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Article

Amending Subsoil with Composted Poultry Litter-II: Effects on Kentucky Bluegrass (*Poa pratensis*) Establishment, Root Growth, and Weed Populations

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Abstract: Turfgrasses established on a soil deprived of the topsoil during construction disturbance often have low levels of density and uniformity making them susceptible to weeds. Field experiments evaluated composted poultry litter incorporation into subsoil on Kentucky bluegrass growth attributes and subsequent effects on weed populations. Top 20 cm of topsoil was removed and composted poultry litter was incorporated at 0.1, or 0.2, or 0.4 cm/cm-soil into the exposed subsoil to a depth of 12.7 cm before seeding or sodding, and was compared to N-fertilized (50×10^{-4} kg m^{-2}) and control plots. A greenhouse experiment was also conducted to determine the effect of compost incorporation rates on turfgrass rooting depth. Turfgrass yield from seeded plots with compost incorporation rates of 0.1, 0.2, and 0.4 cm/cm-soil, were 200%, 300%, and 500% more, respectively, compared to control plots. Composted poultry litter incorporated at 0.1 cm/cm-soil resulted in at least 70 seedlings in 7.6 cm^{-2}, which was sufficient to attain 100% turf cover. Higher incorporation rates in seeded plots maintained lower numbers of buckhorn plantain and red clover than untreated plots. Rooting depth also increased linearly with compost rates. Overall, compost treatments were able to maintain superior turf cover and quality compared to conventionally fertilized or control plots.

Keywords: alternative; cultural; integrated weed management; preventative; housing development lawn

Nomenclature: large crabgrass; *Digitaria sanguinalis* (L.) Scop.; buckhorn plantain [*Plantago lanceolata* L.]; Kentucky bluegrass; (*Poa pratensis* L.); dandelion; [*Taraxacum officinale* Weber in Wiggers]; red clover [*Trifolium pratense* L.].

1. Introduction

Establishing turfgrasses in a suitable medium is paramount to its vigor and ability to tolerate weeds. During construction disturbance, topsoil is often either lost or mixed with subsoil low in organic matter and available nutrients. Furthermore heavy equipment may compact the soil and make conditions unfavorable for turfgrass establishment and growth in these disturbed soils [1]. Turfgrasses established on such disturbed soils are not as dense or uniform as those established in a proper medium, and are hence more susceptible to weed infestations. Amending such disturbed soils with composted organic wastes can improve the physical and chemical properties of soil and provide a more suitable medium for establishing turfgrasses.

An increasing urban waste stream and restrictions on the methods of waste disposal have fueled resurgence in the use of composted organic wastes that have the potential to serve as useful resources in turfgrass management [2]. Various kinds of organic wastes such as biosolids, municipal sewage, poultry litter (PL), sewage sludge (SS), and yard trimmings (YT) have been used as amendments for turf areas. Land application of poultry litter is considered to be a feasible, practical, and environmentally sound method of disposing this waste product [3]. Larney and Janzen [4] reported that hog manure and poultry manure could restore productivity to eroded soils by substituting for lost topsoil.

Turfgrass establishment was significantly enhanced by the incorporation of composted biosolids into disturbed soil [1]. Other beneficial effects of compost as an amendment and topdressing in turf have been well-documented [5–9]. Turf grown in compost-amended soils established faster with improved density, and color [10,11], and with larger root systems [12]. Municipal solid waste has been shown to increase the root-mass of St. Augustine grass [*Stenotaphrum secundatum* (Walter) Kuntze] in a sandy soil [13]. Various compost and organic materials helped recuperation of cored turf, suppression of dollar spot, and reduction in thatch [14]. Composts have also proved to be an effective nutrient source to increase tall fescue (*Festuca arundinacea* Schreb.) yield [15,16]. Angle *et al.* [17] demonstrated that composts improved the rate of establishment and appearance of tufrgrasses grown from seed and sod.

Municipal solid waste and biosolids compost applied to soils may suppress weeds due to the presence of certain phytotoxic compounds and high CO_2 levels resulting from biological activity [18,19]. The process of composting generates heat to levels sufficient to kill inherent weed seeds such as ivyleaf morning glory [*Ipomoea hederacea* L.], barnyardgrass [*Echinochloa crus-galli* L.], and common purslane [*Potulaca oleracea* L.] [18]. Composted manure may contain fewer weed seeds compared to non-composted forms of the same, thereby offering dual benefits of improving soil fertility levels and reducing weed seed banks.

The ability of composts to suppress certain diseases has also been documented [20–22]. Composted poultry litter decreased the susceptibility of Kentucky bluegrass (*Poa pratensis* L.) to *Drechslera* leaf spot disease [23]. The competitive ability of turf established using composts may also provide for a sustainable system to manage other pests. Although different composts have been used as amendments to study effects on turfgrass growth and establishment, limited information is available on the usefulness of composted poultry litter (CPL) to amend subsoil for turfgrass growth, establishment, and weed control. The objectives of this research were to evaluate (a) the effects of CPL incorporation into subsoil on the establishment and subsequent growth attributes of Kentucky bluegrass (*Poa pratensis* L.), (b) its consequent effects on weed population levels, and (c) the effects of CPL on Kentucky bluegrass root growth.

2. Results and Discussion

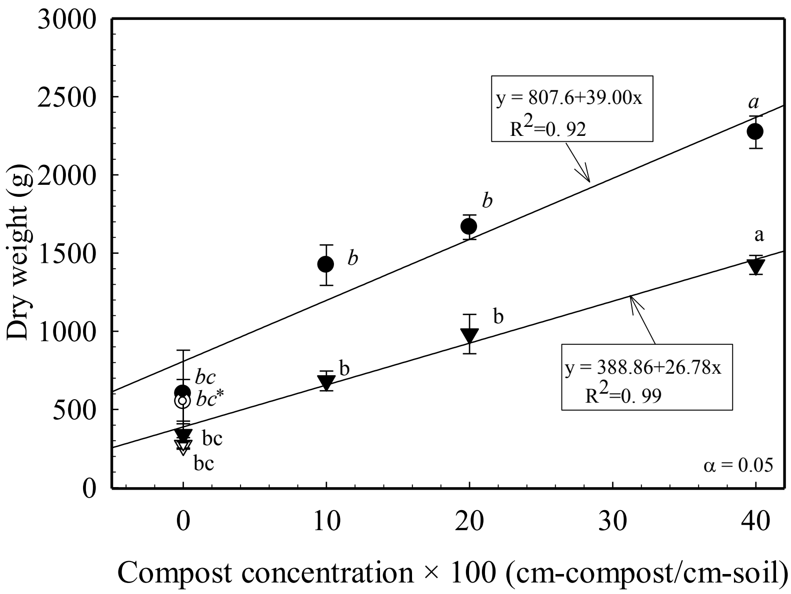
2.1. Dry Matter Yield

Turfgrass growth, as measured by clipping dry weight (yield), was found to be greater for compost-amended plots (Figure 1) than for control and fertilized plots. A positive linear relationship was observed between compost application rates and yield of Kentucky bluegrass (sodded, R^2 = 0.92; seeded, R^2 = 0.99). Dry weights of clippings from sodded and seeded plots increased by approximately 500% and 300% with the application of 0.4 and 0.2 cm-compost/cm-soil, respectively compared to that of plots that received no compost (control) and fertilizer (Figure 1). Turfgrass yield attributes showed similar trends but were higher in sodded plots compared to seeded plots. This could be explained by the well-established turf in sodded plots as compared to newly-germinated seedlings in seeded turf.

Enhanced growth of turfgrass in compost-amended plots may be attributed to higher levels of mineral nutrients provided by compost compared to fertilizer (or untreated plots) and the overall effects of compost on soil physical and chemical properties, findings related to which are available elsewhere [24]. In compost-amended plots, the higher amounts of available nutrients (N, P, Ca, Mg, and K) coupled with the increased soil pH and CEC improved the fertility status of the subsoil. Apart from an increase in total N content of soil by adding CPL, its low C:N ratio (10:1) and high rate of mineralization may have also increased the pool of available N [25]. Landschoot and McNitt [12] and Gentilucci *et al.* [10] attributed the poor establishment of turf following the addition of compost with high C:N ratio (>30:1) to increased rates of immobilization and denitrification.

Our results are also comparable to other research findings. Wood *et al.* [26] observed a 556% increase in bermudagrass [*Cynodon dactylon* (L.) Pers.] yields with 2.2×10^{-4} kg m^{-2} PL application compared to yield from control plots. Lucero *et al.* [3] observed curvilinear increase in the yields of a blend of Kentucky bluegrass and tall fescue with increasing rates of PL. Loschinkohl and Boehm [1] observed a 244% increase in turfgrass dry weight as a result of compost treatments. These results corroborate our study where we observed an increase of 318% in dry weight of turfgrass clippings, compared to untreated plots, from plots that received CPL at 17.5 kg m^{-2}, providing N at 0.34 kg m^{-2}.

Figure 1. Effect of incorporating composted poultry litter into top 12.7 cm of subsoil on Kentucky bluegrass clipping dry weight for ● sodded compost; ○ sodded fertilizer; ▼ seeded compost; and ▽ seeded fertilizer plots; * Means with same letters are statistically insignificant based on Fisher's Protected LSD test ($P \leq 0.05$) (italicized statistics correspond to sodded treatments).



2.2. Turf Cover

All compost-treated plots showed 50% higher turf cover than control plots in April 2004 (Figure 2). Fertilized plots had 20% more bare area compared to the control plots. Significant improvements in turf cover were observed one year after establishment (September, 2004). The high (100%) turf cover in compost-treated plots as opposed to fertilized plots (76%) may be attributed to the changes in soil physical and chemical properties as a result of CPL addition [24]. In this study, no significant differences in turf cover were recorded due to varying compost rates indicating that 0.1 cm-compost/cm-soil application was sufficient to achieve healthy turf (Figure 2). Our results agree with those of Lawson [27] who reported increase in turf cover following compost application.

A positive linear relationship ($R^2 = 0.99$) was observed between compost rates, and seedling density (Figure 3). Based on our regression model, it was estimated that 0.1 cm-compost/cm-soil applied to disturbed soils resulted in at least 70 seedlings per 7.6 cm^2, which was sufficient to attain 100% turf cover. Turf cover indicated a linear increase in seedling density with compost rates, whereas turf cover as measured by percent bare area (Figure 2) indicated increases in turf cover from control up to 0.2 cm-compost/cm-soil. There was a positive correlation (r = 0.80) between the two variables indicating that seedling density may be used to predict turf cover. It is important to note that seeded plots took an average of one year to achieve 100% cover regardless of compost application rate. We speculate that the poor turf cover observed in fertilized plots (as compared to control plots) may be due to unhealthy green-up and related susceptibility to certain fungal diseases or due to the acidifying effects of the fertilizer used [23,24].

Figure 2. Effect of incorporating composted poultry litter into top 12.7 cm of subsoil on seeded Kentucky bluegrass cover for ● April-seeded, compost; ○ April-fertilizer; ▼ Sept.-sodded, compost; and ▽ Sept.-fertilizer; * Means with same letters are statistically insignificant based on Fisher's Protected LSD test ($P \leq 0.05$) (italicized statistics correspond to sodded treatments).

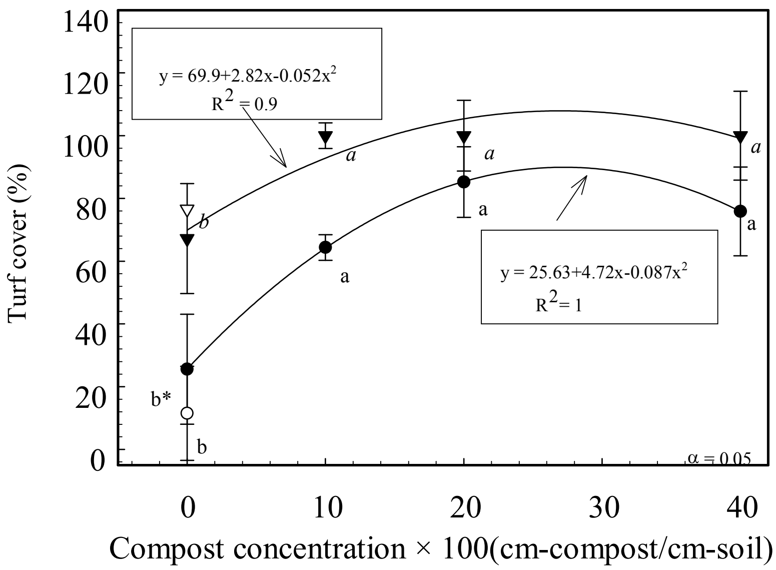
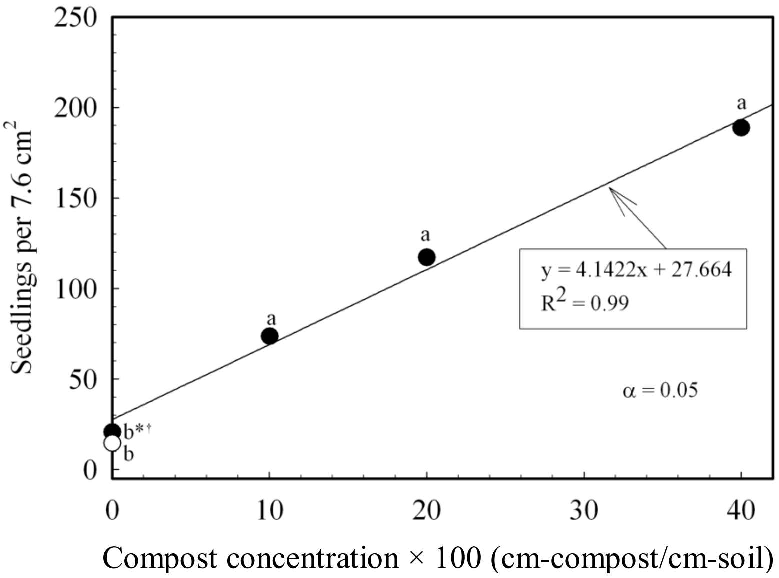


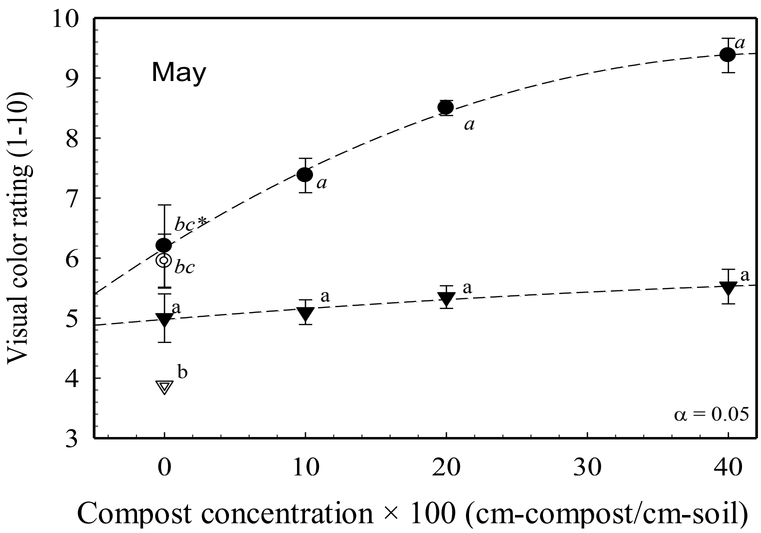
Figure 3. Effect of incorporating composted poultry litter into top 12.7 cm of subsoil on Kentucky bluegrass seedling density; * Means with same letters are statistically insignificant based on Fisher's Protected LSD test ($P \leq 0.05$); † values for standard error were small ranging between 0.21 (min.) to 0.82 (max.) and hence are not shown in figure.



2.3. Turf Color

Turf color ratings were recorded in May and August 2004. In May 2004, compost-treated turf secured significantly higher color ratings compared to control and fertilized plots in sodded turf but not in seeded turf (Figure 4a). The second color rating taken on 26 August 2004 indicated that all compost-treated plots were greener in color than untreated plots (Figure 4b). The most desirable turf color (dark green) was observed in plots with the 0.2 and 0.4 cm-compost/cm-soil rates. We speculate that the better color of compost-treated plots compared to fertilized plots, may be attributed to the difference in the higher amount of mineral nutrients in the compost as well as its ability to increase the availability of micronutrients, especially Fe^{2+} [28,29]. The ability of compost to enhance the turf color was also reported by other researchers [2,11,27,29].

Figure 4. (**a**) Effect of incorporating composted poultry litter into top 12.7 cm of subsoil on Kentucky bluegrass color ● sodded compost-May; ○ sodded fertilizer-May; ▼ seeded compost-May.; and ▽ seeded fertilizer-May; (**b**) Effect of incorporating composted poultry litter into top 12.7 cm of subsoil on Kentucky bluegrass color ● sodded compost-August; ○ sodded fertilizer-August; ▼ seeded compost-August; and ▽ seeded fertilizer-August; * Means with same letters are statistically insignificant based on Fisher's Protected LSD test ($P \leq 0.05$) (italicized statistics correspond to sodded treatments); † values for standard error were small ranging between 0 (min.) to 0.59 (max.) and hence are not shown in figure.



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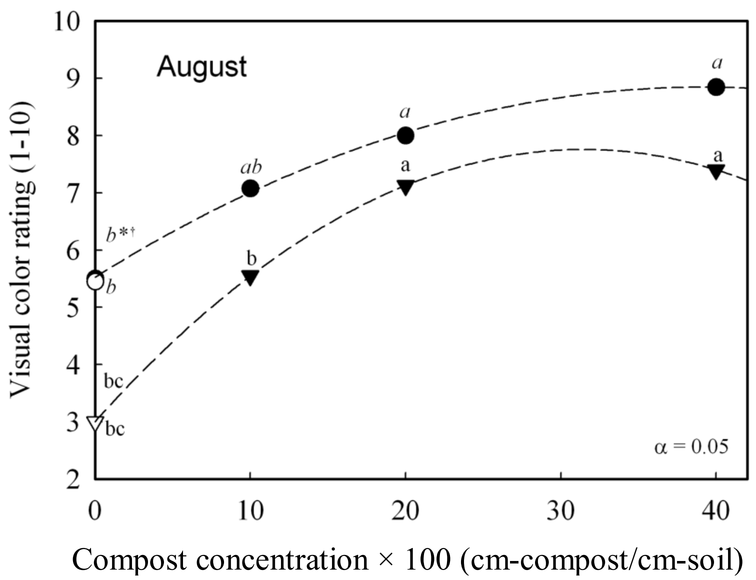

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2.4. Turf Height

Turf height was measured prior to mowing for both seeded and sodded plots during April 2004. Turf height was not affected by the various treatments in seeded plots (Table 1). In sodded plots, turf height was higher in compost-treated plots than control or fertilized plots. This increase in turf height is explained by the better establishment of turf in compost-treated plots. Both seeded and sodded plots that received fertilizer treatment showed 30% and 8% reduced turf height than control plots, respectively (Table 1). This effect may be attributed to lower pH in fertilized plots and their subsequent effects on turf growth and establishment [24].

Table 1. Effect of compost treatments on seeded and sodded turf height.

		Height	
Treatment	**Incorporation rate** (cm-compost/cm-soil)	Seeded	Sodded
		------------ cm ------------	
Compost	0.1	5.49 a*	9.41 a
Compost	0.2	7.64 a	9.04 a
Compost	0.4	7.18 a	10.36 a
Fertilizer	-	4.37 ab	5.8 b
Control	-	6.27 a	6.33 ab

* Means followed by the same letters are not significantly different based on Fisher's Protected LSD test ($P \leq 0.05$).

2.5. Weed Populations

Counts of naturally occurring weeds were recorded in May and that of seeded weeds in September 2004. Natural weed populations consisted of white clover, dandelion [*Taraxacum officinale* Weber in Wiggers], buckhorn plantain [*Plantago lanceolata* L.], red clover [*Trifolium pratense* L.], and yellow woodsorrel [*Oxalis stricta* L.] (Tables 2 and 3). Compost treatment at the higher incorporation rates in seeded plots was able to maintain lower numbers of buckhorn plantain than control and fertilizer-treated plots (Table 2). Naturally occurring red clover were also lower in the plots that received CPL at the high rate compared to control plots. However, contrary to our hypothesis, there were more dandelions in plots that received CPL, especially at lower rates, compared to control and fertilized plots. This may be attributed to increased levels of germination and establishment of dandelion seed deposited in plots that received compost, compared to untreated plots, after the experiment was initiated. In general, individual weed counts were found to decrease with increasing rates of compost, whereas no differences in weed counts were observed between controls and fertilized plots (Table 2). Similar trends were not observed in sodded plots which may be attributed to fewer bare spots in the sod (Table 3).

Relatively fewer than expected weeds were observed in the experimental plots overall. The top 10 to 15 cm of soil contains viable seeds, which germinate under suitable conditions or after breaking dormancy. Seed bank sizes have been estimated at about 1 million seeds/m^2 under dense infestations [30] and out of the 2 million seeds produced by a horseweed [*Conyza canadensis*] plant, about 80% of the total germinable seeds were found within the top 2 cm of soil [31]. The relatively low populations of weeds in our study may be attributed to the removal of most of the weed seed bank residing in the topsoil. Total absence or limited presence of a weed seed bank reduces weed infestations in newly established turfgrass considerably [32].

Out of six weed species seeded, only large crabgrass germinated significantly (Tables 2 and 3). Lower weed germination rates were observed in sodded plots compared to seeded turf plots. Seeded plots that received 0.4 cm-compost/cm-soil had more large crabgrass seedlings compared to the other treatments (Table 2). It is speculated that large crabgrass was able to respond similarly to turfgrass to higher levels of nutrients and other positive attributes offered by CPL. However, sodded plots that did not receive compost recorded more crabgrass seedlings compared to compost-treated plots (Table 3).

In our study, amending subsoil with compost resulted in better turf establishment, which consequently gave rise to a healthy and well established turf, with a tendency to out-compete a few weed species present in low numbers. Due to low numbers of weeds and their variability we failed to prove our hypothesis conclusively. However, long-term effects on weed populations based on turf establishment could not be documented due to the brevity (one growing season) of this experiment. Other researchers have observed weed suppression followed by compost application [33–35].

2.6. Turf Rooting Depth

Turfgrass root depth, as measured by observing presence/absence of roots at 1-mm increment to a depth of 10 cm, was found to increase linearly ($R^2 = 0.89$) with increasing rates of compost (Figure 5). These findings indicate that the benefits of CPL, as outlined earlier, were expressed by the turf roots. Our results concur with data reported by Chandran who determined similar responses by St. Augustine grass roots to composts based on municipal waste products [13]. A positive correlation existed between rooting depth and turf yield ($r = 0.94$) (Figure 6), indicating a strong relationship between a well-established root system and overall turf vigor.

Our study demonstrated that CPL can be used effectively to establish turfgrasses on disturbed soils. This is of particular benefit in the establishment of new lawns on nutrient-deficient sub-soils where turf is slow to establish resulting in a weak turf. Compost applications resulted in an improvement in turf quality, growth, and establishment, as well as a deeper root system. Although high quality turfgrass ratings and low populations of certain weeds were obtained when 0.4 cm-compost/cm-soil amendment was applied, 0.1 cm-compost/cm-soil application was considered to be adequate for overall establishment of healthy turf. No deleterious effects of compost on turfgrass quality were observed, even at the highest compost application rate of 0.4 cm-compost/cm-soil. Our results demonstrated reduced numbers of certain weeds and no suppression of certain other weed species due to incorporation of CPL into the soil profile. The use of composts to improve the establishment and quality of turfgrasses and to manage certain weeds preventatively can prove to be an environmentally safe alternative for the disposal of an increasing amount of urban solid wastes.

Table 2. Number of naturally occurring weeds and manually seeded large crabgrass seeds in seeded turf plots.

		Weed Count					
		Natural					Seeded
Treatment	**Incorporation rate** (cm-compost/cm-soil)	TRFRE *	TAROF	PLALA	OXAST	TRFPR	DIGSA
Compost	0.1	265 a ‡	198 a	132 b	115 a	14 a	0 b
Compost	0.2	172 b	147 a	79 b	21 ab	0 a	35 b
Compost	0.4	26 bc	67 b	8 c	2 b	0 a	128 a
Fertilizer	-	135 b	1 b	238 a	33 ab	3 a	0 b
Control	-	124 b	45 b	240 a	73 a	3 a	0 b

* TRFRE-*Trifolium repens* L., white clover; TAROF-*Taraxacum officinale* G.H. Weber ex Wiggers, dandelion; PLALA-*Plantago lanceolata* L., buckhorn plantain; TRFPR-*Trifolium pratense* L., red clover; OXAST-*Oxalis stricta* L, yellow woodsorrel; DIGSA-*Digitaria sanguinalis* (L.) Scop., large crabgrass; ‡ Means followed by the same letters are not significantly different based on Fisher's Protected LSD test ($P \leq 0.05$).

Table 3. Number of naturally occurring weeds and manually seeded large crabgrass seeds in sodded turf plots.

		Weed Count					
		Natural					Seeded
Treatment	**Incorporation rate** (cm-compost/cm-soil)	TRFRE *	TAROF	PLALA	OXAST	TRFPR	DIGSA
Compost	0.1	10 a ‡	121 a	1 a	3 a	3 b	32 b
Compost	0.2	1 a	101 ab	0 a	13 a	17 b	34 b
Compost	0.4	12 a	148 a	0 a	1 a	7 b	48 b
Fertilizer	-	10 a	311 a	6 a	4 a	104 a	128 a
Control	-	6 a	284 a	11 a	8 a	5 b	102 a

* TRFRE-*Trifolium repens* L., white clover; TAROF-*Taraxacum officinale* G.H. Weber ex Wiggers, dandelion; PLALA-*Plantago lanceolata* L., buckhorn plantain; TRFPR-*Trifolium pratense* L., red clover; OXAST-*Oxalis stricta* L, yellow woodsorrel; DIGSA-*Digitaria sanguinalis* (L.) Scop., large crabgrass; ‡ Means followed by the same letters are not significantly different based on Fisher's Protected LSD test ($P \leq 0.05$).

Figure 5. Effect of incorporating composted poultry litter into subsoil on Kentucky bluegrass root depth; * Means with same letters are statistically insignificant based on Fisher's Protected LSD test ($P \leq 0.05$) (italicized letters correspond to sodded treatments).

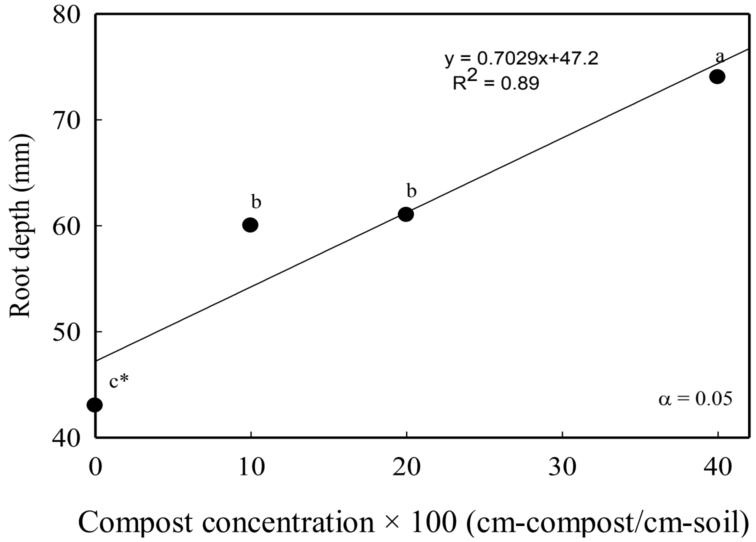
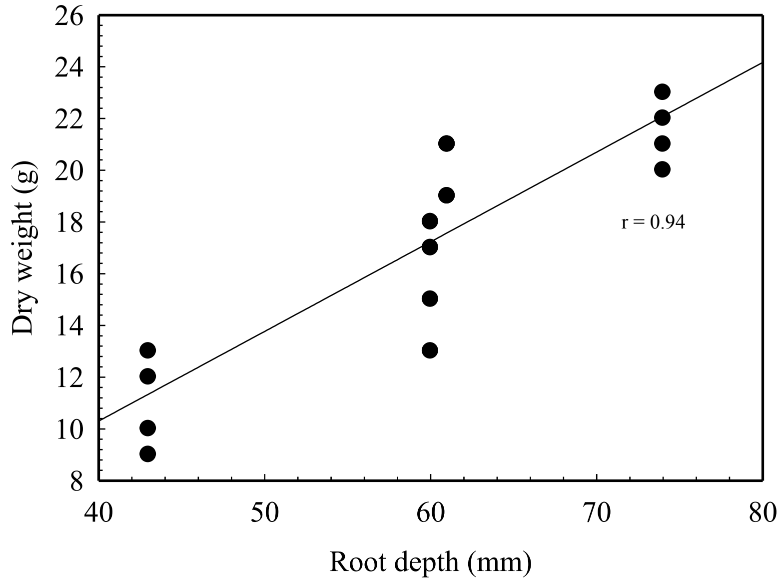


Figure 6. Correlation analysis between turfgrass root depth and turf yield (expressed as dry weight).



3. Experimental Section

Field Experimentation and Location: Field experiments were established in fall 2003 at the West Virginia University, Agronomy Farm, Morgantown (39.66 N, 79.90 W). The soil was a Dormont silt loam (fine-loamy, superactive, mixed, mesic Oxyaquic Hapludalfs). Existing topsoil containing the A-horizon was removed (to a depth of 20 cm), and the subsoil was exposed to simulate construction disturbance. The exposed subsoil was tilled uniformly to a depth of 12.7 cm using a rototiller and plots 4.6 m × 3.1 m separated by 0.6 m alleyways were delineated. The compost utilized for the experiments was derived from poultry litter, with wood chips and cardboard as a primary source of carbon, and had a ratio of 2:2:2 (N, P_2O_5, K_2O) (Borderline LLC, Baker, WV). Other chemical characteristics of the

CPL were described by Mandal *et al.* [25]. Treatments consisted of CPL incorporated to a depth of 12.7 cm at rates of 0.1 cm-compost/cm-soil, 0.2 cm-compost/cm-soil, and 0.4 cm-compost/cm-soil (equivalent to 4.3 kg m^{-2}, 8.75 kg m^{-2}, and 17.5 kg m^{-2}, respectively), control (untreated), and fertilized plots {20-27-5 (N, P_2O_5, K_2O) fertilizer; applied at 50×10^{-4} kg m^{-2}} based on turfgrass nutritional requirements. The fertilizer was applied using a drop spreader and incorporated lightly (1 cm) into the soil using a rake. The three compost treatments provided N at 0.086, 0.172, and 0.34 kg m^{-2}, whereas the fertilizer treatment provided N at 0.001 kg m^{-2}. Based on the different depths to which the compost and the fertilizer treatments were incorporated, it was estimated that the compost provided N at 6.77×10^{-7} kg cm^{-3} whereas the fertilizer provided N at 10^{-7} kg cm^{-3}

The experimental design was a randomized complete block with turf type (seeded or sodded) and amendment treatments arranged factorially. All the treatments were replicated four times. Twenty plots were seeded on 7 October 2003 with Kentucky bluegrass seeds (Scotts "Classic"; 97.75% Kentucky bluegrass, 0.05% other crop seeds, 2.11% inert matter, 0.09% weed seeds) at the rate of 50×10^{-4} kg m^{-2} using a drop spreader. Seeded plots were covered with straw mulch in order to retain soil moisture and to offer protection from predators. The 20 remaining plots were sodded manually on 10 October 2003 with Kentucky bluegrass sod var. "Plush" (Rich Farm, Smithfield, PA, USA). Plots were irrigated uniformly as needed during establishment. After establishment, the turf was maintained at a height of 7.6 cm using a reel-mower and clippings removed. The 2004 growing season was cool and wet; a total of 68.12 cm of precipitation was recorded from May to September 2004. No supplemental irrigation was provided to the plots in 2004.

Turfgrass Establishment and Growth: Turfgrass establishment was assessed by recording percent turfgrass cover and by quantifying seedlings (in sodded plots ground cover remained 100% regardless of different treatments). Percent bare-spots were measured twice during the growing season (April and September 2004) by placing two transects diagonally in each plot and measuring the bare spots linearly along each transect. Any bare spot greater than 5 cm in diameter was included in the measurement. Seedling counts were recorded within a 7.6 cm^2 grid placed randomly at eight different locations within each plot.

Turfgrass growth was quantified by recording the turf yield and height from each plot. Turf height was measured in April 2004 by recording 25 random measurements within each plot to calculate mean height. To quantify turf yield, clippings were collected at a mowing height of 7.6 cm, from May to October 2004, each time the turf grew to a height of 10–12 cm; dry matter yield was reported as the sum of 12 harvests. Clippings were collected from the center of each plot within an area of 3.2 m^2; remaining area was mowed and clippings discarded. Fresh clippings were dried for 4 day at 60 °C, and yield data were recorded on a dry-weight basis. Visual assessment of turf color, being a qualitative parameter, was carried out twice between May and August 2004 by two individuals. Scoring was carried out on a scale of 1 to 9, with a mean score of 1 indicating brown/dead turf, 5 indicating a moderate green color, and 9 indicating a dark green color.

*Weed Population*s: Approximately 500 seeds of black medic [*Medicago lupulina* L.], large crabgrass [*Digitaria sanguinalis* (L.) Scop.], green foxtail [*Setaria viridis* L.], London rocket [*Sisymbrium irio*], white clover [*Trifolium repens* L.], and witchgrass [*Panicum capillare* L.] were seeded linearly in each plot, in rows 0.3 m long for each species. Weed seeding was carried out in June

2004. Counts of the natural weed population and the manually seeded weeds were recorded in May and September 2004, respectively.

Turfgrass Root Growth: Greenhouse experiments were established in fall 2004 to determine the effects of CPL on turfgrass root growth. Containers, (20.3 cm in height and 12.7 cm in diameter), were filled 3/4 with air-dried subsoil collected from the experimental site. Treatments applied to the field study were simulated in the greenhouse. Composted poultry litter was incorporated to a depth of 12.7 cm at the three rates and was compared to fertilizer and control treatments. The media in all containers were allowed to settle uniformly by tapping each container consistently and allowing them to undergo a wet cycle. On August 2004, all containers were seeded manually with Kentucky bluegrass (Scotts "Classic"; Kentucky bluegrass 97.75%, 0.05% other crop seeds, 2.11% inert matter, 0.09 weed seed) seeds at the rate of 50×10^{-4} kg m^{-2}. Containers were irrigated prior to seeding. Containers were then covered with straw mulch and irrigated daily until seeds germinated, after which containers were watered as needed. Kentucky bluegrass was allowed to establish for a period of six months, under natural light and temperature ranging between 18 °C (min) to 35.5 °C (max). Supplemental heat was provided during winter to maintain the temperature at 18 °C. Turf was maintained at a height of 7.6 cm using a pair of clippers. Fresh clippings were dried for 4 day at 60 °C, and yield data were recorded on a dry weight basis. In February 2005, the study was terminated to quantify rooting depth. Containers were saturated with water 1 h prior to separating the container from the soil/root mass. Containers were placed upside down and tapped gently to remove the soil and root mass. Soil mass containing roots was then sliced lengthwise into halves from the middle, and the roots were exposed. A measuring scale was placed along the side of soil mass and presence/absence of roots was observed at 1-mm increments to a depth of 10 cm.

E*xperimental Design and Statistical Analysis:* The experimental design for the field experiment was a randomized complete block with turf type (seeded or sodded) and amendment treatments arranged factorially. Greenhouse experiments were set as a randomized complete block design. All treatments were replicated four times. Analysis of variance was used to analyze the data using PROC GLM™ (general linear models) procedure of the Statistical Analysis System (SAS Institute, 2002). Fisher's Protected Least Significant Difference (LSD) test, with a probability value of 0.05, was used to separate treatment means. Associations between turfgrass root depth and clippings dry weight were examined by correlation analysis (Sigma Plot™, 8.2).

4. Conclusions

In conclusion, our research demonstrated several benefits from incorporating composted poultry litter into subsoil on turfgrass establishment and pest management. Specifically, we noted 2- to 5-fold increase in turfgrass yield as a result of compost incorporation rates of 0.1 to 0.4 cm/cm-soil, compared to control plots. Composted poultry litter incorporation of 0.1 cm/cm-soil was sufficient to attain 100% turf cover. Compost treatments at the higher incorporation rates were able to maintain lower populations of certain weeds. However, dandelions and large crabgrass populations were noted to be higher in compost-treated plots compared to control and fertilized plots. Rooting depth increased linearly with compost incorporation rates based on greenhouse studies.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

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