Using Manure Based Composts in Turf Management for Athletic Fields

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Abstract: Reducing use of chemical fertilizers on turf is important for human and environmental health. Use of compost is a promising alternative while ensuring turf quality. Manure-based compost used in turf maintenance was assessed on athletic fields at four sites in New York State. Dairy and poultry composts were top-dressed at two rates on replicated plots, and assessed five times over three years. The impact on soils and turf quality were analyzed. The use of manure-based compost on turf grass improved soil organic matter, increased the pH of acidic soils, and decreased bulk density, which are important in reducing injuries on playing fields. Long-term application, improved turf grass quality, reduced weeds and increased grass cover. Turf managers at the sites reported earlier spring green-up on compost-treated plots. Composted livestock manure applications resulted in excess soil phosphorus. High salt levels and immature composts had some short-term detrimental effects. After three years, there was an upward trend in the compost treated plots at all but one site. On sites where fields were poorly constructed or where field-use was very high, compost additions could not overcome these limitations and did not significantly improve turf quality. Lower Phosphorus composts may avoid P concentration with good results.

Key words: Manure-based compost, Turf, Turfgrass, Athletic fields, Compost quality, Soil health

1 Introduction

Turfgrass conditions on athletic fields are not only an aesthetic concern, but can have an effect on play and safety. Athletic fields are prone to compaction due to heavy traffic, use of the fields when conditions are wet, and the weight of vehicles used on the fields. Wet and/or hard surfaces can cause injury to the turf and the players. In a study conducted by Harper, et al, it was reported that approximately 20% of injuries occurring on high school football fields in Pennsylvania were considered field-related and could have been prevented or made less severe by more favorable field conditions [8]. Compaction restricts rooting depth, reducing the uptake of water and nutrients by plants, which can lead to poor growth and loss of turf cover. The addition of organic matter to the soil promotes aggregation of soil particles, increasing porosity and reducing bulk density to reduce compaction. Compost has been used successfully in establishing athletic fields [5] and as topdressing on golf courses [2, 23] and other turfgrass fields [9, 10, 11], but little research has been done on repeated compost applications on heavily used athletic fields. The objective of this study was to assess manure-based compost use on athletic fields, to add and maintain organic matter content, as well as examine the soil physical and chemical properties associated with repeated application.

The environmental problems associated with livestock manure and over-application to agriculture fields has encouraged farms to export manure for sale. Composting livestock manure adds value and can help farms move excess nutrients. Because composted manure generally has lower nitrogen (N) content than raw, and exists in a stable organic form, N losses during storage and field application are minimized. In a 2 year study, topdressing composted manure on Kentucky bluegrass increased the overall quality and clipping yield suggesting that compost acts as a slow-release fertilizer, providing nutrients throughout the growing season [9]. However, due to the high phosphorus (P) and potassium (K) content in livestock manure, repeated application over time may result in increased soil salinity, and P accumulation in the soil may possibly increase P runoff.

Building and maintaining organic matter (OM), especially through the addition of organic amendments improves the quality of soil, reducing compaction and crusting, and increasing drainage and water holding capacity [1]. Soil OM binds plant nutrients and micronutrients, so they are available for plant uptake. Soil pH also has an effect on the available of soil nutrients, most minerals and nutrients are more soluble or available in acid soils. A pH range of approximately 6 to 7 promotes the most readily available plant nutrients. Manganese (Mn) plays an important part in photosynthesis and deficiencies in soil Mn can cause poor growth. Iron deficiencies in turfgrass uptake results in iron chlorosis, which causes leaves to turn yellow or white and die [3].

The physical structure of the soil is important to keep good turf grass cover and favorable conditions on athletic fields. Bulk density is an indicator of compaction and reflects the soil's ability to function for structural support, water and soil aeration. Soil bulk density was reduced and water infiltration rate increased in turfgrass fields that were topdressed with composted manure [6]. In fields with restricted infiltration, there will be poor soil aeration, which leads to poor root function and plant growth, as well as reduced nutrient availability and cycling by soil organisms [21]. Soil organic matter affects infiltration through its positive effect on the development of stable soil aggregates. Soil with good aggregates will have pores and channels of many sizes that will allow rainfall to percolate, reducing erosion. Aggregates form readily in soil receiving organic amendments, such as manure [20 USDA].

Overall turfgrass quality (TQ) is a measure of aesthetics (i.e. density, uniformity, texture, smoothness, growth habit and color), and functional use. The most common way of assessing turfgrass quality is a visual rating system that is based on the turfgrass evaluator's judgment. Quality is based on 9 being best and 1 the lowest quality. A

rating of 6 or above is generally considered acceptable [13 NTEP]. Turf quality has been shown to improve with manure-based compost application as well as better fall and winter color [2, 9].

2 Materials and Methods

Field research was conducted at four sites in New York State (NYS) from September 2003 through July 2006. At each site there were six treatments and 3 replicates for each treatment distributed in a randomized block design. Treatments were applied five times. The composts used were analyzed prior to application for pathogen levels (fecal coliforms and *salmonella*), at Woods End Laboratories, Mt. Vernon, ME using EPA Method 1680 and 1682 for pathogens [4], and chemical/physical properties at Agricultural Analytical Services Lab at Penn State University, University Park, PA using TMECC methods [18]. Soil samples from the 18 plots at each site were taken for analysis of chemical and physical properties at the beginning (before application of treatments) and four additional times throughout the study. Turf quality ratings were done monthly during the growing season by trained turf professionals. Water infiltration rates were determined at the beginning and end of the study.

Sites

Two of the sites used in this study were located in Western New York in Clarence and Rochester, and two were in south eastern New York in Pine Island and Minisink. The sites were very different in their use and management. In Clarence, the experimental plot was on the far edge of a baseball field in a park, and was more like a lawn than a sports field in traffic intensity and use. It was mowed weekly at 2” and did not receive supplemental irrigation, nor was there any weed control. The soil texture is a loam (43% sand, 17% clay). In Rochester, the experimental plot was on a soccer field used by both schools and the community for about 2 games per week. The site started out with about 60% grass, 30% weeds and 10% bare spots. It had moderate traffic during the study. The field was mowed at 2 ½” approximately every 10 days and weed control was not used. The soil texture is a very fine sandy loam (61% sand, 10% clay). At Pine Island, the experimental plot was on a community recreation field that hosts about 25-30 baseball games per season and a summer recreation program from July to August. It was mowed weekly at 3”. The soil here is a coarse sandy loam (66% sand, 11% clay) that was established on rubble and had no more than 2 to 2 ½” of actual soil. At Minisink, the experimental plot was on a high school sports field with excessive use and highly compacted soils. It was used for high school football practice and games. It also served as the daily physical education site. The field was mowed twice a week at 2 to 2 ¼”. Weed control was used. The soil texture is a sandy loam (68% sand, 8% clay).

Composts

Two types of manure-based compost (dairy and poultry manure) from four different suppliers were used in this project. Table 1 shows the average range of properties of composted dairy and poultry manures used at the four sites for the three years of the study. The compost properties listed in the table below can have an effect on the suitability of that compost for use on turf. The moisture content can have an effect on the ability to spread the compost on the turf. At Pine Island and Minisink, where the moisture content of the dairy compost was above 60%, it was difficult to spread evenly without getting clumps, and the poultry, although easy to spread, tended to be dusty. The more alkaline pH in the poultry compost used in Clarence and Rochester indicated that the compost could have been more mature. There was a definite ammonia smell with some of the applications. This caused a problem for those spreading it, as well as those playing on it. The salt concentration of the poultry compost at Minisink caused some problems with “burning” (dehydration of) the turf. Organic matter was high (approximately 50% or greater) for all composts except the dairy compost used in Clarence and Rochester. This was due to the fact that this compost was made in windrows on a soil pad. The phosphorus level was high in both poultry composts. The carbon to nitrogen (C:N) ratio was good for all composts.

Table 1 Average range of properties of composted dairy and poultry manures used over three years

Compost Property	Dairy compost for Clarence and Rochester	Poultry compost for Clarence and Rochester	Dairy compost for Pine Island and Minisink	Poultry compost for Pine Island and Minisink
Moisture (%)	33 – 60	27 – 39	67 – 75	20 – 27
pH	7.9 – 8.5	8.8 – 8.9	7.4 – 7.9	6.9 – 8.0
Soluble salts (mmhos/cm)	1.5 – 4.3	7.7 – 9.9	1.0 – 4.4	10.9 – 13.1
Organic matter (% dm basis)	23 – 39	44 – 56	49 – 64	35 – 43
Total nitrogen (% dm basis)	1.2 – 1.6	1.8 – 2.2	1.6 – 1.9	2.5 – 3.0
Phosphorus (% dm basis as $(P_2O_5)^3$)	1.0 – 1.4	5.0 – 6.4	1.1 – 2.1	4.0 – 5.7
C:N ratio	11 – 12	11 – 14	16 – 21	7 - 9

Design

Each field had a 10.4 x 21.3 meter area designated for the experiment. There were eighteen 3 x 3 m plots with a 0.6 meter buffer around each for 3 replicates of 6 treatments (Figure 1). Each site received 5 applications of compost applied on a volume basis of 6mm (65 m^3 ha^{-1}) and 12 mm (130 m^3 ha^{-1}). Because composts varied in moisture content and they were applied on a volume basis, the dry weight and thus the quantity of nutrients, organic matter and other constituents added varied. Treatments started in September of 2003 and continued in June and September of 2004 and 2005. The treatments were as follows: 1) 6 mm layer of poultry manure compost (LP), 2) 12 mm layer of poultry manure compost (HP), 3) 6 mm layer of dairy manure compost (LD), 4) 12 mm layer of dairy manure compost (HD), 5) Fertilized control with no compost (FNC) and 6) Unfertilized control with no compost (NFNC). All plots, except the unfertilized control received nitrogen fertilizer (no phosphorus) at the rate of 0.5 kg/92.9 square meters. At Minisink, however, after September 2003, all plots, including the unfertilized control, received fertilizer.

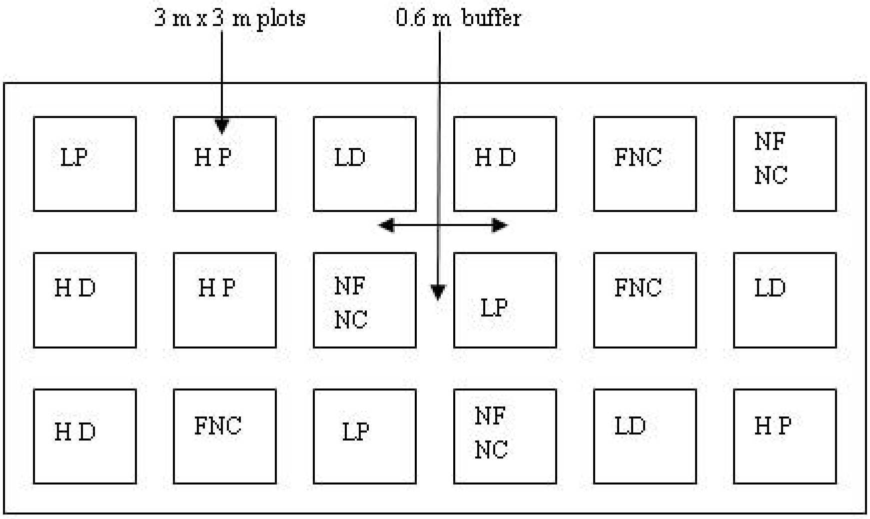

Fig.1 Plot design at each site

Prior to application of compost, soil samples were taken for chemical (pH, manganese, iron, phosphorus and organic matter) and physical analysis (bulk density and aggregate stability). Analysis of chemical properties was conducted at the Cornell Nutrient Analysis Laboratory, Ithaca, NY using Natural Resources Conservation Service Soil Survey Laboratory Methods [22]. Analysis of physical properties was conducted at the Cornell Soil Health Laboratory, Ithaca, NY using methods described in their Soil Health Manual [7]. The plots were then core aerated. Compost was weighed and applied on a volume basis (two bushel baskets for the 6 mm rate and 4 for the 12 mm rate) and raked into an even layer on the plots. The plots were then core aerated a second time to help work the compost into the soil. Unfertilized control plots were then covered with tarps and fertilizer was applied to the remaining plots. Water infiltration rates were determined at the beginning of the study in September 2003 and at the end in June 2006. Individual plots at all sites were rated approximately monthly during the growing season for percent grass, weeds and bare, and overall turfgrass quality rating using the National Turfgrass Evaluation Program (NTEP) method [13 NTEP].

Statistical Analysis

Statistical analysis of soil chemical properties, soil physical properties, turf quality data and infiltration data at the 4 sites were analyzed using the S-PLUS® statistical package [15]. Each site was analyzed separately. Changes over time for each treatment were analyzed by linear regression and subsequent analysis of variance of the linear regression. Treatment differences at each sampling were analyzed using analysis of variance (ANOVA) for multiple comparisons with Tukey corrections, considering a significance level of $p < 0.05$. Statistical analysis of the difference between the treatment means was conducted only for those treatments where the analysis of variance indicated a difference. All data was observed for normality prior to analysis using a normal quartile plot. When data in its raw state was not fairly normal, a log 10 transformation of the response variable was made and those numbers were used for analysis.

3 Results and Discussion

Soil Chemical Properties

Organic Matter

Healthy productive soils have a good supply of organic matter. Organic matter serves as a reservoir of nutrients and water in the soil, aids in reducing compaction and surface crusting, and increases water infiltration into the soil. Because turf has little opportunity for the automatic return of much organic matter to the soil, it will eventually be depleted if it is not added. For turf, values between 7 and 10% are considered acceptable. Table 2 shows the percent change in soil organic matter obtained over 3 years. Soil organic matter levels in the compost treated plots increased significantly compared to the control plots for all compost types and levels at all sites, except Clarence, where the LD compost treatment did not cause a significant increase in organic matter over the course of the study. Compost application, especially poultry compost greatly improved the organic matter content at these sites. However, it took repeated applications of compost to see a significant difference. These results are consistent with improved soil OM from both surface application and incorporation of composted beef feedlot manure applied over 3 years [24].

Table 2 Percent change in soil organic matter over 3 years by treatment at each site

Treatment	Clarence	Rochester	Pine Island	Minisink
LP	19.8^{bc}	30.7^{b}	181.9^{ab}	53.6^{a}
HP	57.4^{a}	78.1^{a}	218.8^{a}	68.2^{a}
LD	21.7^{bc}	32.6^{b}	101.4^{c}	43.5^{a}
HD	38.7^{ab}	51.8^{ab}	129.9^{bc}	43.8^{a}
FNC	-12.0^{c}	2.3^{c}	27.7^{d}	4.2^{b}
NFNC	-5.1^{c}	1.0^{c}	23.4^{d}	0.0^{b}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

pH

Soil pH has an effect on the availability of soil nutrients. Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils. A pH range of approximately 6 to 7 promotes the most readily available plant nutrients. Compost application did not have an effect at Clarence and Rochester where the pH started at 7.4, averaged over all plots, and ended at about 7.6. At Pine Island the application of poultry compost over three years did significantly increase the pH from 6.1 to 7.2 for the 6 mm (LP) treatment plots and from 5.0 to 7.3 for the 12 mm (HP) treatment plots. The addition of 12 mm dairy compost (HD) at Pine Island increased the pH from 5.9 to 7.0. At Minisink, all of the plots, including the control plots, showed an increase in pH over the course of the study (from 6 to 7). Johnson, et al [10] did not find any significant difference in pH among Kentucky bluegrass plots topdressed with 0, 33, 66 or 99 m^3 ha^{-1} composted dairy manure, but there was only one application made in that study. Considering that organic matter buffers the soil against swings in pH, the additional organic matter at Pine Island and Minisink could account for the increase in pH which took several applications to occur. This same increase in pH was seen by Wortmann and Walters when composted beef cattle manure was applied over 3 years [24].

Iron and Manganese

Both manganese (Mn) and Iron (Fe) are micronutrients whose availability can be affected by pH. In both cases, the higher the pH, the less available are Mn and Fe. Iron is essential for chlorophyll synthesis and can thus help with turfgrass color [3]. Acceptable iron levels are approximately 2.5 to 5.0 mg/kg [13]. All sites fell within those levels except Pine Island, where soil iron levels started at approximately 1.0 mg/kg (Table 3). The iron levels in soil on the poultry compost treated plots appeared to go up, although not significantly, but did reach closer to acceptable levels, and it was reported that the best color occurred in the poultry treated plots. Other sites also reported that there was earlier spring green-up, and the best color occurred in the poultry treated plots. At Minisink and Rochester, the soil iron levels remained the same on the compost treated plots, while they decreased over time on the plots that received no compost.

Table 3 Soil Iron (mg/kg) at Pine Island over Time by Treatment

	LP	HP	LD	HD	FNC	NFNC
Fall 03	0.9	1.0	1.0^{b}	1.0	1.6	1.0^{a}
Fall 04	2.0	1.7	1.4^{a}	1.8	1.1	1.0^{a}
Spring 05	2.3	1.3	1.3^{ab}	2.8	0.6	0.4^{b}
Fall 05	1.2	1.7	1.0^{b}	1.1	1.9	0.5^{b}
Spring 06	2.2	2.2	1.6^{a}	1.9	1.5	1.2^{a}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Manganese plays a role in photosynthesis and helps to suppress both leaf and root diseases. When the pH is below 7.0, adequate levels of manganese are in the range of 4.6 – 12 mg/kg, while levels of 12 – 20 are considered high and above 20 very high. At pH 7.0 and above, 5.1 – 15 mg/kg is adequate, 15 – 50 high and above 50 very high. The soil manganese level increased by between 24 and 190% with the use of poultry compost at all sites bringing the soil Mn to high and very high levels (Table 4). At Clarence, where soil Mn went from 17 to 38 mg/kg, and Rochester, where it went from 18 to 43 mg/kg, only the HP plots were affected, and it took 3 years for the increase to be evident. Since the pH was above 7 at all times at Clarence and Rochester, manganese levels were adequate in the dairy and control plots, while the poultry plots were high. At the other 2 sites, the increase was immediate and was seen at both levels of poultry applications (100% increase for LP and 140 to 190% increase for HP). At both Pine Island and Minisink, where pH was below 7, manganese levels were high for all plots at all times. The combination of acceptable iron and manganese levels in the compost treated plots, especially poultry, most likely contributed to the report of better color on those plots.

Table 4 Percent change in soil manganese over 3 years by treatment at each site

Treatment	Clarence	Rochester	Pine Island	Minisink
LP	24.2^{b}	51.1^{b}	108.0^{b}	100.2^{b}
HP	83.8^{a}	168.7^{a}	190.5^{a}	144.3^{a}
LD	19.6^{b}	26.9^{b}	18.4^{c}	18.2^{c}
HD	24.5^{b}	39.3^{b}	-5.0^{c}	15.8^{c}
FNC	15.1^{b}	15.3^{b}	18.5^{c}	8.1^{c}
NFNC	16.1^{b}	29.7^{b}	-4.0^{c}	30.8^{c}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Phosphorus

Phosphorus (P) in the soil is important for both agronomic production and environmental protection. Levels of 4.5 mg/kg P are considered to be high and levels approaching 50 mg/kg may become an environmental issue as they are more prone to discharge P to the environment in water runoff. Soil phosphorus started high at Pine Island and Minisink and was optimum in Clarence and Rochester (Table 5). There was an immediate effect on soil P levels from the poultry compost, but it took longer to see an effect from the dairy compost. By the end of three years, all compost treated plots had significantly greater soil P levels than non-compost treated plots at three sites. At Minisink though, as P levels increased in the non-compost treated plots as well, only the ½” compost levels (both poultry and dairy) had greater soil P. Many other studies have found this same increase in soil P [6, 9, 10, 14, 16], especially since composting reduces the amount of N in manure, so the ratio of plant-available nitrogen to phosphorus is narrowed. This means that there will likely be an accumulation of P when compost is repeatedly applied based on crop needs. At the same time, however, several studies have shown that runoff and the concentration of P in runoff are decreased with the use of compost [6, 17].

Table 5 Beginning and Ending Average Soil Phosphorus Levels (mg/kg) by Treatment

	Clarence		Rochester		Pine Island		Minisink	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
LP	3.3	164.6^{a}	7.4	179.8^{a}	15.1	237.3^{a}	40.4	194.9^{ab}
HP	4.7	160.5^{a}	6.6	135.1^{a}	11.1	236.9^{a}	40.9	274.0^{a}
LD	4.2	142.8^{a}	5.8	86.7^{a}	17.3	158.5^{a}	35.3	173.3^{ab}
HD	5.8	94.6^{a}	7.3	125.0^{a}	16.3	181.6^{a}	36.0	228.5^{a}
FNC	5.7	11.0^{b}	7.0	11.0^{b}	20.1	38.1^{b}	33.4	73.0^{b}
NFNC	4.3	9.0^{b}	6.0	9.5^{b}	14.5	38.9^{b}	30.4	68.3^{b}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Soil Physical Properties

Bulk Density

Bulk density is an indicator of soil compaction. As a rule of thumb, a medium textured soil with about 50%

pore space will have a BD value of 1.33 g/cm^3 [20]. Due to the texture of the soils at the sites, a BD value of < 1.6 is ideal for plant growth. The soil BD at Clarence and Rochester started at approximately 1.4 g/cm^3, but the BD at Pine Island and Minisink was approximately 1.6. The addition of organic matter is considered to have a profound effect on soil physical properties. It stabilizes and holds soil particles together as aggregates, helps soil to resist compaction, promotes water infiltration and reduces runoff. It also improves the soil's ability to store and transmit air and water, and makes the soil more friable and easier for roots to penetrate. Johnson, et al [10] found that one application of compost on Kentucky Bluegrass decreased bulk density by 5.6% over the control, and Tejada, et al [17] found that the addition of compost applied annually over 4 years reduced the bulk density of soils by 20% compared to the control. This study found at least that. Table 6 shows the change in soil bulk density over the study period for all 4 sites. Bulk density decreased over the course of the study on all plots, including the controls, due to the core aeration performed as part of the experiment, however one or more of the compost treated plots at each site had a significantly greater decrease in bulk density than at least one of the control plots, indicating that the addition of organic matter helped improve bulk density.

Table 6 Percent decrease in soil bulk density over 3 years by treatment at each site

	Clarence	Rochester	Pine Island	Minisink
LP	25.0^{b}	26.0^{ab}	14.9^{ab}	35.0^{ab}
HP	20.8^{b}	36.4^{b}	16.1^{ab}	39.7^{b}
LD	17.9^{ab}	24.1^{ab}	14.6^{ab}	32.7^{ab}
HD	24.6^{b}	28.2^{ab}	20.6^{b}	39.2^{b}
FNC	15.8^{ab}	16.4^{a}	0.9^{a}	25.2^{ab}
NFNC	9.3^{a}	16.7^{a}	3.8^{ab}	20.4^{a}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Aggregate Stability

Aggregate stability refers to the ability of soil aggregates to resist disruption when outside forces (usually associated with water) are applied. Since aggregation affects erosion, movement of water, and plant root growth, it is desirable to have aggregates that are stable against rainfall and water movement. A value of 20% is considered low, and 70% is considered high. Although other studies have found an increase in aggregate stability through the addition of compost [17] and aggregate stability generally increases as organic matter increases [19], this study showed no change in aggregate stability over the time period for which this analysis was done. We did not analyze aggregate stability until spring 2005 (after there had already been 3 compost applications) and the soil aggregate stability at that time ranged from 45 to 75% on all plots at all sites. By the end of the study, in the spring of 2006, the only significant difference in aggregate stability for any compost treated plots over the controls occurred at Rochester, where HP and HD plots had 39 and 38% aggregate stability compared to only 19% for NFNC plots.

Water Infiltration Rate

The infiltration rate of a soil is the rate at which water soaks into it, measured in this study as centimeters of water soaking in per hour (cm/h). If the steady infiltration is very low, less than 0.5 cm per hour, even very gentle rain falling on moist medium will cause surface ponding or runoff of water. The surfaces of playing fields will remain mushy for days after rain, allowing play to cause much damage to the turf. Infiltration rate is a useful indicator of aeration in the soil. Good aeration is probable if the steady infiltration rate is greater than 2 cm/h. Poor turf growth can be traced to poor aeration of the root zone. The approximate steady infiltration rate of loam soils is between 0.5 and 2.0 cm/h, depending on the type of loam. Initial infiltration rates at all sites were within or greater than this range (Table 7). Once again, although several studies have found that the addition of compost increases water infiltration rate [6, 16] and the addition of organic matter is supposed to improve infiltration [21], this was not observed here. Final infiltration rates were generally higher for all plots at all sites (especially at Minisink, where the rate ranged from 4.7 to 7.9 at the end of the study), but there were no significant differences by treatment between the final rates or the change in rate from beginning to end.

Table 7 Initial infiltration rate (cm/h) by treatment at four sites

	Clarence	Rochester	Pine Island	Minisink
LP	12.7	6.3	18.5	1.4
HP	10.2	5.6	25.2	1.1
LD	15.3	4.4	6.3	1.0
HD	9.4	7.6	11.3	1.3
FNC	6.4	6.3	12.1	1.1
NFNC	11.8	4.3	3.7	1.3

Visual Appearance

Turfgrass Quality

Overall turfgrass quality (TQ) is a measure of aesthetics (i.e. density, uniformity, texture, smoothness, growth habit and color), and functional use [12]. The most common way of assessing turfgrass quality is a visual rating system that is based on the turfgrass evaluator's judgment. Quality is based on 9 being best and 1 being poorest. A rating of 6 or above is generally considered acceptable. The average TQ rating over all plots at the beginning of the study was just under being considered acceptable at Clarence (5.4), Rochester (5.3) and Pine Island (5.6), and low at Minisink (3.8). Figure 2 shows the change in turf quality ratings over time by treatment at each of the four sites. In Clarence, all treatment plots except the unfertilized control showed a significant increase in TQ over time indicating that there was no additional improvement at this low-use site with the application of compost over and above that of applying a nitrogen fertilizer. In Rochester, all compost treated plots showed a significant increase in TQ over to 5.7 for the LP and HP plots, 5.9 for the LD plots and 5.8 for the HD plots. The plots that received no-compost did not increase TQ over time, but remained at 5.3 for NFNC and 5.4 for NFC. The same was true for Minisink; all compost treated plots showed an improvement in TQ over time while no-compost treated plots did not. Long-term compost application at these two medium use sites showed a benefit to turfgrass quality. Johnson, et al [9] also showed that compost application consistently improved turf quality over the control, but in another study by the same authors [10], TQ did not improve with only one application of dairy manure compost. At Pine Island, however, all of the plots, both compost and no-compost treated, decreased in turf quality over time. Compost application could not overcome the limitations imposed by this poorly constructed field.

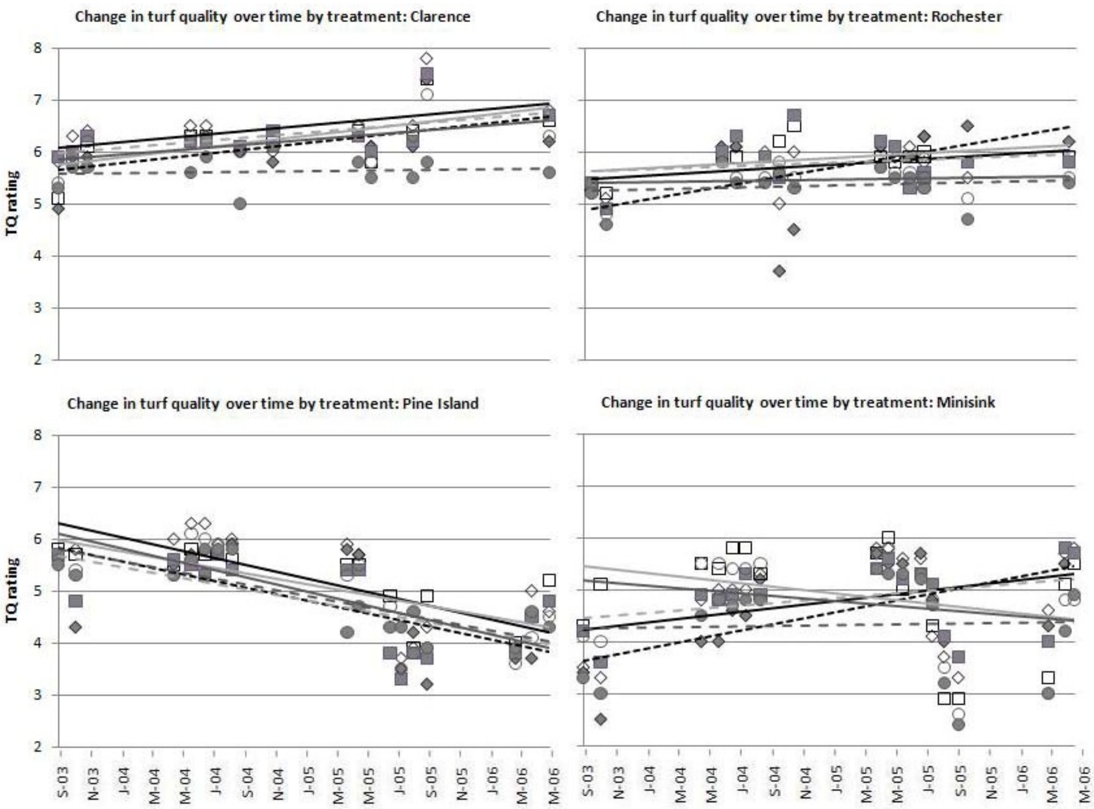

Fig.2 Change in turf quality ratings over time by treatment for Clarence (upper left), Rochester (upper right), Pine Island (lower left) and Minisink (lower right).

Percent grass cover

Table 8 shows the percent change in grass cover over 3 years by treatment at each site. Poultry compost (with its high soluble salt concentration) tended to burn the grass in the first month after application when applied at the high rate, but after that , percent grass increased with the use of compost at three of the sites. At Clarence, the HP and LD plots showed significantly greater grass coverage than the NFNC plots, but so did the FNC plots. At Minisink, both poultry compost doses, as well as the no-compost plots showed significantly greater change in grass coverage than the dairy compost plots, and at Rochester, grass coverage decreased for the no-compost treated plots, but increased for LP, HP and HD plots. Once again, at Pine Island, where the field was poorly constructed, compost application was not able to overcome its limitations in terms of grass coverage.

Table 8 Percent change in grass cover over 3 years by treatment at each site

	Clarence	Rochester	Pine Island	Minisink
LP	60.0^{cd}	20.9^{a}	-8.2^{a}	330.7^{a}
HP	350.2^{a}	4.5^{b}	-14.6^{a}	253.7^{ab}
LD	183.8^{b}	-3.5^{b}	-18.5^{ab}	45.3^{c}
HD	40.3^{cd}	3.0^{b}	-33.1^{b}	27.5^{c}
FNC	128.5^{bc}	-16.5^{c}	-18.5^{ab}	152.7^{bc}
NFNC	24.0^{d}	-23.2^{c}	-20.9^{ab}	319.3^{a}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

4 Conclusions

The use of manure-based composts on athletic fields improves soil organic matter content, increases the pH of acidic soils closer to neutral, and decreases bulk density. Over the long-term it can improve turfgrass quality, although in some cases, fertilizer without compost had similar impacts. In addition, many of the managers at the sites reported earlier spring green-up on the compost treated plots, as well as better color in the poultry compost treated plots. The improvements made by the application of compost to playing fields can help to prevent, or make less sever, injuries occurring to athletes that are related to field conditions, but these improvements may take time. High salt levels and immature composts can have short-term detrimental effects such as burning of the grass and exacerbation of weed problems. Application of manure-based composts increases soil P levels high enough to cause concern that elevated runoff or leaching losses of P may occur. Before using any compost, it would be advisable to test the soil to see where deficiencies lie and to test the compost to make sure it is not too high in soluble salts and has a moisture content and particle size that will be conducive to application.

References

[1] Cooperband, L. Building soil organic matter with organic amendments. A resource for urban and rural gardeners, small farmers, turfgrass managers and large-scale producers. Center for Integrated Agricultural Systems, College of Agriculture and Life Sciences, University of Wisconsin-Madison. Available online at: http://www.cias.wisc.edu/wp-content/uploads/2008/07/soilorgmtr.pdf, 2002.

[2] Dinelli, F. D. Using composts to improve turf ecology. *USGA Green Section Record* **37 (**1999), (4):16-18.

[3] Duble, R. L. Iron chlorosis in turfgrass. Texas A&M University. Available online: http://plantanswers.tamu.edu/turf/iron.html, accessed 2/22/07.

[4] US Environmental Protection Agency. Methods and guidance for the analysis of water, version 2 (includes US EPA Series 500, 600, 1600 methods). Available online at: http://www.ntis.gov/products/epa-water-methods.aspx, 1998.

[5] Farrell, M. Improving playing fields with compost. *BioCycle* **39** (1998), (4):62.

[6] Gaudreau, J. E., Vietor, D. M. and White, R. H., et al. Response of turf and quality of water runoff to manure and fertilizer. *Journal of Environmental Quality* **31** (2002), 1216-1322.

[7] Gugino, B. K., Idowu, O. J. and Schindelbeck, R R., et al. Cornell soil health assessment training manual, second edition, Cornell University, Geneva, NY (2009), 1-58.

[8] Harper, J. C., Morehouse, C. A. and Waddington, D. V., et al. Turf Management, Athletic-Field Conditions, and Injuries in High School Football. Pennsylvania State University Department of Crop and Soil Sciences - Cooperative Extension, available online at: http://turf.psu.edu/extension/factsheets/turfgrass-management-football, accessed 2/2007.

[9] Johnson, G. A., Qian, Y. L. and Davis, J. G. Effects of compost topdressing on turf quality and growth of Kentucky bluegrass. Online. *Applied Turfgrass Science* doi:10.1094/ATS-2006-0113-01-RS, 2006.

[10] Johnson, G. A., Davis, J. G. and Qian, Y L., et al. Topdressing turf with composted manure improves soil quality and protects water quality. *Soil Science Society of America Journal* **70** (2006), 2114-2121.

[11] Landschoot, P. Using composts to improve turf performance. *Grass Management* **1** (1996), (1):32-34.

[12] Morris, K. N. and Shearman, R. C. NTEP Turfgrass evaluation guidelines. Online. *National Turfgrass Evaluation Program*, http://ntep.org/information.htm.

[13] Sartain, J. B. Iron nutrition improves turf's mettle. *Grounds Maintenance* **34** (1999), (8):24-28.

[14] Soldat, D. J. and Petrovic, A. M. Soil phosphorus levels and stratification as affected by fertilizer and compost applications. Online. *Applied Turfgrass Science* doi: 10.1094/ATS-2007-0815-01-RS, 2007.

[15] S-PLUS® 7. Computer software. Insightful Corporation, Seattle, WA, 2005.

[16] Spargo, J. T., Evanylo, G. K. and Alley, M. M. Repeated compost application effects on phosphorus runoff in the Virginia Piedmont. *Journal of Environmental Quality* **35** (2006), 2342-2351.

[17] Tejada, M. and Gonzalez, J. L. Influence of organic amendments on soil structure and soil loss under simulated rain. *Soil and Tillage Research* **93** (2007), 197-205.

[18] US Composting Council. Test Methods for the examination of composting and compost (TMECC), US Composting Council, Rokonkoma, NY, 2002.

[19] USDA Natural Resources Conservation Service. Soil Quality Indicator Information Sheets: Aggregate Stability. Available online at: http://soils.usda.gov/sqi/assessment/assessment.html#indicator_sheets, 2008.

[20] USDA Natural Resources Conservation Service. Soil Quality Indicator Information Sheets: Bulk Density. Available online at: http://soils.usda.gov/sqi/assessment/assessment.html#indicator_sheets, 2008.

[21] USDA Natural Resources Conservation Service. Soil Quality Indicator Information Sheets: Infiltration. Available online at: http://soils.usda.gov/sqi/assessment/assessment.html#indicator_sheets, 2008.

[22] USDA Natural Resources Conservation Service Soil. Survey Laboratory Methods Manual. Available online at: ftp://ftp-fc.sc.egov.usda.gov/NSSC/Lab_Methods_Manual/SSIR42_2004_view.pdf, 2004.

[24] Wilkinson, J. F.. Applying compost to the golf course. *Golf Course Management*, March (1994), 80-88.

[24] Wortmann, C. S. and Walters, D. T.. Phosphorus Runoff during four Years following Composted Manure Application. *Journal of Environmental Quality*, **35** (2006), 651-657.