INSECT PEST POPULATIONS AND GROWTH RATES ASSOCIATED WITH COMPOST TOP-DRESSED, FAIRWAY CUT TURFGRASS

A Thesis

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ABSTRACT

Golf courses face many problems in maintaining playable turf. Fertility, disease, and insects are among the most demanding. For the past fifty years chemicals have been the first choice in managing pests and maintaining fertility. In this study compost top-dressings were evaluated for potential insect population suppression. Composts have proven to be effective in reducing the incidence of plant diseases, however the incorporation of large amounts of organic matter into the soil, thatch complex provides an ample food source for thatch feeding black turfgrass ataenius beetles, *Ataenius spretulus* (BTA). Populations of BTA, earthworms (Oligochaeta) (EW), black cutworm, *Agrotis ipsilon* (BCW), fall armyworm, *Spodoptera frugiperda* (FAW), and sod webworms (Pyralidae: Crambinae) (SWW) were all monitored for two years using disclosion techniques on bentgrass, *Agrostus palustris*, 'Penncross' maintained under fairway conditions. BTA, FAW, BCW, SWW, and EW represent the most important invertebrate pests on golf courses. In addition to the population monitoring, the potential nutritional effects of compost were determined by measuring the growth rates of FAW larvae by feeding them exclusively on clippings obtained from the experimental plots.

Statistical analysis of the invertebrate data revealed no consistent significant differences over the two year duration of this study nor were there any differences in the growth rates of the FAW when feed compost-treated turfgrass clippings.

To my wife Samantha for picking me up when I was down, giving me strength when I was weak, for grounding me when I got too high, and checking me when I got out of control; and to my daughter Alex for reminding me that there is no better time than the wide-eyed wondrous time spent with a child; and to all the people who touched me and believed in me, especially when I did not.

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CHAPTER 1

LITERATURE REVIEW

1.1.1 History of Turfgrass Management and Compost Usage

Management of turfgrass as an industry can be documented to have originated in 1885 in the United States. This year is significant because it was the beginning of the United States Golf Association (USGA), the first golf course in South Manchester, Connecticut was established, and the United States Department of Agriculture (USDA), Department of Botany was created (Fay 1996, Couch 1995). The introduction of turfgrass management brought with it the need to understand the dynamics of the turfgrass system. This understanding includes, but is not limited to, nutritional requirements, pathogens, pests, management tolerances, and physical limitations of the system.

Early turfgrass management strategies concentrated on furthering knowledge and techniques for maintaining turf at high quality (color, density, root development) and fitness (ability to withstand stress and wear). Mowing improved with the availability of tractors to replace the horse-drawn mowers that were being used until the early 1920s (Ferguson 1921). This allowed for mowing of turf several times weekly and reduced the amount of damage caused by operator error as well as damage caused by horses hooves while pulling the mowers (Harban 1924). Understanding the influence of proper water usage on turf also made significant advances during the 1920s. W. P. Miller (1924) developed an overview of the benefits of drainage. Miller proposed proper drainage would result in: 1. elimination of excess ground water thereby reduced puddling damage; 2. removal of surface water and excess groundwater from the soil, thus increasing plant-available water; 3. maintenance of soil to produce a sponge-like condition that can handle greater rainfall amounts while reducing the amount of surface water run-off; 4. increased penetration of air into soil, by reducing or correcting compaction, which promoted bacterial activity; and, 5. reduced winter kill and frost heaving of the grass roots. Following these recommendations the maintenance of proper water management would result in better turfgrass growth and vigor.

Fertilization and the use of composted materials were nearly synonymous into the late 1920s. While the elemental nutritional needs of plants were understood (Myne and Hatch 1913), it was also known that the use of compost alleviated the need to use more expensive, inorganic sources of nutrients (Piper and Oakley 1921). Because of the increased usage of internal combustion engines, the raw material for compost, manure from horse stables, became a limited and high cost ingredient. The cost of manure with the availability and improved economic availability of inorganic fertilizers and pesticides quickly bought about a chemical revolution in the turfgrass industry and the end of compost top-dressing (USGA Greens Section, 1928).

1.1.2 Relevant History of Chemicals in Turfgrass Management

During the 1900s, a proliferation of chemical weapons occurred both for war and turfgrass management. Heavy metal-based pesticides dominated the formulations in the early years of this revolution. One such chemical was Bordeaux mixture, a copper-containing fungicide, that was used extensively both in agriculture and turf by 1917 (Monteith and Dahl 1932). In 1921, the first use of a mercury compound, mercuric chloride, for the control of turf pathogens was documented (Monteith 1926). In the mid-1900s, both during and before the Second World War, new chemical biocides were developed. This chemistry, the synthetic organic compounds, included the chlorinated hydrocarbons (e. g.,dichloro-diphenyl-tricholoroethane or DDT, chlordane, and 2-4D), and the organophospates (e. g. carbophenothion, parathion, azinphosmethyl, diazinon, and others). These synthetic chemical pesticides soon dominated pest control strategies (i.e. chemical control approach) and virtually eliminated other previously used strategies such as cultural, mechanical, and biological controls.

The search for better ways to control common pests, increased cost and reduced availability of compost, pressure from the golfing community for perfect turf, and the availability of synthetic compounds all contributed to the Chemical Revolution. However, this revolution was eventually questioned in 1962 by the best selling book *Silent Spring* by Rachel Carson. Carson pointed out numerous problems associated with then popular DDT. DDT was found to have wide ranging affects on the environment including non-target animals and soon became the target for reducing reliance on synthetic chemical insectides.

1.1.3 Reduction of Chemical Pesticides Dependence and Return to Cultural and Biological Control Methods

Rachel Carson brought to light the environmental ramifications of indiscriminate use of broad spectrum pesticides. She advocated the need to develop management strategies that would be "gentle" on the environment. This is the problem faced by today's turfgrass manager: the need to be "gentle" on the environment and yet still maintain turf at the highest possible quality. This "environmental awareness" caused agronomic management techniques to come full circle, back to a point were emphasis is placed on cultural and biological practices rather than chemical ones in order to manage problems associated with pests.

In addition to the search for more environmentally benign chemicals, people are faced with a need to develop better methods of waste management. In the 1920s, manures were used as organic fertilizers but as the number of horses decreased so did their wastes. Now we are faced with a nearly unmanageable waste flow due to human overpopulation. One way of alleviating the strain on the waste disposal problem is to use sewage sludge as a raw material for a composted organic fertilizer. Sewage sludge when added to other organic materials, like garbage, yard waste, etc., can be composted to produce a product useful for adding organic matter to soil and supply essential nutrients for plant growth. Such composts have more recently been shown to have additional benefits.

Hoitink et al. (1991) showed the benefits of using composts in potting mixes to reduce the incidence of root rot disease caused by *Pythium* spp. These same principles have also been applied to turfgrass cultures.

Today, the need to maintain disease-free, vigorous turfgrass, despite increasingly more stringent government restrictions on the types and amounts of pesticides and inorganic fertilizers, leads the turfgrass industry to look more closely at the benefits of compost. With more than 3000 registered composting facilities in the U.S. (Hansen et al. 1995) and some composting facilities capable of producing 25 dry tons per day, there is an ample source of this organic fertilizer. With increasing research into the other benefits of compost, there is sure to be an increase in the management practices that are similar to those used in the 1920s when compost played a key role in the maintenance of turfgrass.

1.2 COMPOSTING PROCESS

Composting is the process by which chemically complex materials are consumed and digested by microorganisms. The process begins with the fermentation (anaerobic breakdown of organic molecules) and the degradation of simple carbohydrates by mesophilic microorganisms that function at temperatures below 38ºC. Consumption of carbohydrates by these microorganisms produces carbon dioxide, water, and energy in the form of heat. As heat energy increases in the host material (38^0 to 66^0C) and carbohydrate sources are extinguished, the mesophilic microorganism population declines and is mainly replaced by thermophilic actinomycetes capable of digesting more complex molecules

(Hoitink et al. 1991). These complex molecules consist mainly of cellulose, lignocelluloses, and hemicelluloses which are long-chain, interlinked polymers that make up the principal structural components of plants. As the cellulose and cellulose-like components are depleted in the compost pile, the temperature drops and the populations of actinomycetes rapidly decline. The pile is then said to be in a "maturing phase".

The entire composting process is driven by a C:N ratio of 10:1 (Lynch 1992) to 30:1 (Hoitink et al. 1991). Nitrogen is the principal, nutritional requirement of microorganisms in this system and is required for their growth and reproduction.

The composting process is also dependent upon two other basic requirements - water, and oxygen. Temperature is important but it is a byproduct of the decomposition process itself and is not dependent on the environmental ambient temperature. The amount of moisture in the composting pile is ideally 60%. As the percent moisture increases, the ability of the piled material to remain in solid form is compromised, and oxygen movement within the pile is inhibited as water fills the micro-spaces. Oxygen is vital to proper composting. A lack of oxygen, by either depletion or exclusion by excessive water, can lead to anaerobic conditions and fermentation. Anaerobic break down of organic matter produces toxic chemicals like ammonia, methane, and sulfur compounds. A C:N ratio of 30:1 is required for optimum growth of the microorganisms involved in the composting process. As the level of nitrogen increases, excess nitrogen (particularly in the form of ammonia) is released into the atmosphere. This can be a problem with high N composts like chicken manure.

Alternatively, as the carbon levels increase, the rate of composting decreases because the nitrogen necessary for microbial growth is not available.

According to Chen and Inbar (1992), mature compost can be used for field application since “organic matter is composted to the degree of decomposition that has no adverse effects on growth of various crops when applied at annual rates up to 50 tons ha^{-1} at least 6 weeks before sowing or planting (during the warm season in which decomposition can take place).” Mature compost consists largely of the lignins, and aromatic polymers consisting of phenylpropane units bound to cellulose which provide part of the structural elements of plant tissues.

1.3 NUTRIENT RECYCLING IN TURF SYSTEMS

Like most biological systems, turfgrass can be considered to be a system that recycles materials in a perpetual manner with only water, oxygen and sunlight inputs. Organic materials and nutrients that are taken from the soil by plants are returned to the soil though a complex web of producers, primary consumers, predators, and decomposers. Plants are the primary producers and therefore remove nutrients from the soil. Nutrients are returned directly to the soil either through plant sloughing or indirectly by way of consumers that feed on the plants. Consumers use the nutrients that the plant removed from the soil and then these consumers are either consumed themselves or die. Consumers and producers are eventually degraded by scavengers and decomposers. As the nutrients move though this chain there is a fraction that can not be used by the subsequent link of the chain and that portion is excreted as waste. Waste ultimately reaches the soil surface were it is also attacked by decomposers that can utilize the material being excreted. This decomposition continues until all that remains of the excrement are fundamental nutrients that can then be taken up by the producers to begin the cycle over. Although this process is multi-tiered and extremely complex, many of the components are analogous in composting. In composting, high energy, complex materials enter the process and low energy, basic nutrients come out.

When this system is not within a proper range of peramiters, problems can occur. Artificial nitrification of the soil with fertilizers leads to vigorous and copious plant growth. More vigorous plant growth provides greater resources for consumers, like foliage feeding lepidopteran larvae. Increased sloughing of senescing tissues can lead to an abnormally thick layer of thatch which tends to increase populations of primary decomposers/consumers, such as soil-dwelling scarabaeid larvae. All of these situations can be detrimental to the turf. Foliage feeders can over-graze. Soil dwellers can destroy sufficient roots mass to render the plant unable to obtain water and nutrients which ultimately leads to death of the plant.

High levels of thatch can provide harborage that protects pests from predators as well as providing protection for pathogens. This phenomenon has been observed in the no-till farming system where plant residues from the previous year leads to an increased population of destructive pests the following year (Willson and Eisley 1992). All of the problems associated with excessive nitrification can be detrimental to the system as a whole, but the perceived need for thick, lush, vigorous turf forces turf managers to continue with this practice and deal with the repercussions of an unbalanced system as they arise. Currently, chemical pesticides are the weapon of choice to combat the numerous turf pests that include pathogens insects, and weeds.

1.4 PRIMARY TURF CONSUMERS EVALUATED IN THIS STUDY

1.4.1 Black Turfgrass Ataenius, *Ataenius spetulus* (Haldeman)

Black turfgrass ataenius (BTA) is a Scarabaeidae beetle that is a first order consumer/decomposer. The beetle larvae feed primarily on dead, decaying organic matter that ranges from thatch to cow droppings, but on turf they also consume the living turf roots. BTA was first identified as a pest of turf in 1932 (Hoffman 1935) but did not become a recognized, significant pest of Ohio golf courses until 1973. In turf, the larvae live and feed in the soil-thatch interface. In this zone, they graze on the thatch as well as feed on the root mass that grows in the soil-thatch interface (Niemczyk and Dunbar, 1976). This feeding first produces irregular patches of dry, wilted turf that eventually results in death of the turf. Infestations and damage can range in size from several square centimeters to covering entire fairways. Under sufficient pressure from the feeding by BTA, the turf wilts and dies irrespective of the amount of water applied.

BTA, like any animal, requires a minimum amount of resources to survive. But because the BTA larvae are not highly mobile in the soil, finding adequate resources for the larvae is most likely the responsibility of the adult female. Female BTA dig into the soil of a prospective oviposition site and assess the quality of the site.

If the site is adequate, they will oviposit. From that point on, the larvae must complete their life cycle in the area in which they hatched.

1.4.2 Noctuidae - Cutworms and Armyworms

Agrotis ipsilon (Hufnagel), black cutworm (BCW), is an important economic pest of many agricultural crops (Rings et al. 1974) where its feeding on foliar tissues can kill plants and reduce yields at an economically significant level (Willson and Stinner 1994). On turfgrass, BCWs feed on the foliage of the plant producing small palmate to circular depressions in the turf canopy that can disrupt the tracking of a putted golf ball (Niemczyk 1981). While the BCW feeding does not kill the turf, it does cause a poor quality turf putting surface and therefore warrants control on tees and putting greens.

Unlike BTA, BCW adults appear to put little effort into selecting a suitable ovipostion site. BCW seem to randomly distribute single eggs on turf leaf blades. When the eggs hatch, the first three instars must survive on the turf that is in the immediate area. Once the larvae reach third and forth instars, they become much more mobile and then seek out new feeding sites. This behavior reduces the risk of predators and parasites that would hone in on the fouling odors that come from the feeding sites. This behavior also allows for the larger larvae to seek out feeding sites that are more conducive to growth (i.e. more nutritious turf).

Spodoptera frugiperda (J. E. Smith),fall armyworm (FAW), is also an economic pest of agricultural grain crops (Glover 1856, Pencoe and Martin 1981b). FAW causes significant economic loss in field crops by reducing yield. In this study FAW, was used primarily as a laboratory animal for turf quality assessment. FAW has been used in turf resistance screening as well as in choice tests (Pencoe and Martin 1981a and 1981b). For this reason, we felt that FAW would make a good experimental animal for turf quality assessment.

1.4.3 Pyralidae - Sod Webworm

“Sod webworm” (SWW) a Lepidopteran generally refers to a large subfamily of Pyralidae, the Crambinae. These insects are mainly larval pests of turf grasses and can cause significant damage to managed turf (Bohart 1940). First and second instar larvae construct silken shelters on the turf blade which they then skeletonize. After the second instar, the larvae construct a silken shelter in the thatch and soil. Older SWWs feed on leaf blades of turf. Literature indicates that larvae may cut off leaf blades and pull them into their silken shelters. These shelters, while providing protection from predators and parasites, also serve as locations were the larvae pupate (Kamm 1970). Pupation and overwintering is done in an accessory chamber (hibernaculum) that is constructed off the end of the shelter; they are located 2.5-5 cm in the soil and are silk lined.

SWW do not normally pose a significant pest problem to lawns (high cut turf) except at excessively high populations. However, SWW damage is detectable and economially important on low cut golf course areas such as tees and putting greens. On these low cut turfs, SWW feeding can cause general thinning and stressing of the turf that makes the turf more susceptible to other disorders. Damage is seen late in the infestation as irregular yellow-brown trails or patches.

Because of this damage, SWW is the subject of extensive chemical control programs (Mailloux and Streu 1981).

SWW adult females randomly oviposit on the wing. Because of this strategy, the first though third instars are responsible for finding suitable habitat for completing their life cycles. If the site were the larva hatches is not suitable, the larva move to a new location (Richmond and Shetlar 1999). Once the larva has settled on a suitable location, and has grown large enough, the larva drops down to the soil-thatch layer and begins construction of its retreat.

1.4.4 Oligochaeta - Earthworms

Earthworms (EW) are generally considered important primary/secondary decomposers in the turfgrass system. Their activity in the soil-thatch interface helps to reduce the buildup of thatch (Potter et al. 1985). EW burrowing activity honeycombs the soil with burrows that aid in water percolation and oxygenation of the root zone of the turf profile. The castings (feces) that are left on the surface of the turf are rich in undigested and partially digested nutrients (Salisbury 1924). These castings help to bring soil to the turf surface were it can aid in organic matter decompostion and provide nutrients to plants. Aproximetly 16329 kg (18 tons) of castings per acer are produced annually (Darwin 1882). This is a significant and important service performed by EW, but castings on the surface are not appreciated on high maintenance turf of golf courses. On short cut turf, the castings can create dead spots by smothering the turf plants. The castings, as well as, the dead spots can affect the tracking of a putted golf ball, thereby disrupting play. Castings also contain mineral (i.e. sand) deposits that can dull the blades of mowing equipment and hasten equipment failure (Backman et al. 1999).

Being the most mobile of the subterranean animals considerd in this study, EW have the ability to relocate throughout their life but would still be expected to concentrate in the areas were the richest nutrients are avalible.

1.5 INSECTS AND COMPOST

Little work has been done to investigate the effects of adding compost to turf and its effect on the insect pests. Work similar to this study has looked at the effects of conventional vs. organic farming on the populations and damage produced by various agricultural pests. In organic farming, no chemical pesticides nor inorganic fertilizers are used. The crops are produced by managing the soil in which the plants grow. The concept is that by improving the soil with composts and other organic amendments, the plants will be better suited to resist feeding damage and may even better defend themselves with allelochemicals (plant defensive chemicals). Phelan et al. (1996) and Culliney & Pimentel (1986) found significant relationships between the type of soil treatment and the influence that had on the insect pest. Both studies attributed the differences to the quality of the soil and the avalibilty of nutrients in the soil to be utilized the plants. This study seeks to find a relationship between the use of compost and the population of various turf insect pests.

CHAPTER 2

INFLUENCE OF COMPOST TOP-DRESSING ON PEST POPULATIONS

2.1 INTRODUCTION

The purpose of this study was to investigate the influence of applying composted topdressing to bentgrass turf on insect and EW populations. This was accomplished by periodic sampling of insects in turf plots that were variously treated with compost. The data were analyzed to determine if there was a correlation between the compost, fertility rates, airification, and the number of insects or EW collected. The rationale for conducting this study is as follows.

1. Compost top-dressing provides increased amounts of nutrients for turf in the form of organic fertilizer. Well nourished turf grows more vigorously, thereby increasing biomass in the area.

2. More vigorous turf in turn provides a more nutritious food source for turf feeding insects.

Therefore we would expect to see higher populations of destructive turf pests in the turf plots that were treated with compost. Alternately, if the better nourished turf was less susceptible to attack by insects, we would expect to see a reduction in pest populations due to emigration, reduced ovipostion, or mortality.

3. Compost amendments to turf should increase the amount of organic matter (OM) in the upper soil layer and improve soil conditions that increase the root mass of the turf. This increased root mass in the zone where white grubs feed should increase grub populations.

It is known that insects are capable of monitoring their dietary intake of nutrients. (Friedman et al. 1991). Normally, an insect would be able to obtain all of its required nutrients from its normal food source. For mobile lepidopteran (LEP) insects, if the food source (turf foliage) was suboptimal, we would expect to see lower numbers of LEP pests in our study. For nonmotile pests like the BTA, if the food source were suboptimal, we would expect to see fewer insects, either by reduced oviposition or through increased mortality of the larvae. If population reduction is caused by reduced oviposition due to the adult's ability to detect deficient turf, then there should be fewer adults in our samplings. If the reduction in BTA populations is due to larval mortality then there would be equivalent numbers of BTA adults in the plots but a significant reduction of larvae in our sampling. These trends in populations would exist whether the compost acted as a deterrent to pest feeding or an attractant. If the compost was an attractant, we would see a shift in the populations to favor of the plots receiving the compost. If the compost acts as a deterrent to feeding, then the shift in populations would be to the plots not receiving compost.

2.2 MATERIALS AND METHODS

2.2.1 Experimental Design

Field plots were established at The Ohio State University OTF Turf research facility in 1996. One-hundred-sixty-two (162) plots were established in 1996 they were composed of bentgrass, *Agrustus polustrus* ‘Pencross’, a common turf grass used on golf courses because of its aesthetic qualities and ability to thrive at short mowing heights preferred on golf courses, and annual blue grass, *Poa annua,* an intrusive weed common to golf course situations. The plots were mowed at a height of 1.27 cm three times a week during the growing season. These plots were divided into three replicates of 54 plots. Within each replicate, 18 plots each received inorganic fertilizer applied at a rate of 0.45, 0.91, or 1.81 kg nitrogen per 92.9 m^2 (= 2, 4, and 8 lbs N/1000ft^2) . Half of the 18 plots receiving nitrogen fertility were then core aerified (cored) at 1/4 inch plug diameter. Once the plots were core aerified, three of the plots received either a composted bio-solid, composted bio-solid-yard waste blend, or no compost. Each of the compost treatments was further subdivided into single plots that received a preventive pesticide schedule, an IPM schedule based on overall amount of grazing damage and number of animals in each plot (Watschke et al. 1995), or a no pesticide application.

This resulted in a plot desing that included 3 replicates x 54 plots*3 three fertility rates (2, 4, 8, lbs N/1000)*2 cored/notcored*3 compost treatments*3 pest control programs = 162 plots (Figure 1).

2.2.2 Field Sampling

An irritant disclosing solution (soap solution) was used to sample BTA adults, BCW, FAW, SWW, as well as earthworms (Watschke et al. 1995). Sampling was performed by using a frame constructed of ½ inch PVC pipe with matching PVC elbows that formed a 0.42 m^2 rectangular frame. The irritant solution was made by adding approximately 14.7 ml of liquid Joy Ultra® (Procter and Gamble) dishwashing soap to 3.8 liters of water. The solution was mixed in 19 liter buckets then poured into7.6 liter garden watering cans. The solution was then poured onto the turf in a manner that achieved even distribution of the soap solution. Application was contunued until the solution began to pool on the turf surfice. The soap in the solution acts as an irritant, driving the insects to the surface within 3-5 min with the exception of SWW which require approximately 45 min to reach the surface. The insects were then removed from the turf surface and placed in vials containing KAAD (Borror et al. 1989) for later analysis. EW on the surface were also counted. This sampling was performed on a twice-a-year schedule, once in May and once in October.

BTA grub samples were also obtained once a year, in July, using a standard golf corse cup changer. Using the cup changer three 43.1 cm^2 (4.25 in) diameter cores were taken from each plot. These cores were crumbled and the number of grubs and pupae was recorded for analysis.

2.2.3 Data Analysis

ANOVA *p* values were determined for the insect and earthworm population differences among all trial variables, including interactions, using Statistica ™ (StatSoft® Tulsa, OK. USA).

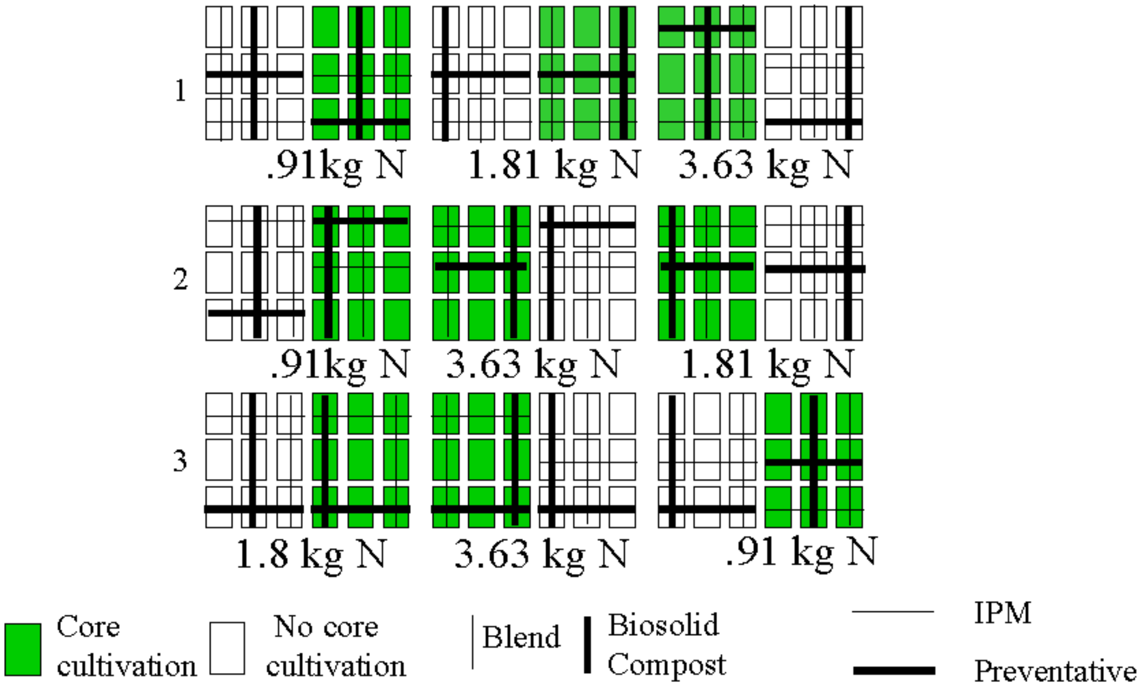


Figure 1. Experimental Design of a Creeping Bentgrass Fairway for insect density determinations.

2.0 RESULTS

2.3.1 Population Counts

Data for the earthworm population sampling are listed in Table 2.1 according to treatments and blocks. The standard deviation for many of the means exceeded the mean value. It was also noted that block one generally had fewer earthworms then blocks two and three. Analysis of the data with significance values for each treatment and the treatment interactions for each date are presented in Table 2.2. There were no significant differences detected at $p \leq 0.05$ except for the block effect (Oct 98 and Sept 99). Though a significant interaction between N and Core was detected for May 98, this interaction was not observed in later samplings.

Data for sod webworm populations are listed in Table 2.3 by treatment and block. Again the standard deviation exceeds the mean population sample size in most of the samples taken. The large discrepancy between population sizes between the two samplings is atributed to the difference in the dates. The 99 sampling was done at a time when populations of the various sod webworm species were at their greatest (personal communication, D. Shetlar). ANOVA analysis of the sod webworm data revealed only one significant interaction at N and compost in 98 sampling date (Table 2.4).

Noctuid population data are listed in Table 2.5 by treatment and block. Standard deviation on Table 2.5 again commonly exceeded the means. We see various trends within treatments but these trends do not hold up when viewed across the sampling dates. Table 2.6 shows several instences of significance in the 98 sampling year but none of the significant treatments carry over to the 99 sampling periods.

Data for black turfgrass ataenius adult populations are listed in Table 2.7 by treatment and block. The standard deviations for the population sizes are ≥ the sample means following the trend set by the other organisms in this study. Again the block data show a dramatic difference between blocks 1 and 2-3. Analysis of the data given in Table 2.8 shows that mean block populations were significantly different at every sampling date. Compost was also significant on May of 99 and core x compost was significant on Oct. 98 but these do not represent trends but rather single instances of isolated significance.

Data for black turfgrass ataenius larval populations are listed in Table 2.9 by treatment and block. As with the adult black turfgrass ataenius data, the standard deviation is large when compared to and, even exceds, the mean populations. There are two instances of significance on Table 2.10. Core in July of 98 and compost in June of 99 both indicate strong significances but still only represent isolated occurrences rather than trends.

Data indicated in tables 2.1-2.10, while showing some instances of significance, do not indicate any long term sustainable influences of the treatments performed to the turf on insect and earthworm populations. There is however a strong relationship between populations and block. Block one had a highly significant reduced population of organisams as compared to blocks two and three. Significance levels were set at $p \leq 0.05$ for the treatments.

	May 98	Oct 98	May 99	Sept 99	n
2N	1.11 ±1.18	7.89 ±3.95	2.67 ±3.40	4.89 ±5.28	54
4N	2.83 ±0.54	8.17 ±4.36	3.06 ±3.17	7.39 ±8.87	54
8N	1.67 ±2.20	9.00 ±6.07	4.72 ±3.95	5.67 ±6.83	54
Core	2.33 ±3.39	9.52 ±3.96	3.96 ±3.46	4.41 ±4.82	81
No Core	1.41 ±1.82	7.19 ±5.36	3.00 ±3.68	7.56 ±8.60	81
BL Comp A	1.83 ±2.04	9.33 ±3.51	3.44 ±2.79	5.17 ±6.91	54
Bl Comp B	1.94 ±3.30	8.22 ±5.74	3.94 ±4.08	6.33 ±6.84	54
No Comp	1.83 ±2.90	7.50 ±5.01	3.06 ±3.86	6.44 ±7.80	54
IPM	N.A.	N.A.	1.13±1.94	2.31±3.67	54
Preventative	N.A.	N.A.	1.19±2.03	1.67±2.38	54
No pesticide	N.A.	N.A.	0.94±1.70	2.02±4.00	54
Block 1	0.94 ±1.06	4.56 ±3.50	1.17 ±2.31	0.50 ±0.86	54
Block 2	3.39 ±4.07	8.50 ±3.20	4.39 ±3.82	7.44 ±7.89	54
Block 3	1.28 ±1.36	12.00 ±4.50	4.89 ±3.34	10.00 ±6.51	54

Table 2.1: Mean ± SD number of earthworms recovered from treatment plots for dates indicated. (N.A. = data not recorded)

	May '98	Oct '98	May '99	Sept '99
N	0.58	0.90	0.39	0.72
Core	0.38	0.09	0.32	0.50
Comp.	0.96	0.47	0.39	0.41
Pest.	N.A.	N.A.	0.79	0.71
Block	0.31	0.04	0.07	0.01
NxCore	0.05	0.44	0.43	0.75
NxComp.	0.64	0.99	0.58	0.14
NxPest	N.A.	N.A.	0.70	0.78
CorexComp	0.78	0.90	0.30	0.49
CorexPest	N.A.	N.A.	0.50	0.53
CompxPest	N.A.	N.A.	0.88	0.70
Nxcompxpest	N.A.	N.A.	0.81	0.13
Nxcorexpest	N.A.	N.A.	0.26	0.58
corexcompxpest	N.A.	N.A.	0.86	0.94
NxCorexComp.	0.77	0.63	0.40	0.20
NxCorexcompxpest	N.A.	N.A.	0.52	0.30

Table 2.2: Table of p values for main ($p \leq 0.05$) and interaction plots ($p \leq 0.15$) based on ANOVA of means for earthworms. (N.A. = data not recorded)

	Oct 98	Sept 99	n
2N	0.11 ±0.47	22.28 ±16.36	54
4N	0.33 ±0.77	27.11 ±15.80	54
8N	0.056 ±0.24	42.39 ±31.19	54
Core	0.15 ±0.46	28.85 ±15.91	81
No Core	0.19 ±0.62	35.00 ±28.55	81
BL Comp A	0.28 ±0.75	32.83 ±24.45	54
BI Comp B	0.56 ±0.24	32.67 ±21.77	54
No Comp	0.17 ±0.51	30.28 ±24.24	54
IPM	0.02±0.14	10.30±9.47	54
Preventative	0.09±0.45	5.89±12.67	54
No pesticide	0.06±0.30	15.60±16.48	54
Block 1	0.17 ±0.51	34.78 ±19.37	54
Block 2	0.28 ±0.75	17.89 ±13.14	54
Block 3	0.06 ±0.24	43.11 ±27.68	54

Table 2.3: Mean ± SD number of sod webworms recovered from treatment plots for dates indicated.

	Oct '98	Sept '99
N	0.57	0.46
Core	0.85	0.86
Comp.	0.42	0.68
Pest.	0.52	0.01
Block	0.75	0.07
NxCore	0.30	0.39
NxComp.	0.04	0.82
Nxpest	0.68	0.60
CorexComp	0.36	0.31
CorexPest	0.23	0.44
CompxPest	0.80	0.09
Nxcompxpest	0.58	0.90
Nxcorexpest	0.87	0.03
corexcompxpest	0.76	0.73
NxCorexComp.	0.21	0.48
NxCorexcompxpest	0.67	0.53

Table 2.4: Table of p values for main ($p \leq 0.05$) and interaction plots ($p \leq 0.15$) based on

ANOVA of means for sod webworms.

	May 98	Oct 98	May 99	Sept 99	n
	BCW	FAW	BCW	BCW	
2N	0.50 ±0.71	4.06 ±4.36	1.06 ±1.16	0.83 ±0.99	54
4N	0.89 ±1.28	5.11 ±5.25	0.44 ±0.51	0.94 ±1.00	54
8N	1.00 ±1.19	6.00 ±5.74	0.56 ±0.92	0.78 ±0.81	54
Core	0.85 ±1.29	6.15 ±5.72	0.56 ±0.89	0.78 ±0.89	81
No Core	0.74 ±0.85	3.92 ±4.25	0.56 ±0.96	0.93 ±0.96	81
BL Comp A	0.67 ±0.69	6.44 ±5.20	0.67 ±0.91	0.67 ±0.91	54
BI Comp B	1.28 ±1.32	6.22 ±6.18	0.72 ±1.02	1.17 ±1.04	54
No Comp	0.44 ±1.04	2.50 ±2.41	0.67 ±0.91	0.72 ±0.75	54
IPM	N.A.	1.63±2.92	0.20±0.41	0.22±0.46	54
Preventative	N.A.	1.72±1.84	0.33±0.73	0.39±0.63	54
No pesticide	N.A.	1.70±2.02	0.19±0.39	0.26±0.44	54
Block 1	0.89 ±1.28	1.94 ±1.95	0.44 ±0.92	1.11 ±0.90	54
Block 2	0.83 ±1.15	8.94 ±6.38	0.94 ±0.94	0.78 ±1.06	54
Block 3	0.67 ±0.84	4.27 ±3.18	0.67 ±0.91	0.67 ±0.77	54

Table 2.5: Mean ± SD number of noctuids recovered from treatment plots for dates indicated. (N.A. = data not recorded)

	May '98 BCW	Oct '98 FAW	May '99 BCW	Sept '99 BCW
N	0.55	0.26	0.18	0.90
Core	0.98	0.036	0.31	0.50
Comp.	0.0048	8.2E-05	0.99	0.34
Pest.	N.A.	0.97	0.17	0.29
Block	0.93	0.012	0.14	0.24
NxCore	0.67	0.35	0.74	0.48
NxComp.	0.0078	0.36	0.44	0.56
NxPest	N.A.	0.59	0.03	0.50
CorexComp	0.56	0.0039	0.63	0.37
CorexPest	N.A.	0.50	0.97	0.87
CompxPest	N.A.	0.53	0.06	0.26
Nxcompxpest	N.A.	0.63	0.48	0.51
Nxcorexpest	N.A.	0.26	0.47	0.77
corexcompxpest	N.A.	0.67	0.94	0.13
NxCorexComp.	0.052	0.35	0.26	0.82
NxcorexCompxPest	N.A.	0.76	0.69	0.92

Table 2.6: Table of *p* values for main ($p \leq 0.05$) and interaction plots ($p \leq 0.15$) based on

ANOVA of means for Noctuidae. (N.A. = data not recorded)

	May 98	Oct 98	May 99	Sept 99	n
2N	4.28 ±4.06	1.00 ±1.33	6.33 ±3.74	1.17 ±1.54	54
4N	6.00 ±4.78	0.67 ±1.28	10.00 ±5.27	4.50 ±7.84	54
8N	4.28 ±3.61	0.72 ±1.41	9.83 ±7.57	4.89 ±8.49	54
Core	3.96 ±3.33	0.89 ±1.25	7.63 ±4.27	5.19 ±9.02	81
No Core	5.74 ±4.78	0.70 ±1.41	9.81 ±7.07	1.85 ±2.76	81
BL Comp A	4.50 ±3.60	0.83 ±1.25	7.00 ±4.70	4.61 ±8.57	54
BI Comp B	4.50 ±4.49	1.00 ±1.57	7.72 ±3.66	2.22 ±2.88	54
No Comp	5.56 ±4.53	0.56 ±1.15	11.44 ±7.79	3.72 ±7.74	54
IPM	N.A.	0.02±0.14	2.89±2.37	0.87±2.56	54
Preventative	N.A.	0.09±0.45	2.81±2.69	1.02±3.50	54
No pesticide	N.A.	0.06±0.30	2.80±3.13	1.83±3.95	54
Block 1	2.39 ±2.17	0.50 ±1.34	5.00 ±2.93	0.06 ±0.24	54
Block 2	6.39 ±4.48	0.39 ±0.50	11.78 ±7.40	2.39 ±3.31	54
Block 3	5.78 ±4.45	1.50 ±1.62	9.39 ±4.45	8.11 ±9.87	54

Table 2.7: Mean ± SD number of black turfgrass ataenius adults recovered from treatment plots for dates indicated. (N.A. = data not recorded)

	May '98	Oct '98	May '99	Sept '99
N	0.32	0.57	0.07	0.15
Core	0.33	0.41	0.08	0.08
Comp.	0.56	0.60	0.01	0.75
Pest.	N.A.	0.67	0.98	0.34
Block	0.03	0.02	0.01	0.005
NxCore	0.80	0.37	0.07	0.30
NxComp.	0.38	0.42	0.50	0.95
NxPest	N.A.	0.85	0.72	0.42
CorexComp	0.48	0.04	0.86	0.53
CorexPest	N.A.	0.19	0.48	0.91
CompxPest	N.A.	0.69	0.56	0.25
Nxcompxpest	N.A.	0.89	0.42	0.34
Nxcorexpest	N.A.	0.54	0.24	0.42
corexcompxpest	N.A.	0.56	0.17	0.28
NxCorexComp.	0.55	0.66	0.43	0.75
NxCorexCompxPest	N.A.	0.31	0.23	0.71

Table 2.8: Table of p values for main ($p \leq 0.05$) and interaction plots ($p \leq 0.15$) based on ANOVA of means for black turfgrass ataenius adults. (N.A. = data not recorded)

	July 98	June 99	n
2N	4.17 ±4.08	6.78 ±5.80	54
4N	6.00 ±8.15	16.22 ±8.40	54
8N	3.83 ±5.61	16.39 ±10.97	54
Core	1.96 ±2.24	14.85 ±8.65	81
No Core	7.37 ±7.51	11.41 ±10.39	81
BL Comp A	3.39 ±3.81	15.33 ±9.66	54
Bl Comp B	6.22 ±8.03	13.22 ±9.07	54
No Comp	4.39 ±5.83	10.83 ±10.14	54
IPM	N.A.	3.944.46	54
Preventative	N.A.	4.835.62	54
No pesticide	N.A.	4.545.12	54
Block 1	3.28 ±3.77	15.50 ±10.14	54
Block 2	6.11 ±6.36	17.61 ±8.58	54
Block 3	4.61 ±7.64	6.28 ±5.98	54

Table 2.9: Mean ± SD number of black turfgrass ataenius larvae recovered from treatment plots for dates indicated. (N.A. = data not recorded)

	July 98	June 99
N	0.79	0.23
Core	0.01	0.09
Comp.	0.34	0.003
Pest.	N.A.	0.45
Block	0.48	0.17
NxCore	0.11	0.53
NxComp.	0.78	0.15
NxPest	N.A.	0.37
CorexComp	0.98	0.41
CorexPest	N.A.	0.31
CompxPest	N.A.	0.17
Nxcompxpest	N.A.	0.71
Nxcorexpest	N.A.	0.40
corexcompxpest	N.A.	0.37
NxCorexComp.	0.91	0.66
NxCorexCompxPest	N.A.	0.35

Table 2.10: Table of *p* values for main ($p \leq 0.05$) and interaction plots ($p \leq 0.15$) based on ANOVA of means for black turfgrass ataenius larvae. (N.A. = data not recorded)

2.4 DISCUSSION

2.4.1 Conclusion

The addition of composted organic matter to turf in this study was expected to significantly change populations of insect herbivores and decomposers (i.e. black turfgrass ataenius adults and larvae, sod webworms, black cutworms and earthworms. Analysis of the data indicate that adding compost does not seem to cause any consistent influence on the populations of these organisms. Possible explanations for finding a lack of measurable influence are as follows:

Black turfgrass ataenius adults may possess the ability to assess the nutritional quality of a potential oviposition site, by sent or taste, for availability of organic matter (primary source of food for grubs). In compost, however, the usable components of organic matter (primarily cellulose) have already been consumed by the microorganisms involved in the composting process, and therefore, no longer offer a raw food source for the BTA grubs. Compost does, however, provide nutrients in the form of elements and other basic molecules for the turf plants to grow and build root mass. Root mass is also enhanced by proper fertility applications. In this study, the check plots (not reciving core aerification or compost) received a minimum of 98.9 kg N per hectare (2 lbs N /1000 ft^2). This was done to maintain turf survival but not produce high quality turf that would normally be found on a golf course where 247-297 kg N /ha (5-6 lbs N /1000 ft^2) fertility rates are normally used. This low rate of fertilizer might have masked the influence of compost on the growth of root mass. It appears that in this study none of the plots were at a low enough fertility to produce root mass and other organic matter that was sub-optimal for BTA adult selection for oviposition or survival of BTA larvae.

There also was no observed influence of compost on the foliage feeding pests considered in this study. One of two events was expected to happen with the addition of compost to the turf as it relates to foliage feeding pests. The addition of compost to the soil would supply additional nutrition to the turf plant so that the turf could produce more tissues or defensive chemicals. If the plants did indeed utilize the nutrients provided by the compost amendments for tissue development, then we would expect the pest populations to increase. If the turf plants utilized the nutrients provided by the compost for defensive chemistry then a decrease in population would be expected to occur in those plots receiving compost. This also did not occur. Rather there were no significant differences in population size between the plots receiving compost and those that did not. Populations remained relatively consistent within the study. Populations did change between the seasons in which the samples were taken; this is a normal occurrence as the natural populations of these insects increase thought the year, and is not attributable to the treatments applied in this study.

Core aerification is a common turfgrass agronomic practice. Aerification helps to break up the soil profile thereby reducing compaction which allows for greater water percolation and oxygen penetration into the root zone. Loosened soil would also allow for a less dense tunneling and burrowing medium. If we assume that soil dwelling animals prefer to live in a medium that requires less expenditure of energy for burrowing, less compact soil would require less energy to live in. For this reason we expected an increase in the numbers of earthworms and BTA larvae in the core aerified plots. We did not see an influence from core aerification possibly because the soil in this study was not sufficiently compacted in the non aerifed plots to represent an undesirable living environment for the BTA and EW. An alternate possibility for the lack of distinction between core and non-cored plots is that the food source available in the non-cored plots was sufficiently great for the organisms to continue to live in the more compacted soil.

Interactions of the three treatment variables (fertility, compost, and core aerification) also failed to yield any significant influence on the BTA, SWW, BCW, FAW, and EW this study. While it is believed that no significant interactions were the result of the control plots receiving adequate fertilizer, another possible explanation for the lack of differences is that these plots were created from an existing stand of bentgrass already rich with a thatch layer, extensive root system and organic matter levels in the top inch of soil greater then typical Ohio agricultural soil. Had this experiment been created with a new stand of turf the results might have been different. However, the turf manager who will utilize these treatments on an established fairway can expect no change in the insect and earthworm populations that are already present in the turf.

While none of the agronomic practices produced any significant effects on the populations of the organisms considered in this study the blocking of the study did have a significant effect. In most instances replicate one produced lower numbers of specimens as compared to replicate two and three. There were two primary reasons for the dramatic differences seen in replicate one. Replicate one had chronic difficulties with irrigation and competition and shading from a nearby tree line of black walnut (*Juglans nigra*). Lack of irrigation and tree root competition caused replicate one to be in a constant state of drought which in turn produced poor quality turf. Poor quality turf in turn reduced the numbers of collected specimens and produced the significant variance seen in the statistical analysis of this study.

CHAPTER 3

GROWTH RATE OF FALL ARMYWORM

3.1 INTRODUCTION

This study focuses on the effects of compost top-dressings on turfgrass quality and the effect that quality has on insect pests. One of the difficulties of assessing the quality of turf as a food source in the field is that there is no easy way to measure the growth and development of an insect that feeds on it. Also, simple chemical content analysis of turf, which determines nitrogen, carbon, phosphorus, and trace element content does not indicate how the turf utilizes these molecules in its tissues (food quality). Those elements could be used for structural components or for defensive chemical manufacture, as well as for operation of cellular processes involved in nutrient storage. For these reasons, we felt that it was necessary to bring the turf into the laboratory for a feeding assay.

Spodoptera frugiperda (J. E. Smith),fall armyworm (FAW) has previously been used as a feeding assay subject (Pencoe and Martin 1981b, Quisenberry and Wilson 1985) and therefore represents an appropriate and precedented test subject for this study.

Prior studies with noctuid larvae have helped define growth and survival rates for this group of herbivores. These rates serve as a useful base-line reference for the feeding study conducted.

In this study, we hypothesized that various treatments used in this study, primarily, fertility levels and compost usage, and secondarily, core aerification with compost incorporated, should change the nutritional value of the turf. If these nutritional value changes are sufficiently large, FAW larvae should respond by having differential growth and survival rates.

MATERIALS AND METHODS

3.2.1 FAW Culture

In August 1999, egg masses of the FAW were collected in Naples, Florida by Dr. David Shetlar and transported to the laboratory in Columbus, Ohio. Resulting larva were reared on artificial diet following the procedure outlined by Reese et al.(1972) for two generations to establish a sufficiently large test population, free of parasites and other disorders, in order to perform the test.

3.2.2 Experimental Design

This study was conducted by feeding FAW larvae turf clippings taken from established bentgrass plots treated as outlined below. Experimental plots consisted of three fertility regimes, 77.5, 155.1, or 310.1 kg nitrogen per hectare (= 2, 4, and 8 lbs N/1000ft^2). These treatments were subdivided into core aerified and non-core aerified areas. These subplots were further divided into three areas each, receiving compost A, compost B, or no compost. This represents 18 treatment parameters (3 fertilities x 2 core aerification x 3 compost) which were replicated three times for a total of 54 plots (diagram 2). Clippings from each of the 54 plots were taken to the laboratory and placed into two 59 ml (2 oz) plastic Solo^{tm} cups with matching lids. Five neonate FAW caterpillars were placed in each cup (= 10 larvae per plot) . We then took the remaining clippings from replicate one and blended them with the corresponding plots from replicates two and three to form a fourth replicate for the laboratory. The fourth replicate elevated the total number of experimental points from 54 to 72. This was done in order to obtain a larger number of experimental data points for a more resolute analysis. Caterpillars were held in a Percival ™ growth chamber at 24^{O} C and 14:10 hr. day:night light conditions.

At two-day intervals, the caterpillars were counted and weighed together on a Mettler AG204 DELTA RANGE ™ scale. The larvae were then returned to new cups and were provisioned with fresh turf clippings. Mean weights and mortality were recorded for statistical analysis.

3.2.3 Data Analysis

ANOVA *p* values were determined for the growth rate differences between the eighteen trial variables using Statistica ™ (StatSoft® Tulsa, OK. USA).

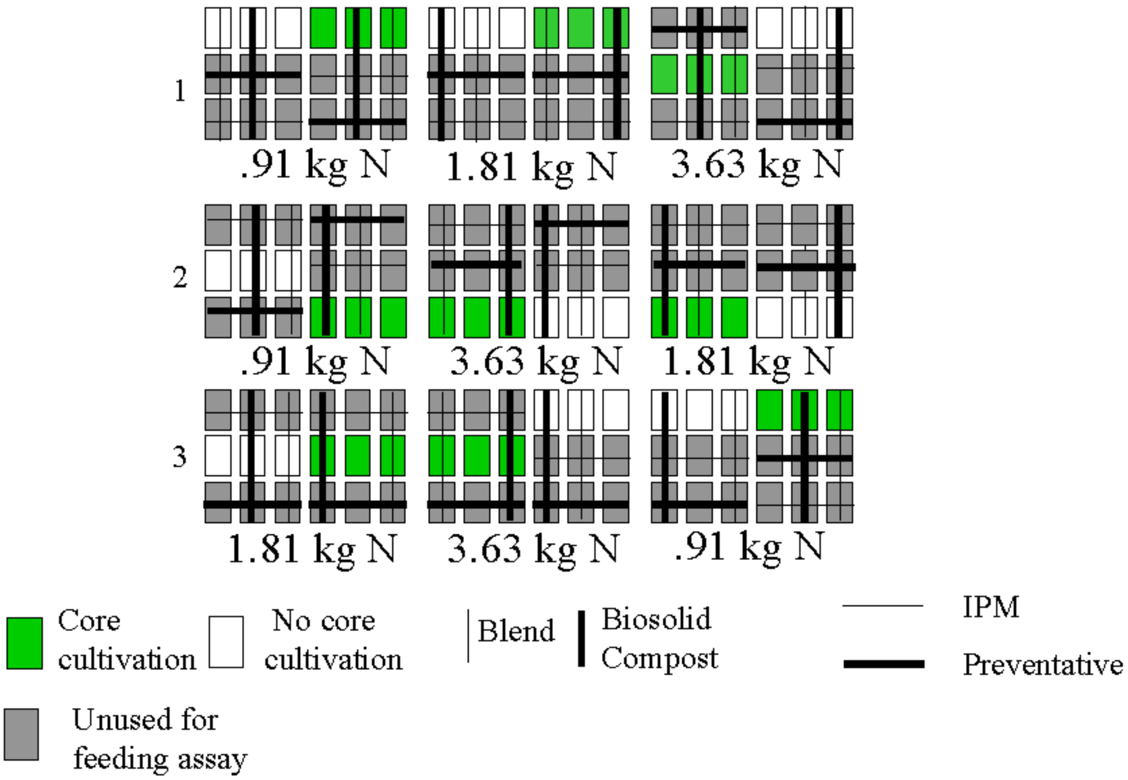


Figure 2. Experimental Design of a Creeping Bentgrass Fairway for Noctuid growth assay.

RESULTS

3.3.1 Feeding Assay

Mean weight data for fall armyworm feeding are presented in Table 3.1. While standard deviation seems high in this table they do not represent a large percentage of the of the mean weights. While the data indicate a strong relationship between age (i.e. days) and size, there does not appear to be any trend indicating a treatment influence on the growth of the caterpillars. The lack of trends is shown in Table 3.2 where ANOVA data shows only a significance related to a block effect. There was strong significance between age and weight but this relationship was expected and represents a well known and understood age-growth relationship.

The data listed in table 3.2 indicate that no significant influences occurred from the treatments on fall armyworm growth. There is however a strong relationship between growth rate and block. Block one had a highly significant reduction in weight gain as compared to blocks two and three. Significance levels were set at $p \leq 0.05$ for the treatments.

Table 3.2 present data showing the mean survivorship of fall armyworm caterpillars. Block one data appears to be the only treatment that shows a standard deviation which makes up a significant portion of the mean data. All treatments represented in table 3.2 show similar fall armyworm counts with the exception of block which indicate a mean one caterpillar difference throughout the testing period.

Table 3.4 indicates the ANOVA p values for the survivorship of fall armyworms. As suggested by the data listed in table 3.2 block is the only treatment showing significant variation in the number of caterpillars that survived the testing process.

Charts 3.1 and 3.2 show the foliar fertility levels taken from Garling (submited for publication 1999). Data for 1998 and 1999 are represented in the aforementioned charts. The data indicate that foliar nitrogen is significantly different among the six treatments (composts 3.1 and nitrogen levels 3.2). In 1998 it can be seen that the Fall compost application has a direct effect on the foliar nitrogen level. However in 1999 the Fall application was not made and thus the foliar nitrogen level is not known.

		mg	SD	n			mg	SD	n
2 N	DAY_4	1.61	±0.79	48	4 N	DAY_4	1.53	±0.87	48
	DAY_6	13.93	±7.42	48		DAY_6	12.17	±7.55	48
	DAY_8	50.80	±27.61	48		DAY_8	51.39	±28.42	48
	DAY_10	159.33	±84.49	48		DAY_10	164.73	±80.05	48
	DAY_12	304.67	±107.47	48		DAY_12	283.37	±120.55	48
	DAY_14	559.38	±239.36	48		DAY_14	569.66	±221.92	48
	DAY_16	72.85	±156.52	48		DAY_16	103.21	±155.20	48
8 N	DAY_4	1.57	±0.90	48					
	DAY_6	12.24	±7.28	48					
	DAY_8	50.77	±27.69	48					
	DAY_10	158.91	±76.73	48					
	DAY_12	281.99	±118.96	48					
	DAY_14	602.36	±239.44	48					
	DAY_16	108.01	±160.56	48					
Core	DAY_4	1.58	±0.87	72	No Core	DAY_4	1.55	±0.83	72
	DAY_6	13.07	±7.36	72		DAY_6	12.49	±7.50	72
	DAY_8	54.14	±27.09	72		DAY_8	47.82	±28.16	72
	DAY_10	158.72	±75.84	72		DAY_10	163.25	±84.36	72
	DAY_12	287.42	±115.45	72		DAY_12	292.60	±116.24	72
	DAY_14	584.25	±229.99	72		DAY_14	570.02	±236.99	72
	DAY_16	93.74	±157.31	72		DAY_16	95.63	±158.02	72
BL Comp A	DAY_4	1.64	±0.82	48	BI Comp B	DAY_4	1.43	±0.87	48
	DAY_6	13.50	±6.99	48		DAY_6	12.51	±7.62	48
	DAY_8	55.58	±24.65	48		DAY_8	48.95	±29.05	48
	DAY_10	164.41	±73.63	48		DAY_10	152.90	±91.94	48
	DAY_12	279.21	±116.26	48		DAY_12	297.08	±106.15	48
	DAY_14	591.80	±204.72	48		DAY_14	506.81	±282.67	48
	DAY_16	90.39	±144.13	48		DAY_16	85.26	±167.06	48
No Comp	DAY_4	1.63	±0.86	48					
	DAY_6	12.33	±7.71	48					
	DAY_8	48.42	±29.20	48					
	DAY_10	165.66	±74.03	48					
	DAY_12	293.74	±124.89	48					
	DAY_14	632.80	±186.17	48					
	DAY_16	108.42	±161.62	48					

Continued

Table 3.1: Mean ± SD weights of fall armyworm larvae feed with clippings from treatment plots.

Table 3.1 Continued

		mg	n			mg	n
Block 1	DAY_4	0.29 ±0.29	36	Block 2	DAY_4	2.13 ±0.47	36
	DAY_6	2.11 ±1.64	36		DAY_6	13.80 ±4.97	36
	DAY_8	14.38 ±11.05	36		DAY_8	61.39 ±20.68	36
	DAY_10	67.13 ±60.82	36		DAY_10	185.44 ±72.72	36
	DAY_12	162.71 ±126.24	36		DAY_12	296.49 ±104.57	36
	DAY_14	480.88 ±292.72	36		DAY_14	485.04 ±238.02	36
	DAY_16	203.69 ±208.11	36		DAY_16	79.62 ±137.16	36
Block 3	DAY_4	1.84 ±0.40	36	Block 4	DAY_4	2.01 ±0.46	36
	DAY_6	16.05 ±4.43	36		DAY_6	19.16 ±2.56	36
	DAY_8	63.84 ±9.54	36		DAY_8	64.32 ±25.60	36
	DAY_10	192.49 ±44.77	36		DAY_10	198.90 ±54.39	36
	DAY_12	344.88 ±40.77	36		DAY_12	355.96 ±40.72	36
	DAY_14	681.50 ±133.50	36		DAY_14	661.11 ±156.76	36
	DAY_16	49.96 ±116.17	36		DAY_16	45.49 ±90.77	36

	summer 99
N	0.72
Core	0.85
Comp.	0.22
Block	0.00
NxCore	0.21
NxComp.	0.62
CorexComp	0.66
NxCorexComp.	0.38

Table 3.2: Table of *p* values for main ($p \leq 0.05$) and interaction plots ($p \leq 0.15$) based on ANOVA of means for fall armyworm growth rate assay.

		# FAW	SD	n			# FAW	SD	n
2 N	DAY_4	4.50	±1.07	48	4 N	DAY_4	4.21	±1.50	48
	DAY_6	4.23	±1.08	48		DAY_6	3.88	±1.47	48
	DAY_8	3.67	±1.43	48		DAY_8	3.52	±1.75	48
	DAY_10	3.21	±1.79	48		DAY_10	3.35	±1.73	48
	DAY_12	3.23	±1.19	48		DAY_12	2.94	±1.39	48
	DAY_14	2.79	±1.29	48		DAY_14	2.75	±1.06	48
	DAY_16	0.42	±0.94	48		DAY_16	0.58	±0.90	48
8 N	DAY_4	4.21	±1.49	48					
	DAY_6	4.02	±1.45	48					
	DAY_8	3.60	±1.62	48					
	DAY_10	3.40	±1.58	48					
	DAY_12	3.15	±1.47	48					
	DAY_14	2.90	±1.21	48					
	DAY_16	0.56	±0.87	48					
Core	DAY_4	4.21	±1.43	72	No Core	DAY_4	4.40	±1.30	72
	DAY_6	4.10	±1.30	72		DAY_6	3.99	±1.39	72
	DAY_8	3.72	±1.51	72		DAY_8	3.47	±1.68	72
	DAY_10	3.50	±1.65	72		DAY_10	3.14	±1.72	72
	DAY_12	3.13	±1.41	72		DAY_12	3.08	±1.30	72
	DAY_14	2.89	±1.17	72		DAY_14	2.74	±1.20	72
	DAY_16	0.53	±0.92	72		DAY_16	0.51	±0.89	72
BL Comp A	DAY_4	4.48	±1.07	48	BI Comp B	DAY_4	4.08	±1.64	48
	DAY_6	4.19	±1.14	48		DAY_6	3.65	±1.52	48
	DAY_8	3.63	±1.47	48		DAY_8	3.35	±1.82	48
	DAY_10	3.44	±1.58	48		DAY_10	2.96	±1.95	48
	DAY_12	3.13	±1.39	48		DAY_12	3.10	±1.19	48
	DAY_14	2.81	±1.00	48		DAY_14	2.54	±1.40	48
	DAY_16	0.50	±0.83	48		DAY_16	0.50	±1.03	48
No Comp	DAY_4	4.35	±1.33	48					
	DAY_6	4.29	±1.27	48					
	DAY_8	3.81	±1.48	48					
	DAY_10	3.56	±1.49	48					
	DAY_12	3.08	±1.49	48					
	DAY_14	3.08	±1.07	48					
	DAY_16	0.56	±0.84	48					

Continued

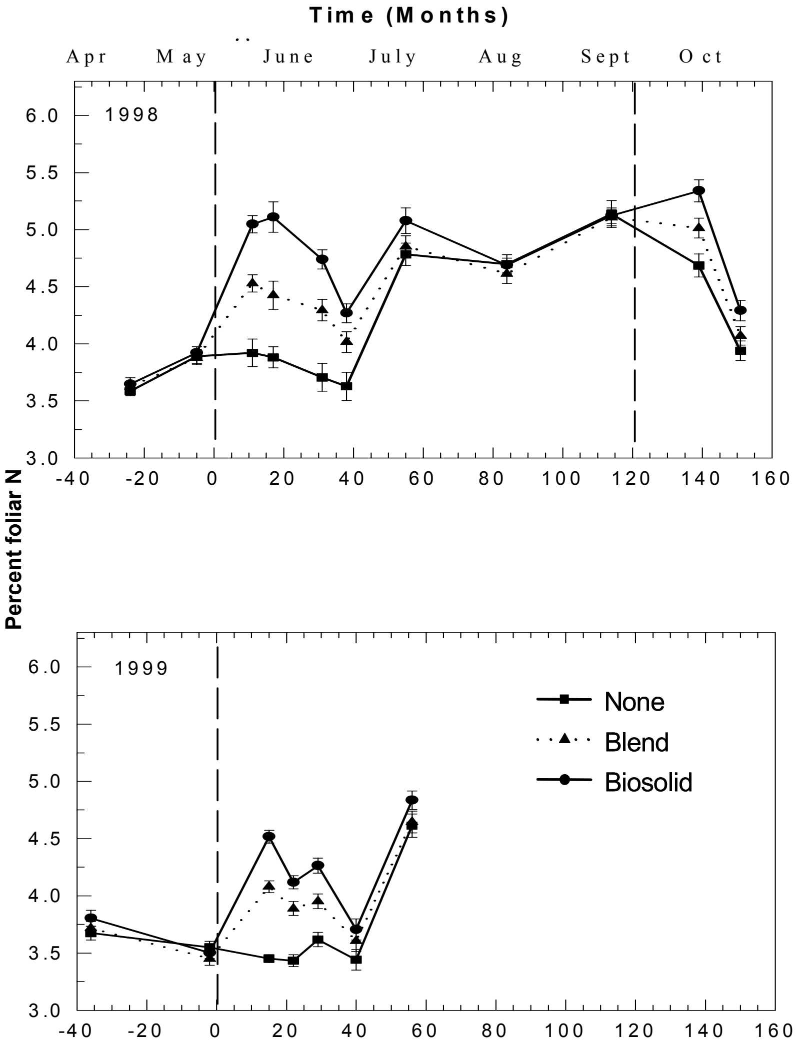
Table 3.3: Mean ± SD number of surviving fall armyworm larvae feed with clippings from treatment plots.

Table 3.3 Continued

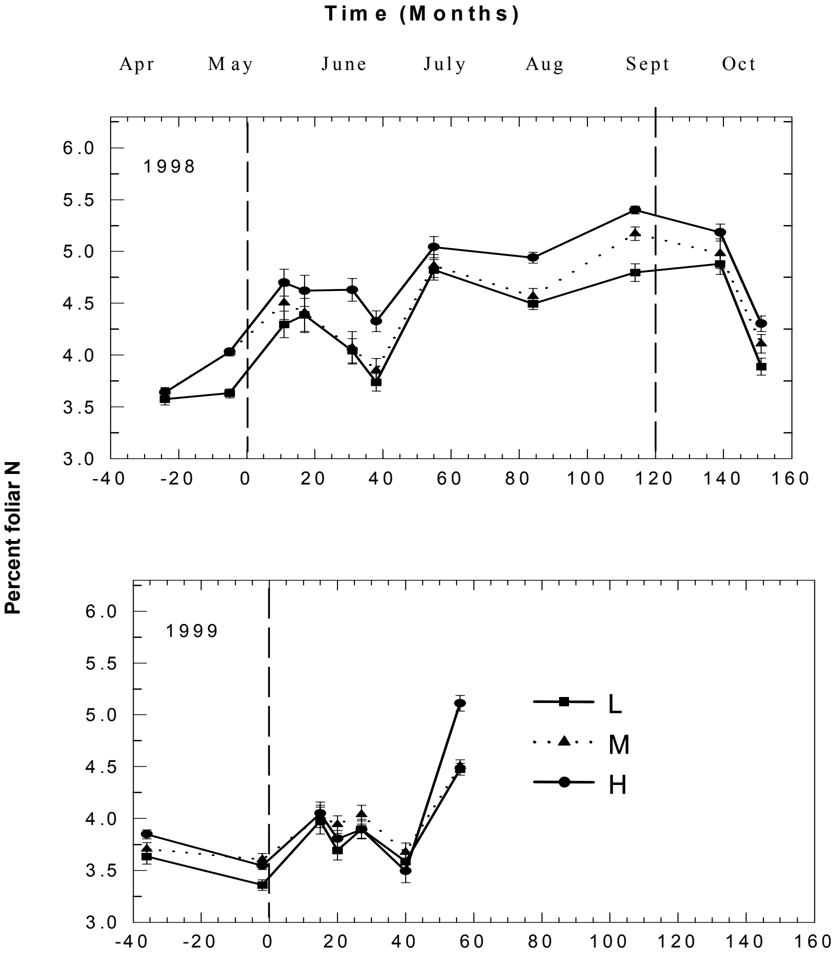
		# FAW	SD	n			# FAW	SD	n
Block 1	DAY_4	3.25	±1.98	36	Block 2	DAY_4	4.53	±1.06	36
	DAY_6	3.36	±1.91	36		DAY_6	4.25	±0.84	36
	DAY_8	2.58	±1.87	36		DAY_8	3.75	±1.50	36
	DAY_10	2.14	±2.14	36		DAY_10	3.33	±1.57	36
	DAY_12	1.81	±1.56	36		DAY_12	3.11	±1.24	36
	DAY_14	1.75	±1.11	36		DAY_14	2.58	±1.11	36
	DAY_16	1.14	±1.27	36		DAY_16	0.42	±0.69	36
Block 3	DAY_4	4.81	±0.47	36	Block 4	DAY_4	4.64	±0.90	36
	DAY_6	4.31	±1.21	36		DAY_6	4.25	±0.94	36
	DAY_8	4.03	±1.18	36		DAY_8	4.03	±1.34	36
	DAY_10	3.89	±1.01	36		DAY_10	3.92	±1.23	36
	DAY_12	3.72	±0.61	36		DAY_12	3.78	±0.72	36
	DAY_14	3.44	±0.69	36		DAY_14	3.47	±0.84	36
	DAY_16	0.28	±0.66	36		DAY_16	0.25	±0.50	36

	summer 99
N	0.39
Core	0.38
Comp.	0.18
Block	0.00
NxCore	0.34
NxComp.	0.38
CorexComp	0.94
NxCorexComp.	0.57

Table 3.4: Table of *p* values for main ($p \le 0.05$) and interaction plots ($p \le 0.15$) based on ANOVA of means for fall armyworm survival assay.



Graph 3.1: Foliar nitrogen level within compost treatments.



Graph 3.2: Foliar nitrogen level within fertilizer treatments.

DISCUSSION

3.4.1 Conclusions

Feeding assays are a simple and powerful way of assessing the quality of a particular food source. By using a feeding assay we hoped to show that compost top-dressing would have a significant impact on the growth rates of fall armyworms (FAW). This effect was not seen in the experiment performed. Rather what was seen was a uniform growth rate across the main treatments as well as the within the interaction treatments. This lack of variation in the growth rate is attributed to the missed Fall 1999 application of compost top-dressing. By the absence of this application of composts we feel that the nutrient state of the turf had drop back to a base leval where all the treatments were equal in there foliar nutrition. Had the Fall compost application been made then we would have expected that the foliar nitrogen content would have resembled the 1998 data and thus at the time of testing we would have seen this difference reflected in the growth rate of the feeding assay subjects. Whether the influence would have been a positive (growth increase) or negative (growth retardation) effect on the caterpillars we can not tell from this data as presented.

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