ponds, lakes or streams.

OTHER STUDIES

A cultivation study on Ram I Kentucky bluegrass at the Hancock Turfgrass Research Center was established in 1987 and will continue through 1989. Treatments include solid and hollow tine aerifying with large, medium and small equipment. No significant data have been taken on these plots as yet. Emphasis will be placed on effects of treatments on the thatch which exists on this turf. Off campus studies established in 1988 include a phosphorus and potassium response study on a very low nutrient testing soil at a condominium site near Detroit.

A series of different mixes of Kentucky bluegrass, perennial ryegrass and tall fescue were established on an unirrigated athletic field near Traverse City. The objective is to determine the establishment rate, adaptability to the environment and tolerance of moisture stress on this sandy soil. Of particular interest is how the tall fescue will survive in that environment.

WEATHER SUMMARY

One need not look at the weather statistics for 1988 to know it was a very unusual year for turf but a review of the numbers may be helpful in explaining why so much turf loss occurred. From mid-April through mid-July about one inch of rainfall occurred. Average rainfall during that period is over six inches. Temperatures were also well above normal with 37 days of high temperatures over $90^{o}F$ compared to an average of 11 per year. During the severe drought period we also experienced mostly sunny days (80% of possible in May through July), strong winds and low relative humidities. Evapotranspiration figures were much higher than normal with many days over .3 inch per day in May, June and early July, figures which would be considered more typical of desert areas. The longest days of the year occur during this time, contributing further to high evapotranspiration rates.

On irrigated sites turf managers had difficulty applying enough water to meet turf needs during the drought. When rainfall resumed and relative humidities rose to normal summer levels (just under .2 inch per day). Disease pressure became a significant problem on many turfs. Ironically, with higher than normal rainfall in August and September and the highest rainfall levels on record in October, we finished the year above normal in rainfall.

Unirrigated turfs turned dormant early in the summer. When rainfall came in July, crabgrass germinated and grew rapidly, responding to the high temperatures and without competition from desired grasses. Many turfs recovered reasonably well in August and September while others had suffered significant turf loss, necessitating overseeding or reestablishement practices. Unfortunately, many turfs were not improved in the fall, leaving a major need for overseeding or reestablishment in the spring of 1989.

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