(not shown) for Penncross, Penneagle and Emerald, respectively. The late fall applications ranked well much of the year considering the rate of nitrogen application.

The thickness of the "thatch" layer tended to be higher at higher rates of nitrogen but there was sufficient variability in the data (Tables 20-22) that differences were not significant. Similarly the amount of organic matter in the thatch tended to increase with the higher nitrogen levels, depending on the grass. Higher nitrogen levels reduced dollarspot numbers for Penncross and Penneagle but were not consistent on the Emerald plots.

Table 23 gives soil test information for two treatments from samples taken in Fall, 1987. Higher nitrogen decreased available phosphorus and potassium levels in both thatch and soil while calcium was reduced somewhat and magnesium was not affected. Levels of available nutrients in soil samples taken from below the thatch layer were markedly lower than in thatch. This may be due to fertilizers being applied on the surface (concentrating the nutrients at the surface) and to the lower density of the thatch layer as mentioned previously.

Another long-term nitrogen fertility study initiated in 1982 was completed on a Penncross creeping bentgrass green at the Hancock Turfgrass Research Center. Emphasis was on nitrogen carriers and timing. Carriers included IBDU, sulfur-coated urea, urea, ammonium nitrate, Milorganite and a greens quality commercial fertilizer, 18-4-10, provided by the Lebanon Chemical Company.

Numerous turf quality and color ratings taken during the year revealed no unusual responses to treatments. Those plots receiving 1 pound nitrogen as a late fall treatment (after growth ceases, about November 5 in central Michigan most years) ranked well throughout the year. Lower rates on greens might be advisable (1/2 to 3/4 pound N). As nitrogen rate was increased from 1 to 7.5 pounds per 1000 sq ft annually, the thickness of the thatch layer increased from 4.5 mm to 10.6 mm.

Soil tests on selected plots revealed few differences among nitrogen carrier effects. Those products not containing P had available soil P levels of 35-39 pounds per acre at the conclusion of the study while plots receiving P had higher soil test levels. Plots treated with 18-4-10 have received 6.2 pounds P_2O_5 over the 7 year period while those treated with Milorganite received 9.3 pounds P_2O_5, assuming the analyses of Milorganite is 6-2-0. The soil P tests at the conclusion of the study were 86 and 116 pounds per acre, respectively for 18-4-10 and Milorganite treated plots. Thus the soil P levels increased dramatically as a result of the continued use of P containing fertilizers.

Phosphorus Needs On Sodded Turfs

Turfs established on subsoils frequently suffer from a lack ofnutrients, especially nitrogen and phosphorus which are naturally very low in subsoils. A study to evaluate phosphorus response on a sodded Kentucky bluegrass lawn in Novi growing on a compacted subsoil was established in 1985. Treatments applied are outlined in Table 24. These treatments have not been repeated. Turf quality ratings in 1986 indicated response to applications of 1 pound of

P_2O_5 per 1000 square feet or more. Although the data do not conclusively prove the need for more P_2O_5, visual observations reflected improved turf at each higher increment of applied P_2O_5. Some improvement in turf density was observed as well.

Phosphorus tests in the soil on this site have consistently been very low and considered limiting for almost any plant growth. Samples taken from these plots in November, 1987 were separated into thatch and 0-2 inch soil depth subsamples. It is clear that most of the phosphorus continued to be found in the thatch. With a thatch depth of 1.5 inches or more the phosphorus is apparently bound in the thatch layer. Adequate phosphorus should be applied at the time of turf establishment to encourage rapid establishment on the site. Because this is often not done it is wise for lawn care companies and other turf managers on such sites to use at least 1 pound of P_2O_5 per 1000 square feet annually unless soil tests indicate otherwise. Soil tests as a basis for phosphorus recommendations are recommended on general sites. Along lakes and streams it is strongly recommended that soil testing be used to determine needs for phosphorus. This is helpful to reduce the possibility of phosphorus pollution of adjacent water bodies.

Soil Preparation Effects on Rooting of Sod

Frequently sodded turfs are established on highly compacted clayey subsoils. This results in poor rooting into the soil with a lack of moisture stress tolerance. This would likely increase susceptibility to patch diseases and other stress related maladies. A series of studies were initiated in 1897 to evaluate the effect of soil preparation practices on rooting of sod after laying. The plots were established on a compacted loam subsoil at the Hancock Turfgrass Research Center. The cultivation treatments outlined in Table 25 were made in August, 1987. The compacted treatment was rolled with a vibrating power roller previous to sodding. Hollow and solid tine cultivations were made with a Ryan's Greensaire using 1/2 inch hollow or solid tines. Rototilling was done to a 4 inch depth. Kentucky bluegrass sod was cut and laid in 1 square foot rooting boxes which were then placed on top of the treated plots. The boxes had plastic screen attached to the bottom of each. The boxes had a hook on each corner to which lifting cables were attached. Evaluation of rooting was based on the weight required to lift the rooting box and on the weight of soil lifted with the rooting box.

Data in Table 25 show the force required to lift the boxes 4 weeks after sodding. Clearly, rototilling and solid tine cultivation resulted in the best rooting. Hollow tine cultivation had somewhat lower lifting weights. This could have been due to less aggressive rooting caused by less loosening of the soil or to the soil cores left on the surface of the soil. These small cores may have created air pockets between the screen and the underlying soil, resulting in less effective rooting. The weight of soil lifted with the sod rooting boxes was well correlated with the force required to lift the sod rooting boxes (Table 25).

The effect of cultivation practice on the degree of loosening of the soil was evaluated with the use of a penetrometer. This is a tool which records the force required to push a rod into the soil. Data for penetrometer readings taken on these plots are given in Table 26. The lower the number for a given soil depth the looser is the soil. Solid tine cultivation and

Table 24. Effect of phosphorus applications on turf quality and phosphorus soil tests of a sodded Kentucky bluegrass turf growing on a compacted clay loam subsoil. Novi, MI. Averages for 3 replications. Phosphorus applied as 0-46-0 in 1985.

P applied	Turf quality rating (9=best)			Turf density (9=densest)		P test (lb/A)	
lbs/1000 sq ft	8/19/86	9/26/86	5/4/87	8/19/86	5/4/87	thatch	soil
0	5.2b*	5.5b	6.8a	5.3b	7.3a	35cd	2bc
1	8.8a	8.2a	7.0a	8.8a	7.5a	49bd	3ac
2	8.8a	8.7a	7.2a	9.0a	7.5a	56bc	4ab
4	8.5a	8.2a	7.2a	8.7a	7.3a	70b	4ab
8	8.5a	8.7a	7.0a	9.0a	7.7a	102a	5a

* Means in columns followed by the same letter are not significantly different from each other using Duncan's Multiple Range test (5%).

Table 25. Lifting force and soil removed with rooted soil in sod rooting study Measurements taken September 9, 1987. Averages for 4 replications.

Treatment	Lifting Force	Soil Weight
	Kg	Kg
Control	21.0a*	1.36a
Compacted	20.6a	1.50a
Hollow tine cultivation	28.4ab	2.27ab
Solid tine cultivation	35.8b	3.32b
Rototilled	34.6b	3.45b

* Means in columns followed by the same letter are not significantly different at the 5% level by least significant difference.

Table 26. Soil strength values as measured by penetrometer readings.

Treatment	Depth Inches				
	0-1	1-2	2-3	3-4	4-5
Control	40a*	86a	103a	120ab	143ab
Compacted	44a	95a	119a	143a	154a
Hollow-tine	21b	37b	57b	95bc	128bc
Solid tine	15b	17c	31c	79cd	119bc
Rototilled	13b	30bc	49bc	69	102c

* Means in columns followed by the same letter are not significantly different at the 5% level by least significant difference.