Poultry Litter as a Nutrient Source for Low Input Forage Systems

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ABSTRACT

Despite high volumes of manure production in the Shenandoah Valley, there are still areas of forage production in the Shenandoah Valley that are nutrient deficient, because manures have traditionally been applied to higher value row crops. Furthermore, anecdotal reports have suggested that application of poultry litter to pastureland may increase the abundance of weeds. This study was conducted to compare the effects of poultry litter and inorganic fertilizers on soil fertility, aboveground botanical composition and soil seed bank composition of established mixed naturalized pastures. Two sites each had the following treatments applied for two consecutive years: 1) split application of litter: 3.36 Mg ha^{-1} in spring and 3.36 Mg ha^{-1} in summer; 2) inorganic fertilizer at same N, P and K rates as Trt. No. 1; 3) single application of litter: 6.72 Mg ha^{-1} in spring; 4) inorganic fertilizer at same N, P and K rates as Trt. No. 3; 5) unfertilized control. Forage yield, soil pH, Mehlich 1 P (M1P), P balance, water soluble phosphorus (WSP), shifts in aboveground botanical composition, seed bank composition, and species richness (SPR) were monitored during this experiment. In addition, we examined whether poultry litter carries germinable weed seeds that can be transferred to forage systems after application. On average, soil pH was 0.2 higher for litter than chemical fertilizer treatments, but this difference was not significant. Mehlich 1 P and WSP both increased throughout the two years, but no significant differences were found amongst split and single application or litter and inorganic fertilizers. Phosphorus balance analysis indicated that forage yield did not remove adequate P to prevent environmental concerns, when using N based applications. Fertilization increased yield 3.5 Mg ha^{-1} on average and yield responses to application timing and fertilizer types were similar. Desirable species abundance increased significantly (linear regression, $P < 0.05$) over time in both fertilizer and poultry litter application treatments. Furthermore at one site, Shenandoah County, poultry litter application actually reduced the number of weedy species in plots (P=0.04). Weedy plant abundance did not differ at either site, and no significant change in species richness (number of species/area) was observed at Rockbridge County for any treatment. No treatment effects were found for seed bank species richness and number of

germinated seeds (m^{-2}). No seedlings germinated directly from poultry litter collected from several sites in Virginia. Poultry litter was comparable to inorganic fertilizer in terms of increasing soil WSP, M1P, forage yield, and above ground composition of desirable forage species. Timing of application made no difference. Additionally, our results indicate that poultry litter has no viable seed and does not increase weed abundance in mixed naturalized pastures.

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DEDICATION

This is dedicated to the many friends and family that have influenced me throughout the process of creating this thesis. The faculty of the Virginia Polytechnic Institute and State University's Crop and Soil Environmental Sciences Department deserve my thanks and gratitude. However, there are two people in particular that merit special appreciation. First and foremost, is my lovely wife Shenandoah who has stood by me and supported me with grace and love. Secondly, I would like to thank the late Dr. John Simon, the man that I considered a mentor and advisor of the greatest honor. John Simon's counsel to continue my education in graduate school was the pivotal point in my decision to pursue higher education, and for that I will forever be grateful.

Chapter 1

LITERATURE REVIEW

Introduction

Poultry litter management in the Shenandoah Valley of Virginia has become an important topic in nutrient management for environmental concerns as well as crop production. Traditionally, animal manures have been applied to high value row crops such as corn. As these farms with higher value row crops become more and more nutrient rich, after years of manure applications, we find ourselves in need to find other cropping systems that can use animal manures as a nutrient source. The Shenandoah Valley is an area of intensive poultry production. This results in an over abundance of manure nutrients relative to crop needs (Maguire et al., 2007).

Many areas of the valley are not used for higher value row crops; instead they are comprised of grazing and haying systems that have been unused or under-fertilized in the past. Presently, the poultry production systems do not have enough land to apply the litter produced by the vast number of birds on-site, to meet and comply with phosphorus (P) based management criteria. Phosphorus based application management is important in order to prevent over application of P nutrients to lands and ultimately decrease the potential for freshwater aquatic pollution (DeLuane et al., 2004; Johnson et al., 2004; D'Angelo et al., 2003; Pote et al., 2003; Schroeder et al., 2004). Phosphorus is relatively insoluble and therefore the major risk of P pollution to freshwater is via surface runoff (Schroeder et al., 2004). However, research has concluded that P from manure applications moved deeper into the soil than P from fertilizer. Additionally, they speculated that the P moved in organic forms, and possible chemical reactions between manure and soil may enhance P solubility (Eghball et al., 1996).

Historically, manure applications such as poultry litter have been applied on crop nitrogen (N) demand basis. Nitrogen based nutrient applications can over apply P (Maguire et al., 2008; Sistani et al., 2008). Continuous over application of P can elevate soil P concentrations to critical levels and increase potential for surface runoff and P leaching (Kaiser et al., 2009).

Despite the need to monitor manure applications for environmental protection purposes, there are many benefits that can arise from using poultry litter as a nutrient source for low input forage systems. Harmel et al., (2008) have looked into the agro-economic effects of fertilizing cropland with poultry litter. Currently, inorganic forms of fertilizer have become more costly. To respond to this overhead increase for farmers, many researchers are investigating the uses of manures as an alternative source of plant nutrition. Specifically in the Shenandoah Valley of Virginia, many producers hope to use manures as a nutrient source to reduce on-farm overhead costs and find ways to advantageously utilize recyclable nutrient sources such as poultry litter.

pH

Soil pH is one of the most important factors in agricultural production. Availability of many plant required nutrients are determined by soil pH. The optimal pH range for Virginia forage production is 6.2 to 6.5. Poultry litter contains calcium carbonate and has a pH of about 8 (Maguire et al., 2008). Thus it has a slight liming effect on soils with lower pH ranges. At pH above 6.5, P may be bound to calcium in the form of calcium phosphate and become less soluble (Spargo et al., 2006). At pH lower than 6.2, P may precipitate as insoluble iron/aluminum-P compounds (Tisdale et al., 1993). Phosphorus is not the only macronutrient affected by pH. Nitrification is enhanced by maintaining a pH of 5.5 to 6.5. At these pH levels the breakdown of organic matter is accelerated and the mineralization of organic N is increased (Tisdale et al., 1993). Soil pH plays a role in plant availability of many nutrients.

Mineralization of organic litter is necessary to release nutrients to the soil and render them plant available. When dealing with forage cropping systems, liming to reach the optimal pH is necessary in order to insure desired forage yields. Inorganic fertilizers typically are acidic in nature. Ammonium nitrate can acidify soil by means of nitrification reaction. For every mole of ammonium nitrate used, two moles of acidity are produced (Wild, 1988). Therefore, when using inorganic nitrogen fertilizers some liming may be required depending on the initial pH of the soil. Typically phosphorus and potassium fertilizers do not affect soil pH. However, some rock phosphates have a slight liming effect (Wild, 1988). Soil pH determines the ionic state of P in soil solution, and ultimately determines plant availability.

Phosphorus

Phosphorus is essential in plant meristem tissue growth, cell division, enzymatic reactions, creation of nucleotides (ADP and ATP), and it plays a key role in the conservation of transfer of energy for a wide range of biochemical processes (Wild, 1988). Phosphorus is absorbed by plants typically as orthophosphate ions, which are present in soil solution (Tisdale et al., 1993). These orthophosphate ions are $H_2PO_4^-$ and HPO_4^{2-}. As previously discussed, pH is the major factor that determines the amount of each ion in soil solution. Plant uptake of HPO_4^{2-} is much slower than that of $H_2PO_4^-$, at pH levels of 7.2 or below $H_2PO_4^-$ is the dominate P species (Tisdale et al., 1993).

Determination of P in soils can be accomplished by many means. Today there are eight common soil testing procedures for determining soil P; each was designed for a specific soil situation (Jones, 2001).

Water extractable phosphorus (WSP) method was introduced to examine the correlation between WSP and crop yields (Luscombe et al., 1979). Furthermore, a study conducted by Pote et al., (1996) determined a direct correlation between WSP and dissolved reactive P concentrations in runoff. However the WSP fraction of total P is relatively small and can only give estimates of how much P will be extracted from infiltrating water and surface runoff.

In the Shenandoah Valley of Virginia the most commonly used extraction method is Mehlich 1 or Mehlich 3. Since many ridge and valley soils are low in organic matter and have a slightly acidic nature M1P is typically used to determine soil P and create a basis for fertilizer requirements in croplands. However, Maguire and Sims (2002) concluded that the Mehlich 3 test can be used to predict phosphorus leaching potential in agronomic soils. Poultry litter is an excellent source of P for plant growth, and can provide adequate concentrations of soil P for maximum crop yields if properly applied.

P Based Nutrient Management

Eutrophication of fresh surface waters is becoming a major environmental concern worldwide. Recently, researchers have determined that phosphorus pollution is the major factor in freshwater eutrophication (Correll, 1998). Furthermore, agricultural researchers have determined that nonpoint-source pollution from agricultural land application of fertilizers and manures is a relatively large fraction of the problem (Daniel et al., 1998). This problem can partially be attributed to the over application of manures as a nutrient source for agricultural lands. Manures contain greater amounts of P than N, on a crop demand basis. When manures are applied to crops based on crop N demands, P typically is over applied to the amount of P that crops require. This may elevate soil P values to levels that can promote P pollution via runoff or leaching (Daniel et al., 1998; Kaiser et al., 2009; Maguire et al., 2008). To deal with this phenomenon many researchers and producers, in many states, are promoting manure applications to be applied based on crop P demand. Additionally, many states have developed a P-Index for crop lands that will still allow additional P applications despite high soil test P values (DeLaune et al., 2004; Gburek et al., 2000; Mallarino et al., 2002). Depending on state specific index criteria, producers can still apply P to high soil test P lands if there is little threat of losing P to surface or groundwater systems. These criteria are based on slope, distance to surface waters, and presence of buffer strips. Also, recent research in application methods (tillage, injection, knifing, etc.) have aided in reducing potential surface runoff of P from manures and lowered the potential for agricultural nonpoint-source pollution of P (Eghball et al., 1996).

Poultry Litter

Farmers have reaped the benefits of manure applications to soil to increase fertility and crop yields for many, many years. Poultry litter is manure that is comprised of bedding material (usually peanut hulls and woodchips), turkey or chicken excrement, and residual feeds. Poultry production is dominant in the southeastern mountainous regions of the United States. Litter application in these regions have greatly increased forage and beef outputs from land that has been previously considered marginal for agricultural production (Pote et al., 2003). In 1998, the U.S. poultry industry generated 12 million Mg of broiler litter, most of which was applied to grassland as fertilizer (Finlay-Moore et al., 2000). The state of Georgia is one of the top broiler chicken producing regions of the United States with 1.29 billion broilers raised in 2002 (Schroeder et al., 2004). Many other states such as Maryland, Virginia, Arkansas, North Carolina and more have massive turkey and chicken production systems that produce much of the world supply of poultry meat. These production systems produce vast amounts of usable litter for agricultural fertilizer. Litter can be collected from bird houses or used in free range systems where litter is applied directly to lands from fecal excretion (Kratz et al., 2004). The bird housing systems produce vast amounts of litter that must be collected and transported to agricultural lands. These transportation costs limit the geographical distances that the litter can travel for application (Harmel et al., 2008). Broiler litter is approximately a 3-3-2 grade (N-P_2O_5-K_2O) fertilizer (Stephenson et al., 1990; Mitchell and Donald et al., 1995). This low N-P-K grade creates a transportation problem when litter volume that equals crop demands is in Megatons.

The transportation of this litter remains a major overhead cost, and a cost benefit analysis should be used to evaluate the relative value of using litter as a nutrient source (Harmel et al., 2008). According to Bosch and Napit, (1992) the export of litter from surplus to deficient areas for use as fertilizer was found to be economically viable in Virginia… such transfers would result in substitution for inorganic commercial fertilizers and fewer nutrients would be applied reducing the potential for environmental water quality concerns. Farmers and producers that have agricultural fields located within close proximity to poultry houses can benefit the most from using litter as a nutrient source.

Litter Application Methods

Poultry litter can be applied by means of surface broadcast application, incorporation tillage, subsurface banding, chemical alteration, and composted surface application. Research has shown that surface application of poultry litter without chemical alteration or composting produces the greatest potential for nutrient losses via runoff or volatilization (Moore et al., 2000; Shreve et al., 1995; Tarkalson and Mikkelsen, 2004; Warren et al., 2006; Warren et al., 2008). Many methods for poultry litter applications have been tested to determine which is best for reducing potential nutrient losses to runoff, leaching, and volatilization while still producing the greatest yield for the crop. Incorporation or tillage has been used historically to prevent runoff of manures and additionally prevent N losses from ammonia volatilization. Tarkalson and Mikkelsen, (2004) reported that incorporation of broiler litter to 13 cm by roto-tillage decreased flow-weighted concentrations of reactive phosphorus in runoff by 97% and mass loss of total phosphorus in runoff by 88 % when compared to surface application. Another study concluded that incorporating litter by knifing method decreased nutrient concentrations and mass losses in runoff by 80-95% while showing a strong tendency to increase forage yield (Pote et al., 2003). The increase in yield by incorporation methods of poultry litter is most likely attributed to reduction in soil nutrient losses by runoff or volatilization.

Composting litter is another method to reduce nutrient losses, especially N, by means of reducing N mineralization, and therefore reducing ammonia volatilization (Brinson et al., 1994). However, Tiquia and Tam, (2000) found that composting chicken litter reduced the amount of initial nitrogen by 59%, due to ammonia volatilization in the composting pile. They continue to speculate that the narrow C:N ratio of the litter (<20:1), and the near neutral pH of the litter pile may have promoted ammonia volatilization. Therefore, when composting litter to reduce N losses, it is important to monitor the composting conditions in order to prevent adverse reactions and ultimately negating the original intentions of the process. Additions of carbon may increase

C:N ratio and decrease volatilization while liming may increase pH to reduce ammonia losses as well.

An additional technique to reduce nutrient losses from litter applied to crops and forage land is to chemically alter the litter, prior to application. Chemical amendments such as alum ($Al_2 (SO_4)_3 \cdot 14H_2O$) and ferrous sulfate ($FeSO_4 \cdot 7H_2O$) may reduce the solubility of manure P through precipitation and/ or adsorption reactions (Shreve et al., 1995). Shreve et al., (1995) reported up to an 87% reduction in P runoff from alum treated litter as well as a maximum reported reduction of P in runoff from ferrous sulfate treated litter. This decrease P loss to runoff retained P in the soil and additionally increased forage yields. Alum treatments to litter have also been reported to decrease ammonia losses by lowering litter pH (Moore et al., 2000).

Application Rates and Timing

Application rates are usually determined by crop demand and soil test analysis results. A recent summary based on agro-economic effects of utilizing poultry litter on cropland determined that, an economically optimal annual litter rate of 1 to 2 tons acre^{-1} is also environmentally optimal according to nutrient run-off and soil nutrient data collected on site (Harmel et al.,2008). This may be true depending on application methods and specific site characteristics. However, soil test P for the specific cropland or forage land should be the ultimate determining factor for application rate. Yield response curves for any fertilizer application have an optimal range of application before the increase in yield is no longer beneficially affected by additional inputs.

Harmel et al, (2008) found that inputs of over 2 tons acre^{-1} of poultry litter did not increase the relative harvest profit per acre. Application rates are typically determined by analyzing the soil within the agricultural land and then determining rates based on crop demands and environmental impact potential. However, application timing is determined by crop type and regional factors such as rainfall and temperature. When working with surface application of poultry litter specifically, application timing to reduce losses to the environment is crucial. Application prior to a small rain event is recommended to insure mineralization of litter into the soil profile, but if litter is surface applied prior to a large rain event, losses to surface and groundwater can be great (Pote et al., 2003; Schroeder et al., 2004). Researchers found that even after ten simulated rainfall events, post litter application, resulted in 6 to 11% of P applied lost to agricultural runoff (Schroeder et al., 2004).

Many agronomic researchers that deal with hay forages and pastures recommend splitting application of fertilizers or manures to insure fertility for late cool-season grass growth (Hanson et al., 1978; Riesterer et al., 2000; Moser et al., 1996). Generally, producers will apply half the amount of fertilizer or manure in the early spring and half after first cutting for hay. This process has been shown to increase cool-season grass yearly total yields (Hanson et al., 1978). Cool season grasses tend to have maximum growth in early spring and early fall. Therefore splitting the application of manures or inorganic fertilizer may aide in late season growth for cool-season grasses.

Forage

Forages, especially cool-season grasses, play a significant role in animal nutrition and supply a great deal of feed for ruminant livestock production (Angima et al., 2008). The attempt to improve forage production and yields has been a great concern for livestock producers. Forage yield for haying, grazing or stockpiling can be a determining factor in overall income for a livestock production family or business. Forage quality factors such as palatability, digestibility, protein, fiber, and carbohydrate content is just as important as yield for producers.

Many areas of the Shenandoah Valley, Virginia have hay and pasture fields that are in dire need for nutrient inputs. Much improvement can be made on these lands with additions of nutrients and optimal production of forage can be achieved but the question remains is it cost efficient to do so. As inorganic fertilizer costs increase rapidly many local Shenandoah Valley producers are looking at means to increase forage production without losing finances due to high costs. Incidentally, as previously discussed the Shenandoah Valley is an area of high poultry production and in turn produces vast amounts of poultry litter. This litter can be used as a nutrient source for these low input forage systems to improve forage quality and quantity at a reduced cost compared to inorganic fertilizers, once transportation issue are equalized.

Forage Composition

The typical unmanaged forage system in the Shenandoah Valley is comprised of a mixture of many cool and warm-season grasses, along with some undesirable weeds and forbs species. Many forages in this area consist of Tall fescue (*Schenodorus arundinaceus Schreb*.), Orchardgrass (*Dactylis glomerata L*.), Bemudagrass (*Cynodon dactylon L.),* Broomsedge (*Andropogon virginicus L.),* Fall panicum (*Panicum dichotomiflorum Michx.),* Kentucky bluegrass (*Poa pratensis L*.), Common Cinquefoil (*Potentilla Canadensis L.),* Broadleaf plantain

(*Plantago major L.*), White clover (Trifolium repens L.), Red clover (Trifolium pretense L.), Black medic (*Medicago lupulina L.*), Common chickweed (*Stellaria media L.*), Dandelion (*Taraxacum officinale*), Chicory (*Cichorium intybus L.*), Common ragweed (*Ambrosia artemisiiflia L.*), Common Yarrow (*Achillea millefolium L.*), and Wild carrot (*Daucus carota L.*) (G. M. Silberhorn, 1982; Uva et al., 1997). However, tall fescue, orchardgrass, kentucky bluegrass, white clover, red clover and black medic seem to be the dominate species of the low input mixed naturalized pastures in Shenandoah and Rockbridge Counties, where this study was performed.

Forage Yield

Forage yield can increase with fertilization of any source (Anigma et al., 2009; Hanson et al., 1978; Pote et al., 2003). Inorganic commercial fertilizers often are used to increase yields of pasture or haying forages. Additionally and historically, many farmers have used manures of many sources to fertilize forage lands to increase yields and recycle excess animal wastes. In the Shenandoah Valley poultry manure is the most available manure that can be used to increase soil fertility and ultimately increase forage yields. Pote et al., (2003) reported that forage plots treated with poultry litter responded well to the additions and treated plot yields were at least 250% greater than mean yield of non-treated control plots. Furthermore, they (Pote et al., 2003) stated that incorporating the litter had additional positive effects on yield in perennial grasses. Researchers have used poultry litter in the past to increase forage yield in unmanaged pastures. Lucero et al., (1995), recommended for a two year application rate of 19.4 Mt ha^{-1} of litter to pasture lands with drastically low nitrogen rates to increase yields. Their total two year yields were 21.5 Mt ha^{-1} of fescue/bluegrass mixed pasture dry matter. Additionally, they matched commercial inorganic fertilizer rates to those of the poultry litter rates and the difference in total yield was 0.2 Mt ha^{-1}, more in yield for inorganic fertilized plots. This is important because it shows that poultry litter can be used as a substitute to inorganic fertilizers.

Forage Composition and Seedbank

Botanical composition in forage systems determines forage quality and potential uses for animal feeds. Tall fescue is considered the most important cool-season grass in the southeastern USA, but it is not considered a desirable grass in feed for many animals, due to toxic alkaloids associated with the fescue (Buckner and Bush, 1979). However, Shenandoah Valley unmanaged forage systems are comprised of a great percentage of fescue. Fertilization of any type can alter the botanical composition of unmanaged forage lands by favoring grass development by increasing its competitive usage of light, nutrients and water (Angima et al., 2009). Poultry litter applications to unmanaged pastures have increased the percentage of tall fescue by 30% and reduced the percentage of bluegrass species (Lucero et al., 1995). This may be beneficial because tall fescue is a greater yielding grass than bluegrass (Buckner and Bush, 1979). Many researchers have reported a decrease in number of plant species post fertilization (Kalmbacher and Martin, 1996; Mikhailova et al., 2000). The decrease in number of species can be beneficial if the species remaining are better quality for animal feeds. The ultimate benefit from altering botanical composition via fertility is to increase desirable forage species and eliminate undesirable weedy or potentially toxic species. Furthermore, fertilization from inorganic commercial fertilizer and/or manure sources can attribute to increasing overall yield by decreasing bare ground in pastures.

Seedbank composition may not be a great indicator of what species of plant that will emerge and proliferate above ground (Tracy and Sanderson, 2000). However, composition of the soil seedbank may predict which species dominate a plant community after disturbance (Nobel and Slatyer, 1980). Knowledge of the seedbank composition in a particular system may be beneficial to pasture managers if they choose to attempt to inhibit a certain species from proliferating and in turn encourage a species that may be desirable. Nevertheless, most research has shown that there is little correlation between seedbank composition and emergent botanical composition (Tracy and Sanderson, 2000).

Statement of Purpose of Research

Our research is an attempt to find data that supports the theories that: (i) poultry litter can be used as a nutrient source and is comparable to inorganic fertilizer sources (ii) splitting application improves overall cool-season grass forage yield (iii) increase desirable forage species by litter fertilization, and (iv) litter applications promote and encourage weed growth.

REFERENCES

Anigma, S.D., R.L. Kallenbach, and W.W. Riggs. 2009. Forage yield of selected coo-season grasses in response to varying rates of nitrogen. Online. Forage and Grazinglands doi:10.1094/FG-2009-0129-01-RS.

Bosch, D.J. and K.B. Napit. 1992. Economics of transporting poultry litter to achieve more effective use as fertilizer. J. of Soil and Water Conservation Soc. 47(4):342-346.

Brinson, S.E. Jr., M.L.Cabiera and S.C. Tyson. 1994. Ammonia volatilization from surface-applied, fresh and composted poultry litter. Plant and Soil 167: 213-218.

Buckner, R.C., and L.P.Busch. 1979. Tall fescue. ASA, CSSA, SSSA. Madison, Wisconson Publishers, Inc.

Corell, David. 1998. The role of phosphorus in the eutrophication of receiving waters: A review. J. Environ. Qual. 27:261-266.

D'Angelo, E.M., M.V. Vandiviere, W.O. Thom and F. Sikora. 2003. Estimating soil phosphorus requirements and limits from oxalate extract data. J. Environ. Qual. 32:1082-1088.

Daniel, T.C., A.N. Sharpley, and J.L. Lemunyon. 1998. Agricultural phosphorus and eutrophication: A symposium overview. J Environ. Qual. 27:251-257.

Daniels, M.B., P. Delaune, P.A. Moore, Jr., A. Mauromoustakos, S.L. Chapman, and J.M. Langston. 2001. Soil phosphorus variability in pastures. J. Environ. Qual. 30:2157-2165.

DCR (Department of Conservation and Recreation). 2005. Nutrient Management Standards and Criteria.

DeLaune, P.B., P.A. Moore Jr., D.K. Carman, A.N. Sharpley, B.E. Haggard, and T.C. Daniel. 2004. Development of a phosphorus index for pastures fertilized with poultry litter-factors affecting phosphorus runoff. J. Environ. Qual. 33:2183-2191.

Eghball, B., G.D. Binford, and D.D. Baltensperger. 1996. Phosphorus movement and adsorption in soil receiving long-term manure and fertilizer application. J. Environ. Qual. 25:1339-1343.

Finlay-Moore, O., P.G. Hartel and M.L. Cabrera. 2000. 17Beta-Estradiol and testosterone in soil and runoff from grasslands amended with broiler litter. J Environ. Qual. 29:1604-1611.

Gburek, W.J., A.N. Sharpley, L. Heathwaite, and G.J. Folmar. 2000. Phosphorus management at the watershed scale: A modification of the phosphorus index. J. Environ. Qual. 29:130-144.

Harmel, R.D., B. Harmel, and M.C. Patterson. 2008. On-Farm agro-economic effects of fertilizing cropland with poultry litter. J. Appl. Poult. Res. 17:545-555.

Hanson, C.L., J.F. Power and C. J. Erickson. 1978. Forage yield and fertilizer recovery by three irrigated perennial grasses as affected by N fertilization. Agron. J 70:373-375.

Johnson, A.F., D.M. Vietor, F.M Rouquette, Jr., and V.A. Haby. 2004. Fate of phosphorus in dairy wastewater and poultry litter applied on grassland. J. Environ. Qual. 33:735-739.

Jones, J.B. Jr. 2001. Laboratory guide for conducting soil tests and plant analysis. CRC press. New York.

Kaiser, D.E., A.P. Mallarino, M.U Haq, and B.L. Allen. 2009. Runoff phosphorus loss immediately after poultry manure application as influenced by the application rate and tillage. J. Environ. Qual. 38:299-308.

Kalmbacher, R. and F. Martin. 1996. Shifts in botanical composition of flatwoods range following fertilization. J. Range Manage. 49:530-534.

Kratz, S., J. Rogasik, and E. Schnug. 2004. Changes in soil nitrogen and phosphorus under different broiler production systems. J. Environ. Qual. 33:1662-1674.

Lucero, D.W., D.C. Martens, J.R. McKenna, D.E. Starner. 1995. Poultry litter effects on unmanaged pasture yields, nitrogen and phosphorus uptake, and botanical composition. Communications in soil sciences and plant analysis. 26:861-881.

Luscombe, P.C., J.K. Syers, and P.E.H. Gregg. 1979. Water extraction as a soil testing procedure for phosphorus. Commun. Soil Sci. Plant Anal. 10:1361-1369.

Maguire, R.O., D.A., Crouse, and S.C. Hodges. 2007. Diet modification to reduce phosphorus surpluses: A mass balance approach. Journal of Environmental Quality. 36:1235-1240.

Maguire, R.O., G.L. Mullins, and M. Brosius. 2008. Evaluating long term nitrogen versus phosphorus based nutrient management of poultry litter. J. Environ. Qual. 37:1810-1816.

Maguire, R.O. and J.T. Sims. 2002. Measuring agronomic and environmental soil phosphorus saturation and predicting phosphorus leaching with Mehlich 3. Soil Sci Soc. Am. J. 66:2033-2039.

Maguire, R.O., J.T. Sims, and F.J. Coale. 2000. Phosphorus solubility in biosolids-amended farm soils in the Mid-Atlantic region of the U.S. Journal of Environmental Quality. 29:1225-1233

Mallarino, A.P., B.M. Stewart, J.L. Baker, J.D. Downing, and J.E. Sawyer. 2002. Phosphorus indexing for cropland: Overview and basic concepts of the Iowa phosphorus index. J. Soil and Water Conservation 57:440-447.

Mikhailova, E.A., R.B. Bryant, D.J.R. Cherney, C.J. Post, and I.I. Vassenev. 2000. Botanical composition, soil and forage quality under different management regimes in Russian grasslands. Agriculture, Ecosystems and Environ. 80:213-226.

Mitchell, C.C. and J.O. Donald. 1995. The value and use of poultry manures as a fertilizer. An. Cir. :ANR-244 Ala. Coop. Ext. Serv., Auburn University, AL.

Moore, P.A., T.C. Daniels, and D.R. Edwards. 2000. Reducing phosphorus runoff and inhibiting ammonia loss from poultry manure with aluminum sulfate. J. Environ. Qual. 29:37-49

Nichols, D.J., T.C. Daniels, and D.R. Edwards. 1994. Nutrient runoff from pasture after incorporation of poultry litter or inorganic fertilizers. Soil Sci Soc Am J. 58:1224-1228.

Nobel, I.R. and R.O. Slatyer. 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. Vegetatio. 43:5-21

Pote, D.H., W.L. Kingery, G.E. Aiken, F.X. Han, P.A. Moore Jr. and K. Buddington. 2003. Water-quality effects of incorporating poultry litter into perennial grassland soils. J. Environ. Qual. 32:2392-2398.

Riesterer, J.L., D.J. Undersander, M.D. Casler and D.K. Combs. 2000. Forage yield of stockpiled perennial grasses in the upper Midwest USA. Agron. J 92:740-747.

Schroeder, P.D., D.E. Radcliffe, and M.L. Cabrera. 2004. Rainfall timing and poultry litter application rate effects on phosphorus loss in surface runoff. J. Environ. Qual. 33:2201-2209..

Shreve, B.R., P.A. Moore, T.C. Daniels, D.R. Edwards, and D.M. Miller. 1995. Reduction of phosphorus in runoff from field-applied poultry litter using chemical amendments. J. Environ. Qual. 24:106-111.

Silberhorn, G.M. 1982. Common plants of the Mid-Atlantic coast. A field guide. Johns Hopkins University Press.

Sistani, K.R., G.E. Brink, and J.L. Oldham. 2008. Managing broiler litter application rate and grazing to decrease watershed runoff losses. J. Environ. Qual. 37:718-724.

Spargo, J.T., G.K. Evanylo and M.M. Alley. 2006. Repeated compost application effects on phosphorus runoff in the Virginia piedmont. J. Environ. Qual. 35:2342-2351.

Stephenson, A.H., T.A. McCaskey, and B.G. Ruffin. 1990. A survey of broiler litter composition and potential value as a nutrient source. Biol. Wastes 34:1-9.

Tarkalson, D.D. and R.L. Mikkelsen. 2004. Runoff phosphorus losses as related to phosphorus source, application method, and application rate on a piedmont soil. J. Environ. Qual. 33:1424-1430.

Tiquia, S.M. and N.F.Y. Tam. 2000. Fate of nitrogen during composting of chicken litter. Journal of Environmental Pollution. 110: 535-541

Tisdale, S.L., W.L. Nelson, J.D. Beaton, and J.L. Havlin. 1993. Soil fertility and fertilizers. Macmillan Pub. Co. New York.

Tracy, B.F., and M.A. Sanderson. 2000. Seedbank diversity in grazing lands of the northeast United States. J. Range Mange. 53:114-118.

Uva, R.H., J.C. Neal, and J. M. DiTomaso. 1997. Weeds of the Northeast. Cornell University Press.

Warren, J.G., S.P. Phillips, G.L. Mullins, and L.W. Zelazny. 2006. Impact of alum-treated poultry litter applications on fescue production and soil phosphorus fractions. Soil Sci. Soc. Am. J. 70:1957-1966.

Warren, J.G., K.R. Sistani, T.R. Way, D.A. Mays, and D.H. Pote. 2008. A new method of poultry litter application to perennial pasture: subsurface banding. Soil Sci Soc Am J. 72:1831-1837

White, H.E., and D.D. Wolf. 1996. Controlled grazing of Virginia pastures. Virginia Cooperative Extension Agriculturalists. 418-012.

Wild, Alan. 1988. Russell's soil conditions and plant growth. 11th ed. John Wiley & Sons. New York.

Chapter 2

Improving Soil Nutrition with Poultry Litter Application in Low Input Forage Systems

ABSTRACT

Despite high volumes of manure production in the Shenandoah Valley of Virginia, there are still areas of forage production that are nutrient deficient, because manures have traditionally been applied to higher value row crops. This study was conducted to compare the effects of poultry litter and inorganic fertilizers on soil fertility and forage production. Two sites had the same treatments applied for two consecutive years, treatments were: 1) split application of litter (half in spring and half in summer); 2) inorganic fertilizer at same N, P and K rates as Trt. No. 1; 3) single spring application of litter; 4) inorganic fertilizer at same N, P and K rates as Trt. No. 3; 5) unfertilized control. Forage yield, soil pH, Mehlich 1 P (M1P), P uptake, and water soluble phosphorus (WSP) were measured during this experiment. On average, soil pH was 0.2 higher for litter than chemical fertilizer treatments, but this difference wasn't significant. Mehlich 1 P and WSP both increased throughout the two years, but no significant differences were found among split and single application or litter and inorganic fertilizers. Fertilization increased yield 3.5 Mg ha^{-1} on average and application timing and fertilizer types produced similar yields. The P balance revealed that either site did not remove adequate P from forage yield to prevent environmental concerns, when using N based applications. Our data showed that poultry litter was comparable to inorganic fertilizer in terms of increasing soil WSP, M1P and forage yield, and timing of application made no difference.

INTRODUCTION

The Shenandoah Valley of Virginia is an area of very intensive poultry and dairy production and this resulted in an overabundance of manure P relative to crop needs (Maguire et al., 2007). Poultry litter applications can present an environmental water quality problem if not properly applied, based on rates and methods (Kaiser et al., 2009). Poultry litter applied to land based on N requirements over applies P compared to crop uptake and can lead to a buildup of P in soils (Maguire et al., 2008). A Phosphorus Index has been developed in most U.S. states and is currently being implemented based on state and federal regulations (DeLuane et al., 2004). Monitoring P uptake from crops and forages is important when determining P balances for a specific production scenario. Excess P in agricultural soils can result in losses to surface and groundwater systems (DeLaune et al., 2004; Johnson et al, 2004; Pote et al., 2003; Schroeder et al., 2004). The increased P in surface waters can lead to excess algal blooms and reduced dissolved oxygen (D'Angelo et al., 2003). Presently, 85 percent of litter is being exported from poultry farms in Virginia (VA Department of Conservation and Recreation, personal communication). The reason litter is being exported from regulated farms is that they do not have enough land to apply the litter according to P-based nutrient management plans. Virginia nutrient management regulations state that you can only apply manure at N based rates up to a soil test of 55 mg kg^{-1} M1P (DCR, 2005). To apply manure above 135-162 mg kg^{-1} M1P, depending on physiographic region, you must apply manure at a P removal rate or run a P Index. The P Index sometimes allows application of manure P to agricultural land to exceed agronomic rates based on specific site characteristics that indicate no excess environmental P losses will occur.

Poultry litter has traditionally been applied to high value row crops throughout the Shenandoah Valley, but there are still large areas of pasture and forage land that are low in P. Local producers can benefit from using poultry litter on forage systems by increasing yield and gaining an economic advantage compared to commercial fertilizer costs (Harmel et al., 2008).

It is not only fertilization rate, but also timing of applications that can benefit forage production. Farmers prefer a single application as this is less time consuming, but there is evidence that splitting fertilizer applications into two separate applications is beneficial. Riesterer et al. (2000) reported a 75% increase in standing forage organic matter with split applications of fertilizers when compared to single applications. Splitting the application of fertilizers in spring and summer is advised to ensure that plant nutritional demand for cool season forages is met later in the season, so fall and winter harvests or stockpiling is adequate for animal feed requirements (Riesterer et al., 2000). Single application of fertilizers in early spring may result in unwanted losses of nutrients to leaching and runoff. Split application of fertilizer can provide adequate N in spring and early summer and replenishment in late summer and early fall. Previous research has reported perennial grass yield to be greater with split application rates of 224 g N ha^{-1}, but at lower rates (56 kg N ha^{-1}) yield benefits were not apparent (Hanson et al., 1978). Traditional regulatory guidelines recommend split application of fertilizers to improve crop yield potentials (DCR, 2005), however split applications of fertilizers produce greater work demand for producers.

Correct rate and timing of nutrient applications is only part of optimum forage production. Adequate precipitation and timing of rainfall is required to mineralize litter and inorganic fertilizers and render them plant available (Kaiser et al., 2009). Too much precipitation directly after application can result in significant runoff or leaching of nutrients. Inversely, too little or untimely precipitation can result in inadequate release of applied nutrients and delayed yield effects (Johnson et al., 2004; Schroeder et al., 2004).

Optimizing forage production for hay and pasture systems is important in animal production. The increasing cost of inorganic fertilizers has driven the agricultural community to seek out alternative sources of nutrients. Animal manures have historically been used as nutrient sources in agriculture, but there is a lack of information on comparing inorganic fertilizer to poultry litter in cool season forage production systems. Therefore, the goals of this research were 1) evaluating poultry litter compared to inorganic fertilizers in cool season forage production, and 2) comparing single versus split application methods.

METHODS

Study Description

On-farm field trials were established in producer fields in Rockbridge and Shenandoah Counties of the Shenandoah Valley, Virginia. These two sites were chosen because of their very low soil test P ratings (6.3 to 11.5 mg kg^{-1}). Site forage species included but were not limited to: tall fescue (Lolium arundinaceum (Schreb.) Darbysh. = Schenodorus arundinaceus (Schreb.) Dumort), kentucky bluegrass (Poa pratensis L.), orchardgrass (Dactylis glomerata L.), and small percentages of various forbs and legumes. Both sites were established in April 2007 and the study was concluded in April of 2009.

There were five treatments, each replicated four times for a total of 20 plots per site. Plots were 3.1 m by 6.1m with a total area for all twenty plots of 0.04 hectares and the treatments were assigned by randomized complete block. Poultry litter was analyzed for nutrient content with a dry-ash method by the Agricultural Services Laboratory, Clemson University. For the surface application of litter, plant available N (PAN) was calculated as (0.6 × organic N) + (0.5 × ammonium N), and total P and K were considered completely plant available, according to VA nutrient management standards (DCR, 2005). Inorganic nutrient sources used to match N, P and K litter rates were ammonium nitrate, triple super phosphate, and potash. Treatments were: 1) Split application of litter: 67.2 kg PAN ha^{-1}, 25.7 kg P ha^{-1} (3.36 Mg ha^{-1} in spring and 3.36 Mg ha^{-1} in summer); 2) Inorganic fertilizer at same N and P rates as Trt. No. 1; 3) Single application of litter: 134.4 kg PAN ha^{-1}, 51.3 kg P ha^{-1} (6.72 Mg ha^{-1} in spring); 4) Inorganic fertilizer at same N and P rates as Trt. No. 3; 5) Unfertilized control. Treatments 1-4 received the same amount of PAN, P, and K on an annual basis. Treatments were surface applied by hand and not incorporated during years, 2007 and 2008. Supplemental lime was added to the Rockbridge County site for both years per Virginia Tech's soil test recommendations (Maguire and Heckendorn, 2009).

Soil and Forage Sampling and Analysis

Soil samples (0-10 cm) were collected by plot prior to treatment applications. Additional samples were collected at one week, one month, and six months after spring application for both years. Soil samples were air dried and ground to pass a 2-mm sieve. Samples were then analyzed for M1P, pH, and organic matter by the Virginia Tech Soil Testing Laboratory (Maguire and Heckendorn, 2009). Additionally, samples were analyzed for WSP at a 1:10 soil:water ratio (Luscombe et al., 1979) with the extract analyzed colorimetrically with an auto analyzer (QuickChem 8500; Lachat Instruments, Loveland, CO).. Iron (Fe), aluminum (Al), and P were determined by oxalate extract procedure (Iyengar et al. 1981) and the extract was analyzed by Inductively Coupled Plasma-Atomic Spectroscopy.

Forage samples were collected by harvesting the middle portion of the plot after plot edges had been mowed. Forage yields were determined by harvesting a 0.76 m width and a 7.5 cm cutting height by a walk behind flail harvester (Swift Machine and Welding Ltd., Saskatchewan, Canada). Harvest area was determined by measuring in-field swath length. Forage plots were harvested four times for Shenandoah County in 2007, three times for Rockbridge County in 2007 due to drought and no late season growth, and three times for both counties in 2008. Harvest was taken at about forty-five day intervals during the growing season. Samples were weighed and then sub-sampled for moisture determination and elemental analysis after drying at 65^0C and grinding to pass a 1.0-mm sieve. Total P determination was performed by using microwave assisted (20%) nitric acid digestion (Link et al., 1998) and analyzing the extract by Inductively Coupled Plasma-Atomic Spectroscopy.

Statistical Analysis

Data were interpreted using the JMP statistical software of the SAS Institute (2007). Means were partitioned using ANOVA test and statements of statistical significance were based upon the significance level of 0.05.

RESULTS AND DISCUSSION

Initial Soil Properties

The Rockbridge County site had a silt loam texture and is from the Frederick series, while the Shenandoah County site had a silt loam texture and is from the Endcav series (Table 1). Both sites had a gentle two percent slope. The average values for oxalate extractable elements for the Rockbridge County site were 774 mg Fe kg^{-1}, 764 mg Al kg^{-1}, and 158 mg P kg^{-1}. The Shenandoah County site had oxalate extractable element values of 565 mg Fe kg^{-1}, 891 mg Al kg^{-1}, and 87 mg P kg^{-1}. The Shenandoah site produced the highest oxalate extractable value for Al, while the Rockbridge site contained the highest value of oxalate extractable Fe and P.

Table 1. Initial soil properties for the Rockbridge and Shenandoah County sites.

County	Soil Series	Texture	Oxalate Fe	Oxalate Al	Oxalate P	Organic Matter
			mg kg^{-1}			g kg^{-1}
Rockbridge	Frederick	silt loam	774	764	158	47
Shenandoah	Endcav	silt loam	565	891	87	50

The oxalate P values for both sites are well below reported values for farms with intensive animal agricultural production (Maguire and Sims, 2002). Aluminum and Fe in crystalline and amorphous species are present in soils and the amorphous species can increase with additions of OM (Maguire et al., 2000). Aluminum and Fe oxides can bind soil P especially at slightly acidic pH (5.8-6.2) values (Arai et al., 2005; Borggaard et al., 1990). The values of oxalate extractable Al and Fe are well within range of soils with similar OM content (Maguire and Sims, 2002). The Al and Fe-P precipitates should be considerable when considering the slightly acidic nature of the soils for both sites and the relatively low soil P values. Arai et al. (2005), found that P was strongly retained in soils that were slightly acidic (pH ≈6.0) and relatively high in oxalate extractable P, Al, and Fe (615-858, 1215-1478, and 337-756 mg kg^{-1}, respectively). The added P from litter and inorganic fertility treatments may become adsorbed to the Al and Fe oxides found in the soils at both sites. The Rockbridge County site had an average OM concentration of 47 g kg^{-1} and the Shenandoah County site had an average value of 50 g kg^{-1} (Table 1). These values were slightly high when compared to published values for soils used for row crops in the Shenandoah Valley (Maguire et al., 2008). The OM values were not changed significantly throughout the fertility trials despite the additions of poultry litter (data not shown).

Change in Soil pH

Rockbridge County site initial pH ranged from 5.4 to 5.6 (Table 2). The Shenandoah County site had pH values ranging initially from 6.8 to 7.0 and received no lime amendments throughout the experiment. The recommended target pH for native forage grasses in Virginia is 6.2 to 6.5 (Maguire and Heckendorn, 2009). To neutralize the acidic nature of the Rockbridge soils, lime was added to the Rockbridge County site only. The Shenandoah County site had an initial pH value that was above the optimal value for native forage grasses, so no lime was added either year. Fertility treatments, whether organic or inorganic, did not offer any significant difference in pH values over the 2 years of the trials to each other or compared to the control plots (Table 2).

Table 2. pH over 2 years, for the five treatments at both sites.

Treatment	Initial†	6 month	1 Year	Final
		Rockbridge County		
Litter Split N	5.6a‡	6.0a	6.0a	6.3a
Fertilizer Split N	5.5a	5.7a	5.8a	6.0a
Litter Single N	5.4a	5.6a	6.0a	6.0a
Fertilizer Single N	5.5a	5.9a	5.8a	6.0a
No Fertilizer	5.5a	5.9a	5.8a	6.2a
		Shenandoah County		
Litter Split N	6.8a	6.8a	6.7a	6.6a
Fertilizer Split N	7.0a	6.7a	6.6a	6.3a
Litter Single N	6.9a	7.0a	6.8a	6.7a
Fertilizer Single N	6.9a	6.7a	6.6a	6.3a
No Fertilizer	6.9a	6.9a	6.7a	6.5a

† Immediately prior to fertilization
‡ Means within the same column for each county followed by different letters are significantly different at the 0.05 probability level

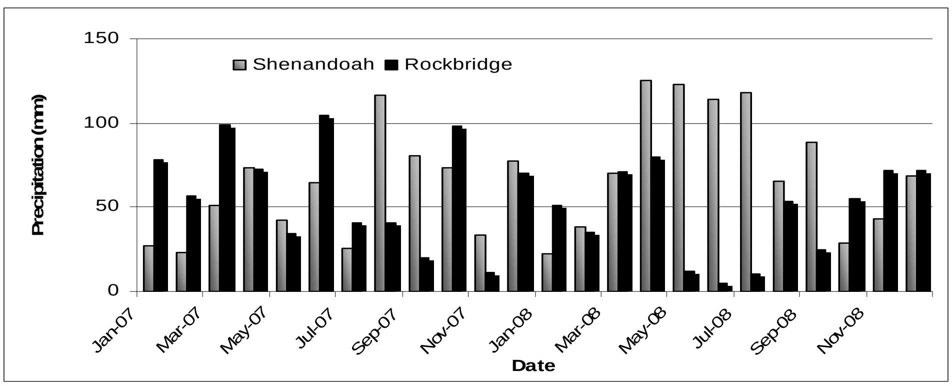
Although not significant after two years, there was a strong trend for higher pH where poultry litter had been used compared to inorganic fertilizer. On average the pH of the litter plots was 0.25 greater than the equivalent inorganic fertilizer plots. Poultry litter has a pH of approximately 8 and contains calcium carbonate, so it would be expected to have a slight liming effect (Maguire et al., 2008). So, if the experiment had been continued for more than two years the differential liming effect of poultry litter compared to commercial fertilizer on soil pH would be expected. The inorganic fertilizer mix that was used in the fertility trials was slightly acidic. This resulted in a decrease in pH over the two years of trials for the Shenandoah lots that were treated with inorganic fertilizers. If the Shenandoah site had received only inorganic fertilizer, it may have required liming eventually to neutralize the inorganic fertilizers acidic nature. The pH of the soil in forage lands can be very important when considering future fertility. If the pH were to decrease below recommended agronomic levels, P could be bound in soil to oxidized Al and Fe and be less plant available (Arai et al., 2005, Borggaard et al., 1990). Therefore, additions of P from any source may not have a positive effect on yield or forage quality until optimal pH levels are stabilized.

Change in Soil Mehlich 1 P

The initial values of M1P were well below the recommended agronomic optimum of 55 mg kg^{-1} for both sites (Table 3; Maguire and Heckendorn, 2009). The Shenandoah site had an initial average of 7.4 mg kg^{-1} M1P and increased to an average for the four fertility treatments of 20.5 mg kg^{-1} over the two year trials. Mehlich 1 P for all four fertilized treatments for Shenandoah County were statistically identical and statistically different than the two year value for the control plots average of 8.0 mg kg^{-1}. The M1P concentration for the Shenandoah site did not reach the recommended agronomic rate of 55 mg kg^{-1} for any treatment. Based on the two year increase in M1P, we can speculate that it would take two or more years of continued N-based fertilization treatments for the soil P concentration to reach 55 mg kg^{-1}. The highest value reached at the Shenandoah site was 26 mg kg^{-1} for the litter split N, but this was statistically identical to the other fertilized plots.

The Rockbridge site had an initial average of 8.6 mg kg^{-1} and increased over two years of fertilization to 56 mg kg^{-1} for the litter split application, 123 mg kg^{-1} for the inorganic fertilizer split application, 64 mg kg^{-1} for the litter single application, 90 mg kg^{-1} for the inorganic fertilizer single application, and 17 mg kg^{-1} for the no fertilizer control group. For Rockbridge County the litter single application and inorganic fertilizer single application were significantly similar which also had statistical significance to the litter split application. Additionally, all fertility treatments for Rockbridge County were significantly higher than the no fertilizer control The Rockbridge site, however, reached up to 123 mg kg^{-1} for the fertilizer split N treatment and 64 mg kg^{-1} for the litter single N treatment (Table 3). These relatively high values for the Rockbridge site can be most likely attributed to litter and fertilizer residue remaining on surface or in the upper soil profile, as a result of reduced mineralization due to lack of precipitation. Rockbridge County received a 30 to 45% decrease in precipitation for 2007-2008 when compared to the thirty year average (Fig. 1). The rainfall at the Rockbridge site was especially low during the May through July 2008 time period, compared to the Shenandoah site (Fig. 1).

Figure 1. Precipitation for both sites in 2007 and 2008.



Additional sampling was done at the Rockbridge site in April of 2009 to examine this phenomenon. The results of the April 2009 sampling show that the higher values decreased so that all fertilized treatments were statistically identical, but with an average of 61 mg kg^{-1}, they still remained slightly above the agronomic recommended value of 55 mg kg^{-1}. The values remained significantly greater than the no fertilizer control value of 19 mg kg^{-1} (Table 3). The reason M1P increased at the Rockbridge site to a greater extent the second year than the first remains unclear.

Table 3. Mehlich 1 phosphorus over two years of fertility trials for both sites

Treatment	Initial†		6 month		1 Year		2 year		Final	
	mg kg^{-1}									
	Rockbridge County									
Litter Split N	6	a‡	15	bc	17	a	56	c	56	a
Fertilizer Split N	6	a	22	a	15	ab	123	a	66	a
Litter Single N	12	a	19	abc	21	a	64	bc	49	a
Fertilizer Single N	12	a	20	ab	21	a	90	bc	73	a
No Fertilizer	7	a	12	c	8	b	17	d	19	b
	Shenandoah County									
Litter Split N	10	a	16	ab	15	a	26	a	-	
Fertilizer Split N	6	a	18	a	17	a	19	a	-	
Litter Single N	7	a	17	a	13	ab	19	a	-	
Fertilizer Single N	8	a	15	ab	14	a	18	a	-	
No Fertilizer	6	a	10	b	9	b	8	b	-	

† Immediately prior to fertilization
‡ Means within the same column for each county followed by different letters are significantly different at the 0.05 probability level

Soil Water Soluble Phosphorus

Rockbridge County had an initial range of WSP from 2.1 to 3.0 mg kg^{-1} and Shenandoah County had initial WSP values between 0.9 and 1.5 mg kg^{-1} (Table 4). Water soluble P can be an indicator of potential P runoff and leaching, since it is most easily lost (Maguire et al., 2008). Maguire and Sims (2002) reported that there was not a significant threat to P leaching until WSP levels approached 8.6 mg WSP kg^{-1}, above which there was a five fold increase in P leaching losses per unit increase in WSP. Only the Rockbridge site surpassed these levels after two years of fertilization (9.0 to 20.7 mg WSP kg^{-1}). This could be relevant to the matter of a significant drought during application times (less than 50 mm of rainfall for Rockbridge County between March – August 2008; Figure 1). Adequate amounts of rainfall must be received to mineralize the poultry litter (Shroeder et al., 2004). The inorganic fertilizer would require less rainfall to mineralize and disperse into the soil than the litter. Phosphorus is relatively insoluble, therefore the amount of P that can be extracted by water from soil is a relatively small proportion of the total. The Rockbridge County site shows a significant increase in WSP for the inorganic commercial fertilizer treatments over time, when compared to the no fertilizer control (Table 4). A probable reason that the Rockbridge County site had significantly higher WSP values than the Shenandoah site on average is due to soil pH. Spargo et al. (2006), states that at pH values greater than 6.5 much of the added soil P can be bound in Ca-P forms. Since poultry litter contains up to 2% calcium as calcium phosphate it is probable that much of this calcium phosphate did not dissolve at the high soil pH Shenandoah site and remained water insoluble. The Rockbridge site had a lower pH range of between 6.2 and 6.5 after two years. However, both sites produced significant increases in WSP when compared to the control plots. At each sampling interval the WSP values increased and were significantly greater than that of the control. This shows evidence that the P values were significantly building up and creating more plant available P than prior to fertilization. Shenandoah County did show statistically similar WSP for litter and inorganic fertilizers for most of the sampling periods and there were not any apparent trends that suggested split application performed differently than single application.

Table 4. Water Soluble Phosphorus over two years of fertility trial for both sites

Treatment	Initial†		6 month		1 Year		2 year	
	mg kg^{-1}							
			Rockbridge County					
Litter Split N	2.1	a‡	3.7	c	4.5	a	9.0	c
Fertilizer Split N	2.8	a	8.3	a	5.1	a	20.7	a
Litter Single N	2.9	a	4.5	bc	4.9	a	10.3	c
Fertilizer Single N	3.0	a	5.8	b	5.8	a	13.6	b
No Fertilizer	2.6	a	2.7	c	2.9	b	4.2	d
			Shenandoah County					
Litter Split N	1.4	ab	3.7	a	3.7	a	3.8	a
Fertilizer Split N	1.0	bc	4.5	a	4.5	a	2.8	ab
Litter Single N	1.5	a	4.0	a	3.8	a	3.3	ab
Fertilizer Single N	0.9	c	3.4	a	4.1	a	2.7	b
No Fertilizer	1.2	abc	2.1	b	2.6	b	1.3	c

† Immediately prior to fertilization
‡ Means within the same column for each county followed by different letters are significantly different at the 0.05 probability level

Forage Yield and Precipitation

Rockbridge Yield

The Rockbridge County site had an average increase of 65% in forage yield, over the two years, for all four fertilized treatments compared to the unfertilized control (Table 5). The two year totals for Rockbridge County resulted in statistically the same increase in yield for split applications of litter and split applications of commercial fertilizer. The highest two year overall yield was for the single application of inorganic fertilizer (10.1 Mg ha $^{-1}$). However, the single application of litter was statistically the same with a yield of 9.2 Mg ha^{-1}, for a two year total. These yield values were almost double the yield of the no fertilizer control group. The greatest re-growth in 2007 for the Rockbridge site was primarily between the first two cuts. The single application of inorganic fertilizer resulted in the greatest yield for the 2007 second cut (2.4 Mg ha^{-1}). After the second cut in 2007 re-growth was minimal for all treatments (0.1 Mg ha $^{-1}$). Rockbridge County did not receive a fourth cut due to no re-growth after the third cutting, due to late season drought (Fig. 1). The re-growth after the first cut for Rockbridge County in 2008 was not as great as in 2007 due to excessive drought during the summer months (less than 50 mm of rainfall for Rockbridge County between March–August 2008; Fig. 1). The first cut in 2008 for Rockbridge County resulted in a greater yield than that of 2007. This may be a result of a build up of nutrients from the previous year added to the new nutrient applications in 2008. The first and second cuts for 2008 were statistically the same for all four fertility treatments. The third cut of 2008 for Rockbridge County resulted in the greatest yields for both split treatments, compared to the single application. However, the 2008 year total yields had shown no statistical difference between the fertilized treatments, although all were greater than the unfertilized control. Split applications of fertilizer and manure are typically recommended to reduce losses to the environment and provide a more efficient use of applied N especially to support forage regrowth in fall (Miller and Reetz, 1995; Barker and Collins, 2003). This was true for Rockbridge County where the third cut split applications produced greater yields than the third cut single applications. However, the Rockbridge County site after two years of yield measurements revealed that single applications of litter and inorganic fertilizer produced greater yields than split applications. So the greater re-growth later in the season may not be enough to offset the increased cost (fuel, machinery, and manpower) required to split apply manures and fertilizers, since the total yield overtime was not greater for split applications.

Shenandoah Yield

The Shenandoah site resulted in a two year average of 38% increase in forage yield when comparing fertilized treatment averages to the unfertilized control (Table 5). The two year yield total for Shenandoah County resulted in a statistically similar increase in yield for litter split N, litter single N, and fertilizer single N treatments (11.5 to 11. 8 Mg ha^{-1}). The fertilizer split N treatment stood alone as having the greatest yield for the Shenandoah site over two years with a value of 14.2 Mg ha^{-1}. The Shenandoah County site produced less re-growth in 2007 for the second cut compared to Rockbridge County. Additionally, there was little difference between treatment groups and control for the third cut of 2007 for Shenandoah County. However, the Shenandoah site did produce enough forage to support a fourth cut. The 2007 total yield were similar for Shenandoah and Rockbridge sites. The split application of inorganic fertilizer produced the greatest yield for 2007 in Shenandoah County. The litter applications in 2007 had no significant increase when compared to the no fertilizer control plots. The first cut for 2008 in Shenandoah County produced exactly the same yield for all four treatments at a value of 3.3 Mg ha^{-1}. The re-growth after the first cut in 2008 for Shenandoah County far exceeded Rockbridge County. The second cut in 2008 had a re-growth value of 3.6 Mg ha^{-1} for the single application of litter. However, the third cut produced the same value (3.6 Mg ha^{-1}) for the split application of inorganic fertilizer. Similar to 2007, the greatest total yield value for Shenandoah County in 2008 was for the split application of inorganic fertilizer. However, the single application of litter produced statistically similar results in the 2008 total yields. Since the highest two year total yield value was for inorganic fertilizer split application, this supports the general fertilization application recommendation for cool-season grasses (Miller and Reetz, 1995). However, the litter applications revealed that single litter application yields exceeded litter split applications. These results suggest that when using poultry litter as a nutrient source, using a single application method may be the best choice for farmers. Additionally, if the increase in yield from splitting inorganic fertilizers does not offset the relative costs of split applying, then single application methods would again be recommended.

The yield responses to fertility treatments for our study range from 3.3 to 9.3 Mg ha^{-1} $year^{-1}$, for the 134.4 kg PAN ha^{-1} $year^{-1}$ added. These results are similar to reported cool-season grass yield values of 5.0 Mg ha^{-1} $year^{-1}$ at 168 kg PAN ha^{-1} $year^{-1}$ (Anigma et al., 2009).

However, Lucero et al. (1995) applied a total of 19.4 Mg ha^{-1} poultry litter over two years to unmanaged pasture land and received a 21.5 Mg ha^{-1} total yield in two years. Our litter application rate was 13.5 Mg ha^{-1} total for two years and our highest two year yield total was 11.9 Mg ha^{-1} (Shenandoah County, single litter application). Lucero et al. (1995) applied 30 percent more litter and received a 45 percent increase in forage yield. This difference could have been related to site specific characteristics like temperature, soil fertility, or precipitation.

Table 5. Yield by cut and cumulative yields for 2 years at both sites

	2007						2008						
Treatment	1st cut	2nd cut	3rd cut	4th cut	Total		1st cut	2nd cut	3rd cut	Total		2 year	
	Mg ha^{-1}												
					Rockbridge County								
Litter Split N	1.9	1.3	0.1	-	3.3	bc	3.7	0.5	1.0	5.2	a	8.5	b
Fertilizer Split N	2.4	1.5	0.1	-	4.0	b	4.0	0.4	0.8	5.1	a	9.1	b
Litter Single N	2.4	1.7	0.1	-	4.3	b	3.8	0.6	0.5	4.9	a	9.2	ab
Fertilizer Single N	2.8	2.4	0.1	-	5.4	a	3.9	0.5	0.4	4.7	a	10.1	a
No Fertilizer	1.8	0.9	0.1	-	2.8	c	2.2	0.3	0.2	2.8	b	5.6	c
					Shenandoah County								
Litter Split N	2.5	0.7	0.2	0.5	4.0	bc	3.3	2.7	1.7	7.6	b	11.5	b
Fertilizer Split N	2.9	0.8	0.4	0.8	5.0	a	3.3	2.5	3.6	9.3	a	14.2	a
Litter Single N	2.2	0.7	0.2	0.3	3.7	bc	3.3	3.6	1.4	8.3	ab	11.9	b
Fertilizer Single N	2.9	1.0	0.2	0.3	4.4	ab	3.3	2.9	1.3	7.5	b	11.9	b
No Fertilizer	2.2	0.7	0.2	0.2	3.3	c	2.1	2.0	1.5	5.7	c	9.0	c

† Means within the same column for each county followed by different letters are significantly different at the 0.05 probability level

Monthly precipitation values can be found in Figure 1. Rockbridge County site received 725 mm of precipitation in 2007 and 540 mm in 2008 (VAES, 2009). These values are significantly lower than the thirty year average of 1034 mm (SERCC, 2009). The Shenandoah site was not as drastically affected by the drought years and received 689 mm of precipitation in 2007 and 905 mm in 2008 (VAES, 2009). These values were lower than the thirty year average of 959 mm for Shenandoah County (SERCC, 2009). The drought years and precipitation timing most likely reduced the impact on yield due to reduced nutrient availability from slower mineralization rates (Schroeder et al. 2004). However, both counties produced a significant increase in forage yield for the fertilizer treatments when compared to the control plots.

Phosphorus Balance

The Rockbridge County site removed an average of 16.0 percent of the P applied while the Shenandoah site removed a slightly higher percentage of applied P with a removal rate of 18.5 percent (Table 6). Consequently, there is an average of 74 kg P ha^{-1} remaining in soil or lost to the environment for the fertilized plots in Rockbridge County and 65 kg P ha^{-1} for Shenandoah County. There was not any significant difference in fertility treatments or split versus single application, for P removal.

Total P removal is related to forage harvest yields with greater yield translating into greater P removal. The only instance where there was a significant lack of parallel between yield and P removal was in Rockbridge County 2008. The data for this site and time reveals that the greatest yield was for the inorganic fertilizer single application, yet this treatment only produced the fourth highest removal rate for 2008 Rockbridge County. Additionally, the fourth highest yield producing treatment (commercial fertilizer split application) produced the second highest P removal rate. Again, this result may be related to the drought in 2008 for Rockbridge County.

Phosphorus recovery rates have been published for many species of forage and row crops. Our results produced a higher recovery rate than that of those published for wheat. Johnson et al. 2004, revealed a P recovery rate of 6.6 to 10.7 percent when litter was applied to wheat. However, corn silage removal rates from published data revealed a yearly removal rate of 63.8 kg P ha^{-1} for litter and commercial fertilizer applied at an N rate in Shenandoah County (Maguire et al., 2008). This value is much higher than our greatest yearly removal rate of 30.2 kg P ha^{-1} for inorganic fertilizer and 29.4 kg P ha^{-1} for Shenandoah County. These differences are most likely relevant to crop and forage species.

Table 6. Total phosphorus additions, removal and mass balance

Treatment	2007 P added	2007 P removed	2008 P added	2008 P removed	Balance	
	kg P ha^{-1}					
			Rockbridge County			
Litter Split N	51.3	8.5	51.3	16.1	78.0	a†
Fertilizer Split N	51.3	11.3	51.3	16	75.3	a
Litter Single N	51.3	12.3	51.3	17.2	73.1	a
Fertilizer Single N	51.3	17	51.3	17.5	67.8	a
No Fertilizer	0	6.9	0	6.2	-13.1	b
			Shenandoah County			
Litter Split N	51.3	11.9	51.3	26	64.7	a
Fertilizer Split N	51.3	16	51.3	30.2	56.4	a
Litter Single N	51.3	10.9	51.3	29.4	62.3	a
Fertilizer Single N	51.3	15.1	51.3	26.2	75.3	a
No Fertilizer	0	7.8	0	11.1	-18.9	b

† Means within the same column for each county followed by different letters are significantly different at the 0.05 probability level

Although forage removal rates were not sufficiently great to remove the majority of P applied to plots, fertilizer application rates may still be determined on an N basis until soil test P values are elevated to or above the agronomic recommended 55 mg kg^{-1} (Maguire and Heckendorn, 2009).The application of litter to forage systems can become a water quality concern if not managed properly (Pote et al. 2003). Therefore once soil test reaches optimum concentrations, P additions must not exceed crop uptake to prevent runoff and leaching of P to surface and ground water systems. Our fertility treatments were based on N rates, because of low soil test P values. However, the P applications far exceeded the harvest removal rate.

CONCLUSIONS

Nutrient management regulations will continue to push poultry litter off poultry farms in the Shenandoah Valley of Virginia, where it has historically been used to fertilize row crops. Our research shows that the exported litter can be beneficially recycled on nutrient deficient forage lands in the Shenandoah Valley. As all fertilized treatments applied more P than removed in crop uptake, they all increased M1P significantly relative to the unfertilized control. Both sites started at approximately 10 mg M1P kg^{-1}, but after two years the Shenandoah site increased to ~20 mg M1P kg^{-1}, while the Rockbridge site had increased to close to the agronomic optimum of 55 mg M1P kg^{-1}. This increased M1P will improve forage nutrition for subsequent years. Nitrogen based litter applications would be required for several more years to reach agronomic optimum levels at the Shenandoah site. For all fertilized treatments the soil WSP increased at both sites, but values did not reach critical levels where water quality impairment is a concern. Yield increase was on average 33 percent for litter or inorganic fertilizer compared to no fertilization. Virginia Tech recommendations and published research recommend that split application of fertilizers can improve forage yield in fall harvest, this may be true sometimes for inorganic fertilizer, but our research showed no significant data to support splitting applications of poultry litter. The minimal rainfall during the growing season, especially in Rockbridge County, may have attributed to the lack of significant difference between application methods. As expected, our research shows that the forage P removal was not sufficient to remove the majority of P applied to the fertilized plots when applying N based rates. Since P levels at each site were initially very low, it is likely that the majority of the P that was not removed by harvest is bound tightly to the soils, given the pH of the soils and sufficient Al and Fe levels required to adsorb or precipitate P. Overall, our results showed that poultry litter provides similar increases in forage yield and soil fertility when compared to inorganic fertilizer.

REFERENCES

Anigma, S.D., R.L. Kallenbach, and W.W. Riggs. 2009. Forage yield of selected cool season grasses in response to varying rates of nitrogen. Forage and Grazinglands. 10:1095-1109.

Arai, Y., K.J.T. Livi, and D.L. Sparks. 2005. Phosphate reactivity in long-term poultry litter-amended southern Delaware sandy soils. Soil Sci. Soc. Am. J. 69:616-629.

Borggaard, O.K., S.S. Jorgensen, J.P. Moberg and B. Ragen-Lance. 1990. Influence of organic matter on phosphate adsorption by aluminum and iron oxides in sandy soils. European Journal of Science 41:3:443-449.

D'Angelo, E.M., M.V. Vandiviere, W.O. Thom and F. Sikora. 2003. Estimating soil phosphorus requirements and limits from oxalate extract data. J. Environ. Qual. 32:1082-1088.

DCR (Department of Conservation and Recreation). 2005. Virginia Nutrient Management Standards and Criteria. Richmond, VA. www.dcr.virginia.gov/documents/StandardsandCriteria.pdf verified April 29th 2009.

DeLaune, P.B., P.A. Moore Jr., D.K. Carman, A.N. Sharpley, B.E. Haggard, and T.C. Daniel. 2004. Development of a phosphorus index for pastures fertilized with poultry litter-factors affecting phosphorus runoff. J. Environ. Qual. 33:2183-2191.

Harmel, R.D., B. Harmel, and M.C. Patterson. 2008. On-Farm agro-economic effects of fertilizing cropland with poultry litter. J. Appl. Poult. Res. 17:545-555.

Hanson, C.L., J.F. Power and C. J. Erickson. 1978. Forage yield and fertilizer recovery by three irrigated perennial grasses as affected by N fertilization. Agron. J 70:373-375.

Iyengar, S.S., L.W. Zelazny, and D.C. Martens. 1981. Effect of photolytic oxalate treatments on soil hydroxyl interlayered vermiculites. Clays Clay Miner. 29:429-434.

Johnson, A.F., D.M. Vietor, F.M Rouquette, Jr., and V.A. Haby. 2004. Fate of phosphorus in dairy wastewater and poultry litter applied on grassland. J. Environ. Qual. 33:735-739.

Kaiser, D.E., A.P. Mallarino, M.U Haq, and B.L. Allen. 2009. Runoff phosphorus loss immediately after poultry manure application as influenced by the application rate and tillage. J. Environ. Qual. 38:299-308.

Link, D.D., H.M. Kingston, and P.J. Walter. 1998. Development and validation of the new EPA microwave-assisted leach method 3051A. Environmental Sciences and Technology, Vol. 32, 3628-3632.

Lucero, D.W., D.C. Martens, J.R. McKenna, D.E. Starner. 1995. Poultry litter effects on unmanaged pasture yields, nitrogen and phosphorus uptake, and botanical composition. Communications in soil sciences and plant analysis. 26:861-881.

Luscombe, P.C., J.K. Syers, and P.E.H. Gregg. 1979. Water extraction as a soil testing procedure for phosphorus. Commun. Soil Sci. Plant Anal. 10:1361-1369.

Maguire, R.O., D.A., Crouse, and S.C. Hodges. 2007. Diet modification to reduce phosphorus surpluses: A mass balance approach. Journal of Environmental Quality. 36:1235-1240.

Maguire, R.O. and S.E. Heckendorn. 2009. Soil test recommendations for Virginia. Virginia Cooperative Extension, Blacksburg, VA. www.soiltest.vt.edu/PDF/Recommendation_Guidebook.pdf Verified April 29th 2009

Maguire, R.O., G.L. Mullins, and M. Brosius. 2008. Evaluating long term nitrogen versus phosphorus based nutrient management of poultry litter. J. Environ. Qual. 37:1810-1816.

Maguire, R.O. and J.T. Sims. 2002. Measuring agronomic and environmental soil phosphorus saturation and predicting phosphorus leaching with Mehlich 3. Soil Sci Soc. Am. J. 66:2033-2039.

Maguire, R.O., J.T. Sims, and F.J. Coale. 2000. Phosphorus solubility in biosolids-amended farm soils in the Mid-Atlantic region of the U.S. Journal of Environmental Quality. 29:1225-1233

Pote, D.H., W.L. Kingery, G.E. Aiken, F.X. Han, P.A. Moore Jr. and K. Buddington. 2003. Water-quality effects of incorporating poultry litter into perennial grassland soils. J. Environ. Qual. 32:2392-2398.

Riesterer, J.L., D.J. Undersander, M.D. Casler and D.K. Combs. 2000. Forage yield of stockpiled perennial grasses in the upper Midwest USA. Agron. J 92:740-747.

SAS Institute. 2007. SAS user's guide: Statistics. SAS Inst. Cary, NC.

Schroeder, P.D., D.E. Radcliffe, and M.L. Cabrera. 2004. Rainfall timing and poultry litter application rate effects on phosphorus loss in surface runoff. J. Environ. Qual. 33:2201-2209.

Southeast Regional Climate Center. Historical Climate Summaries for Virginia.(SERCC) 2009. Weather data for Rockbridge and Shenandoah Counties, VA. www.sercc.com "Verified" March 19th 2009.

Spargo, J.T., G.K. Evanylo and M.M. Alley. 2006. Repeated compost application effects on phosphorus runoff in the Virginia piedmont. J. Environ. Qual. 35:2342-2351.

Virginia Agriculture Extension Services. 2009. (VAES) Weather Mesonet. Weather Data. www.ext.vt.edu/mesonet. "Verified" April 29th 2009.

Chapter 3

Changes in Botanical Composition and Soil Seedbank Diversity in Low Input Forage Systems with Additions of Poultry Litter and Inorganic Fertilizers

ABSTRACT

Anecdotal reports have suggested that application of poultry litter to pastureland may increase the abundance of weeds. In May 2008, a study was initiated at two sites in northwest Virginia to address this issue. The objective of this study was to evaluate how poultry litter and inorganic fertilizer application affected aboveground botanical composition and soil seed bank composition of established mixed naturalized pastures. Two sites had the same fertilizer treatments applied for two consecutive years: 1) split application of litter: 3.36 Mg ha^{-1} in spring and summer, 2) inorganic fertilizer at same N, P and K rates as treatment 1, 3) single application of litter: 6.72 Mg ha^{-1} in spring, 4) inorganic fertilizer at same N, P and K rates as treatment 3, and 5) an unfertilized control. Shifts in above ground botanical composition, seed bank composition, and species richness were monitored for two years. Additionally, we examined whether poultry litter carries germinable weed seeds that can be transferred to forage systems after application. Desirable species abundance increased (linear regression, $P< 0.05$) over time with both fertilizer and poultry litter application treatments Furthermore, one site, Shenandoah County, showed that poultry litter application actually reduced ($P=0.04$) the number of weedy species in plots. Weedy plant abundance did not differ at either site and no significance in change in species richness (# species/area) at the second site, Rockbridge County, for any treatment. No treatment effects were found for seed bank species richness and number of germinated seeds (m^{-2}). No seedlings were found after attempting to germinate poultry litter collected from several sites in Virginia. Our results indicate that poultry litter has no viable seed and does not increase weed abundance in tall fescue swards. Additionally, poultry litter and inorganic fertilizers increase desirable species of above ground composition.

INTRODUCTION

Shifts in above ground botanical composition have been reported with increased fertility from inorganic and organic fertilizer sources (Goetz, 1969; Kalmbacher and Martin, 1996; Mikhailova et al., 2000; Samuel and Hart, 1998; Snyman, 2002). Many researchers have established that increased fertilization increases forage yield (Angima, et al., 2009; Cherney et al., 2002; Hanson et al., 1978). However, increases in total dry matter yield may not be the only intent in fertilization of hay or pasture systems. Increasing the ratio of desirable species to undesirable, less palatable and weedy species can become a priority for forage land managers. Past research has indicated that increasing species diversity in a forage system may increase productivity and stability (Tracy and Sanderson, 2004). However, increased fertilization and management may decrease the number of species in forage systems via increased species competition for light and nutrients. This occurs when grass species are given high levels of nitrogen (N) fertilization and can overgrow weedy species (Kalmbacher and Martin, 1996). Other nutrients may also influence species richness. Tracy and Sanderson (2000b), found an inverse relationship between soil P and species richness. Manure sources of fertility have been scrutinized by producers due to the potential for increases in weed composition in forage lands. Anecdotal reports from producers suggested that poultry litter application may increase weedy species in above ground composition (Virginia Cooperative Extension). However, Lucero et al., (1995) observed a 30% increase in desirable grass species and a significant decrease in weedy grass species, with increased manure fertilization. Although there has been much research on relationships between weedy species encroachment and N fertilization (Kalmbacher and Martin, 1996; Mikhailova et al, 1999; Samuel and Hart, 1998) little work has specifically addressed the idea that poultry litter might increase weed abundance. Weed seeds can potentially be transferred to litter by means of improper storage and management practices, after the litter leaves the bird houses (Cunningham et al., 2004).

An abundance of infertile land in the Shenandoah Valley of Virginia could benefit from poultry litter application. Furthermore, there is an abundance of poultry litter that can act as a source of fertility for these low input, under managed forage systems (Maguire et al., 2008). Before producers commit to using litter as a nutrient source, litter must be shown as not being a potential source for increasing weed abundance.

Seed bank composition is an important component of forage systems and it is possible that poultry litter could increase the weed seed bank in soils. Although seed bank species composition may not reflect the aboveground vegetation (Kirkham and Kent, 1997; Tracy and Sanderson, 2000a), seed banks offer a look at the potential species that could emerge if the existing vegetation was disturbed (Renne and Tracy, 2007). There is also little information comparing the effect of fertility treatments to botanical composition and seed bank population. The objectives of this research were to: 1) determine if poultry litter application increased abundance of undesirable weed species within existing tall fescue swards and in the soil seed bank, 2) compare how poultry litter and inorganic nitrogen fertilizer applications affected botanical composition especially desirable versus weedy species and 3) attempt to germinate poultry litter in greenhouse experiment to determine whether litter carries viable weed seeds that can be spread though application.

METHODS

Study Description

On-farm field trials were established in producer fields in Rockbridge and Shenandoah Counties of the Shenandoah Valley, Virginia. These two sites were chosen because of their very low soil test P concentrations (6.3 to 11.5 mg kg^{-1}). Both sites were established in April 2007 and the study was concluded in March of 2009. The Shenandoah site had soils in the Endcav silt loam series while the Rockbridge site was comprised of Frederick silt loam, both soil series are very similar.

There were five treatments, each replicated four times for a total of 20 plots per site. Plots were 3.1 m by 6.1 m with a total area for all twenty plots of 0.04 hectares and the treatments were assigned by randomized complete block. Poultry litter was analyzed for nutrient content with a dry-ash method by the Agricultural Services Laboratory, Clemson University. For the surface application of litter, plant available N was calculated as (0.6 × organic N) + (0.5 × ammonium N), and total P and K were considered completely plant available, according to VA nutrient management standards (DCR, 2005). Inorganic nutrient sources used to match N, P and K litter rates were ammonium nitrate, triple super phosphate, and potash. Treatments were: 1) Split application of litter: 67.2 kg PAN ha^{-1}, 25.7 kg P ha^{-1} (3.36 Mg ha^{-1} in spring and 3.36 Mg ha^{-1} in summer); 2) Inorganic fertilizer at same N and P rates as Trt. No. 1; 3) Single application of litter: 134.4 kg PAN ha^{-1}, 51.3 kg P ha^{-1} (6.72 Mg ha^{-1} in spring); 4) Inorganic fertilizer at same N and P rates as Trt. No. 3; 5) Unfertilized control. Treatments 1-4 received the same amount of PAN, P, and K on an annual basis. Treatments were surface applied by hand and not incorporated during years, 2007 and 2008. Supplemental lime was added to the Rockbridge County site for both years per Virginia Tech's soil test recommendations (Maguire and Heckendorn, 2009).

Botanical Composition Analysis

Botanical composition was determined visually three times per year starting in May and at 45 day intervals. A 1 m^2 quadrat (0.5 m x 2 m) was placed in the center of each plot and visual estimation of percent cover from each forage species. Percent of visible bare ground was recorded as well. The same observer made all estimations of percent cover. Changes in percent bare ground were computed and compared for each treatment. Species richness (number of species/area) was analyzed for each treatment at each sampling period. The relative importance value (RIV) for desirable and weedy species was calculated for each plot. Desirable forage species were considered tall fescue (Lolium arundinaceum (Schreb.) Darbysh. = Schenodorus arundinaceus (Schreb.), kentucky bluegrass (*Poa pratensis* L.), orchardgrass (*Dactylis glomerata* L.), red clover (*Trifolium pratens* L.) and white clover (*Trifolium repens* L.). The remaining species were considered weeds. The RIV index combines how frequently species occur in treatment plots and their relative percent ground cover. It is calculated by the following equation:

$$RIV= [[\Sigma (\Sigma a/ (b*100))] + [\Sigma c/ (d*100)]/2] / f$$

Where (a) is the frequency in four replication plots, per sampling date, (b) is the number of replications per treatment, (c) is the relative percent cover in each replication, (d) is the sum of relative percent cover for each treatment at the sampling date, and (f) is sum of percent relative importance value for each treatment at the sampling date. For data analysis, the RIV was calculated for each species and then mean RIV of desirable and weedy species was calculated for each treatment.

Seed bank analysis

Soil seed bank composition was determined by taking five soil cores from random locations within each plot, in June 2007. Cores were 10 cm in diameter and taken to 10 cm in depth. Seed bank soil samples were then frozen for four months, air dried at room temperature, and sieved to pass a 2-mm sieve to remove large rocks and roots. Soil cores from each plot were pooled together and spread into plastic trays (25 by 50 by 6 cm) to a depth of 2 cm over 2 cm of sterilized potting soil. Trays were placed in a greenhouse from September to December 2007 and allowed to germinate under natural light. Trays were watered three times daily using overhead misters with tap water. Seedlings were identified, recorded, and removed weekly. Germination trials were conducted for four months until no additional seedlings emerged. Species richness (number of species/area) was calculated and total number of germinated seedlings present in each tray was converted to seedlings germinated per m^2.

Poultry Litter Germination

Turkey and broiler litter was collected from ten poultry houses throughout the Shenandoah Valley, Virginia. The samples were split in half. Half of each sample was frozen and the other was refrigerated for 3 months. Litter was then thawed at room temperature. Half the volume of the samples of each litter (frozen or refrigerated) were then ground and sieved to promote seed scarification. The other half of each sample was surface applied to the germination trays to mimic field application methods. Litter was then spread into plastic trays (25 by 50 by 6 cm) to a depth of 2 cm over 2 cm of sterilized potting soil. Trays were placed in a greenhouse and allowed to germinate under natural light. Trays with litter and soil were watered three times a day and allowed to remain in the greenhouse for two months. Total number of seedlings germinated was recorded.

Statistical Analyses

Treatment means were partitioned by using JMP statistical software (SAS Institute, 2007). We analyzed treatment effects on species richness by using one way ANOVA for each sampling date. If treatment main effects were significant, means were separated using Tukey's test (α= 0.05). We used linear regression to analyze relationships between sampling time and species richness (SPR), desirable species relative importance value (DRIV), and weedy species relative importance value (WRIV), respectively (Sigma Plot 10.0, 2007). Seed bank SPR and germinated seeds m^{-2} were analyzed by JMP ANOVA Tukey's test (SAS Institute, 2007).

RESULTS AND DISCUSSION

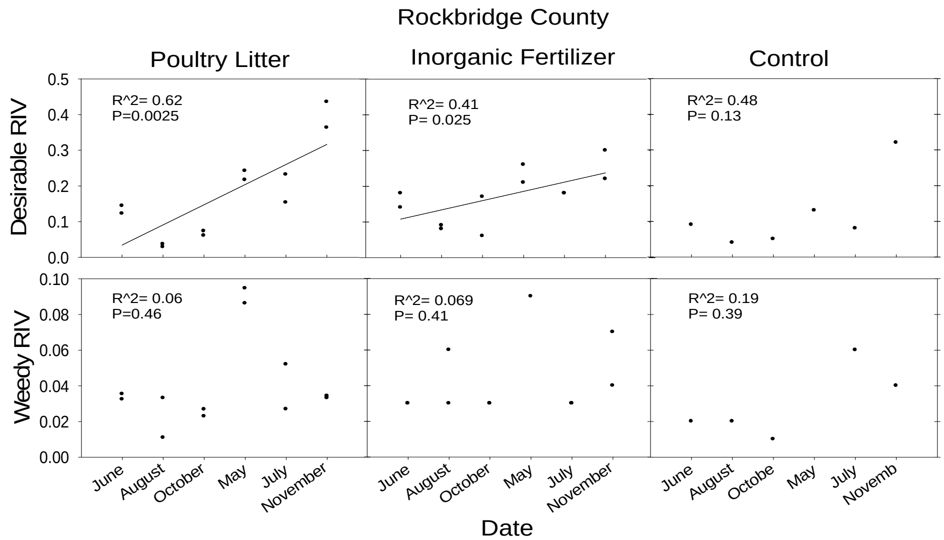
Botanical Composition

The Shenandoah County site was dominated by orchardgrass (*Dactylis glomerata* L.), kentucky bluegrass (*Poa pratensis* L.), tall fescue (Lolium arundinaceum (Schreb.) Darbysh. = Schenodorus arundinaceus (Schreb.), red clover (*Trifolium pratens* L.), and white clover (*Trifolium repens* L.). The main weedy species were: yellow foxtail (*Setaria glauca* L. Beauv.), chicory *(Cichorium intybus* L.), wild carrot (*Daucus carota* L.), oxalis (*Oxalis stricta* L.), black medic (*Medicago lupulina* L.), common bramble (*Rubus* spp.), and wild grape (*Vitis* spp.).

Rockbridge County was dominated by orchardgrass (*Dactylis glomerata* L.), bluegrass (*Poa pratensis* L.), and tall fescue (Lolium arundinaceum (Schreb.) Darbysh. = Schenodorus arundinaceus (Schreb.). The main weedy species were: yellow foxtail (*Setaria glauca* L. Beauv.), witchgrass (*Panicum capillare* L.), sweet vernal (*Anthoxanthum odoratum* L.), and broomsedge (*Andropogon* spp.)

Desirable species for both sites were: orchardgrass, kentucky bluegrass, tall fescue, red clover and white clover. Relationships between time and relative importance value (RIV) for desirable and weedy species for Rockbridge County can be found in Figure 1.

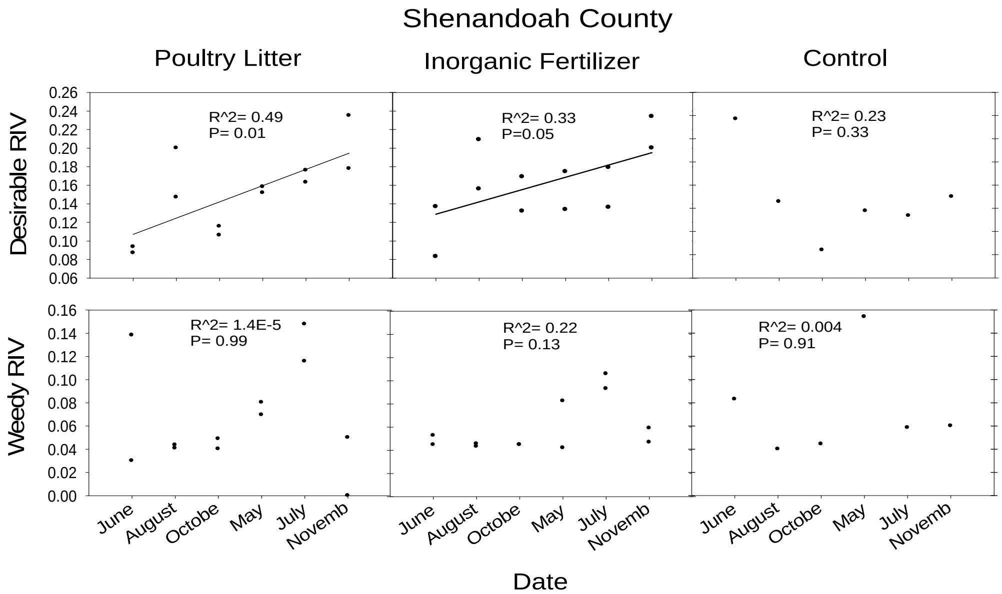
Figure 1. Linear regression for Relative Importance Value (RIV) of above ground botanical composition for 2007 and 2008 (Rockbridge County).



Poultry litter applications significantly increased desirable RIV over the two year experiment (R^2=0.62, P=0.0025). Additionally, inorganic fertilizer treatments significantly increased desirable species RIV (R^2=0.41, P=0.025). The RIV for desirable species in the control treatment did not change over time (R^2= 0.48, P=0.13). Weedy species RIV showed no significant change over time for all three treatment groups (litter: R^2=0.06, P=0.46; inorganic fertilizer: R^2= 0.07, P=0.41; control: R^2=0.19, P=0.39).

The Shenandoah County site showed similar results for desirable RIV (DRIV) and weedy RIV (WRIV) (Figure 2).

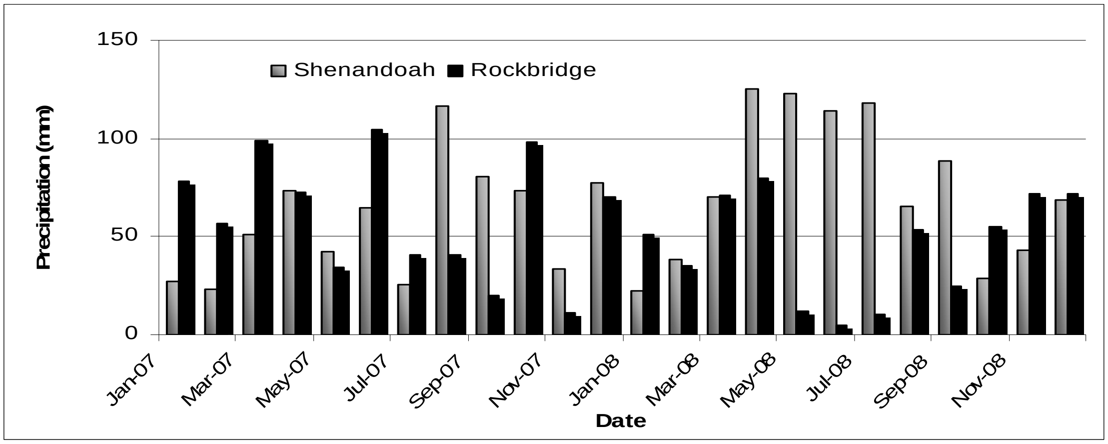
Figure 2. Linear regression for Relative Importance Value (RIV) of above ground botanical composition for 2007 and 2008 (Shenandoah County).



Over time poultry litter treatment increased in desirable species (R^2=0.49, P=0.01). Additionally, inorganic fertilizer treatments showed a positive increase in desirable species (R^2=0.33, P=0.05) although the relationship was not as strong. The DRIV for the control treatment did not change over time (R^2= 0.23, P=0.33). Weedy species RIV showed no significant change over time for all three treatment groups (litter: R^2=0.1.4E^{-5}, P=0.99; inorganic fertilizer: R^2= 0.22, P=0.13; control: R^2=0.004, P=0.91).

These results are similar to other studies that have shown that increased fertility benefits desirable species of grasses and legumes and allows them to out-compete weedy species (Lorenz and Rogler, 1972; Mikhailova et al., 2000; Tracy and Sanderson, 2000). Rockbridge County in 2007 may have had less of a response to fertility treatments, due to excessive drought during the summer months (less than 50 mm of rainfall for Rockbridge County between March–August 2008; Fig. 3).

Figure 3. Rockbridge and Shenandoah County Precipitation (mm) by month for years 2007 and 2008.

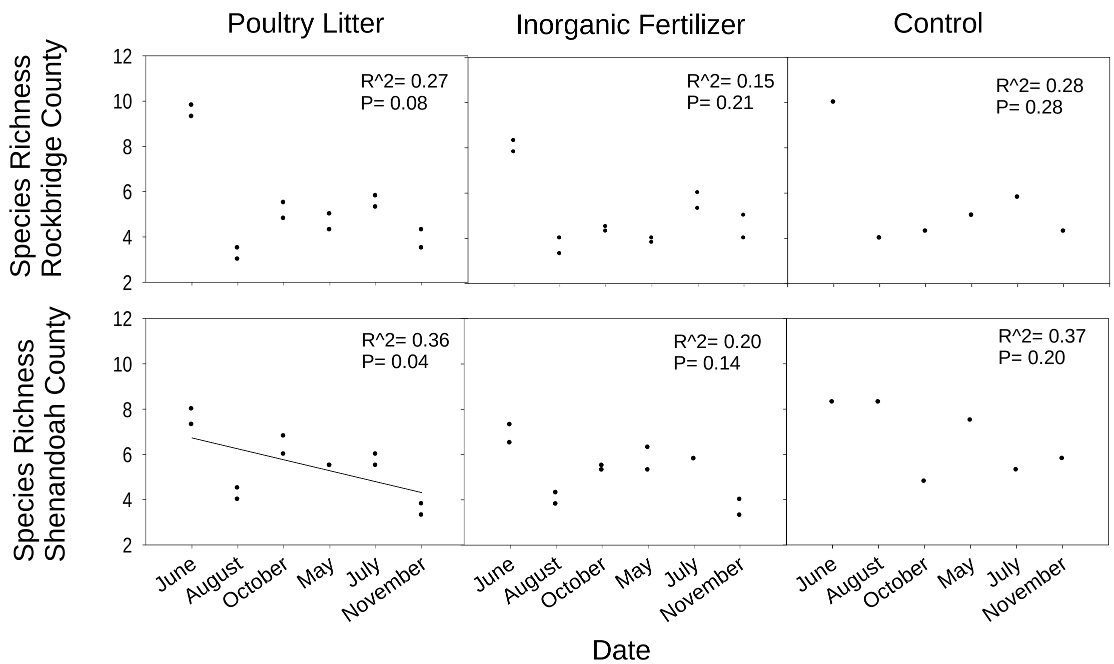


Shenandoah County received much more rainfall than Rockbridge County during the growing seasons, so precipitation may not have affected DRIV and WRIV for Shenandoah County, as much as Rockbridge County. However, the lack of significant change in WRIV for poultry litter applications at either site gives evidence that litter applications do not increase weed abundance in low input forage systems.

Species Richness

Species richness is the number of species per unit area. We observed no significant change species richness for all three treatments for Rockbridge County over time (litter: R^2=0.27, P=0.08; inorganic fertilizer: R^2= 0.15, P=0.21; control: R^2=0.28, P=0.28). However, there was a significant reduction in richness for Shenandoah County's poultry litter treatments (R^2=0.36, P=0.04, Figure 4). Inorganic fertilizer and the control group showed no significant change in richness (R^2=0.20, P=0.14; R^2=0.37, P=0.20, respectively). These results indicate that poultry litter for Shenandoah County reduced the number of species from 8 to 4 over the two year experiment. Most species lost were weedy. Species richness is typically expected to decline over time with added fertilization to a forage system (Kalmbacher and Martin, 1996; Tracy and Sanderson, 2000b).

Figure 4. Species Richness (SPR, # of species) Linear Regression for Rockbridge and Shenandoah Counties for above ground botanical composition for the years of 2007 and 2008.



However, we expected the results to be similar for both sites. Again, environmental and management conditions may play a greater role in species diversity than fertility. Once more, the reduction in number of species for poultry litter applications in Shenandoah County supports the idea that litter applications do not increase weed abundance.

Bare Ground Cover

The amount of bare ground in plots declined over time at both sites (data not shown). No differences were found among treatment groups at most sampling intervals. Plots at the Shenandoah County site originally had an average of 27 percent bare ground and this declined over the two years to four percent. The Rockbridge County site had an average of 18 percent bare ground initially among all treatments (including control) and this increased to an average of 74 percent bare ground at the end of the 2007 growing season. The next year (2008) plots had no bare ground in spring but this value increased to 14 percent by the end of the 2008 growing season. The fluctuation of bare ground percentages for Rockbridge County may have been influenced by the lack of rainfall during the summer growing season (Figure 3). Additionally, periodic mowing may have decreased bare ground percentages throughout the experiment.

Ground cover has been reported to increase or decrease with fertility depending on species present and site specific characteristics (Kirkham and Kent, 1997; Snyman, 2002). Our results suggest changes in ground cover are most likely attributed to precipitation fluxes and the change in species composition. Composition changes from non-desirable weedy species to productive grass species and drought during summer months are hypothesized to be the major factors that influenced bare ground over the two years.

Germinable Soil Seed Bank Composition

Many weedy seedlings germinated from soils collected at both sites. The majority of seedlings that germinated were not abundant in above ground vegetation. There were 27 species that germinated from both sites and there was little difference in types of species found in either sites seedbank. The dominant species in the seed bank germination trials were: oxalis, chicory, crabgrass, dandelion, and kentucky bluegrass. Kentucky bluegrass was the only abundant species in the seed bank that was found to be proliferating in the above ground composition. Nevertheless, little correlation between seed bank species composition and above ground botanical composition was evident. Lack of correlation between seed bank and above ground cover has been reported by previous research (Tracy and Sanderson, 2000a). There was no significant difference among treatments for the number of germinable seeds m^{-2} and species richness of soil seed bank (Table 1).

Table 1. Seed bank species richness and average number of germinated seeds/ m^2 per treatment

Treatment	Species richness		# of germinated seeds/m^2	
	Rockbridge County			
Litter Split N	4.3	a	280.5	a
Fertilizer Split N	3.5	a	262.7	a
Litter Single N	3.8	a	390.2	a
Fertilizer Single N	4.3	a	344.3	a
No Fertilizer	4.3	a	441.2	a
	Shenandoah County			
Litter Split N	2.8	a	102.0	a
Fertilizer Split N	5.8	a	255.0	a
Litter Single N	4.0	a	249.9	a
Fertilizer Single N	3.3	a	140.3	a
No Fertilizer	3.0	a	110.7	a

† Means within the same column for each county followed by different letters are significantly different at the 0.05 probability.

Germinable Seeds in Poultry Litter

Our results in the attempt to germinate poultry litter by several means of germination attempts (freezing, grinding, refrigerating, surface application, subsurface application, and multiple germination conditions) in the greenhouse resulted in zero seedlings germinated from poultry litter itself. We are unaware of any previous research done to determine if poultry litter contains transferable and viable weed seeds. Our findings may put to rest any claims that poultry litter carries viable seeds.

CONCLUSIONS

Nutrient management criteria is advocating the movement of poultry litter from farms that are nutrient rich and promoting exportation to lands with lower value crops such as forage systems or pastures to reduce nutrient loading in freshwater systems. Using poultry litter as a nutrient source has been shown to increase forage yield as much as inorganic fertilizers. Furthermore, our research has shown that fertility application of either organic or inorganic sources should increase desirable forage species in low input mixed naturalized pastures. Additionally, our research supports other studies that found soil seed bank composition to have little effect on above ground botanical composition. Our results suggest that use of poultry litter as a fertilizer does not encourage weed growth and litter itself does not carry viable weed seeds, if managed and stored properly prior to application. We have evidence that supports that fertilization from either source reduces the number of species present in a pasture system and increases the desirable to weedy species ratio. Finally, we conclude that fertility is not the sole factor that controls changes in pasture species composition. Periodic mowing and precipitation also interact with fertility to drive the positive transformation of low input forage systems.

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REFERENCES

Angima, S.D., R.L. Kallenbach, and W.W. Riggs. 2009. Forage yield of selected coo-season grasses in response to varying rates of nitrogen. Online. Forage and Grazinglands doi:10.1094/FG-2009-0129-01-RS.

Cherney, D., J.H Cherney, and E.A. Mikhailova. 2002. Orchardgrass and tall fescue utilization of nitrogen from dairy manure and commercial fertilizer. Agronomy Journal 94:405-412.

Cunningham, D.L., C. W. Ritz, and W.C. Merka. 2004. Best Management Practices for Storing and Applying Poultry Litter. University of Georgia College of Agricultural and Environmental Sciences Cooperative Extension Bulletin 1230.

Donohue, S.J. and S.E. Heckendorn. 1994. Soil test recommendations for Virginia. Virginia Cooperative Extension, Blacksburg, VA. www.vt.edu "Verified March 9th 2009"

Goetz, H. 1969. Composition and yield of native grassland sites fertilized at different rates of nitrogen. Journal of Range Management 22:6:384-390

Hanson, C.L., J.F. Power and C. J. Erickson. 1978. Forage yield and fertilizer recovery by three irrigated perennial grasses as affected by N fertilization. Agron. J 70:373-375.

Kalmbacher, R., and F. Martin. 1996. Shifts in botanical composition of flatwoods range following fertilization. J. Range Manage. 49:530-534.

Kirkham, F.W., and M. Kent. 1997. Soil seed bank composition in relation to above-ground vegetation in fertilized and unfertilized hay meadows on a Somerset peat moor. Journal of Applied Ecology 34:889-902.

Lorenz, R.J. and G.A. Rogler. 1972. Forage production and botanical composition of mixed prairies as influenced by nitrogen and phosphorus fertilization. Ag. Journal. 64:244-249.

Lucero, D.W., D.C. Martens, J.R. McKenna, D.E. Starner. 1995. Poultry litter effects on unmanaged pasture yields, nitrogen and phosphorus uptake, and botanical composition. Communications in soil sciences and plant analysis. 26:861-881.

Maguire, R.O., G.L. Mullins, and M. Brosius. 2008. Evaluating long term nitrogen versus phosphorus based nutrient management of poultry litter. J. Environ. Qual. 37:1810-1816.

Mikhailova, E.A., R.B. Bryant, D.J.R. Cherney, C.J. Post, and I.I. Vasenev. 2000. Botanical composition, soil and forage quality under different management regimes in Russian grasslands. Agriculture, Ecosystems and Environ. 80:213-226.

Renne, I. J. and B. F. Tracy (2007). Disturbance persistence in managed grasslands: shifts in aboveground community structure and the weed seed bank. Plant Ecology 190(1): 71-80.

Samuel, M.J., R.H. Hart. 1998. Nitrogen fertilization, botanical composition and biomass production on mixed-grass rangeland. J. Range Manage. 51:408-416.

SAS Institute. 2007. SAS user's guide: Statistics. SAS Inst. Cary, NC.

Southeast Regional Climate Center. Historical Climate Summaries for Virginia.(SERCC) 2009. Weather data for Rockbridge and Shenandoah Counties, VA. www.sercc.com "Verified" March 19th 2009.

Snyman, H.A. 2002. Short term response of rangeland botanical composition and productivity to fertilization in a semi-arid climate of South Africa. Journal of Arid Environments. 50: 167-183.

Tracy, B.F., and M.A. Sanderson. 2000a. Seedbank diversity in grazing lands of the Northeast United States. J. Range Manage. 53: 114-118.

Tracy, B.F., and M.A. Sanderson. 2000b. Patterns of plant richness in pasture lands in northeast United States. Plant Ecology. 149: 169-180.

Tracy, B.F. and M.A. Sanderson. 2004. Productivity and stability relationships in mowed pasture communities of varying species composition. Crop Sci. 44:2180-2186.

Virginia Cooperative Extension. FAQ 29239. Can we spread chicken litter on our horse pastures? Verified: http://www.extension.org/faq/29239

APPENDICES

Appendix 1. Rockbridge County Soil Data

pH

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month
Litter Split N	5.6	5.6	5.9	6.0	6.0	6.0	6.7	6.3
Fertilizer Split N	5.5	5.8	5.8	5.8	5.8	5.7	6.5	6.0
Litter Single N	5.4	5.7	6.0	6.0	6.0	5.7	6.8	6.0
Fertilizer Single N	5.5	5.6	5.6	5.8	5.8	5.7	6.3	6.0
No Fert Control	5.5	5.7	5.9	5.8	5.8	6.0	6.7	6.2

Organic Matter

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month
	%							
Litter Split N	4.7	3.6	6.3	5.5	5.8	5.3	4.3	6.7
Fertilizer Split N	5.0	3.9	6.4	5.9	5.7	5.6	4.5	7.1
Litter Single N	5.3	3.9	7.2	6.1	6.4	6.3	4.7	6.9
Fertilizer Single N	4.6	3.7	6.7	5.9	6.3	5.8	4.5	6.6
No Fert Control	5.2	4.1	6.3	5.9	6.1	5.5	4.2	6.7

M1P

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month	Apr-09
	mg/kg								
Litter Split N	5.5	9.0	16.0	15.3	17.0	37.0	29.0	56.3	56.4
Fertilizer Split N	6.3	13.3	28.5	22.3	15.3	47.3	67.5	123.0	66.1
Litter Single N	11.5	22.8	17.0	18.8	20.8	59.3	64.8	63.5	48.5
Fertilizer Single N	11.5	32.3	50.0	20.3	21.3	95.5	83.0	89.8	72.5
No Fert Control	7.0	14.8	8.0	12.0	8.0	13.0	15.5	16.5	18.7

WSP

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month
	mg/kg							
Litter Split N	2.1	1.4	4.9	3.7	4.5	3.8	3.7	9.0
Fertilizer Split N	2.8	2.8	7.6	8.3	5.1	6.3	9.9	20.7
Litter Single N	2.9	2.7	5.9	4.5	4.9	7.4	8.3	10.3
Fertilizer Single N	3.0	4.4	17.8	5.8	5.8	10.2	12.0	13.6
No Fert Control	2.6	1.7	2.8	2.7	2.9	1.6	2.2	4.2

Appendix 2. Rockbridge County Forage Data

Protein

	2007				**2008**		
Treatment	1st cut	2nd cut	3rd cut	4th cut	1st cut	2nd cut	3rd cut
	%						
Litter Split N	13.6	10.5	13.7	-	13.2	14.1	9.6
Fertilizer Split N	15.7	10.1	17.2	-	14.0	13.6	10.5
Litter Single N	16.6	11.7	13.9	-	15.0	15.4	9.4
Fertilizer Single N	18.3	12.5	13.6	-	15.3	14.2	8.5
No Fert Control	11.0	10.5	11.9	-	12.7	13.1	9.0

Botanical Composition

Treatment	6/6/2007	8/16/2007	10/17/2007	5/20/2008	7/24/2008	11/11/2008
	# of species					
Litter Split N	9.0	4.0	5.0	5.0	5.0	4.0
Fertilizer Split N	8.0	3.0	5.0	4.0	5.0	5.0
Litter Single N	10.0	3.0	6.0	4.0	6.0	4.0
Fertilizer Single N	8.0	4.0	4.0	4.0	6.0	4.0
No Fert Control	10.0	4.0	4.0	5.0	6.0	4.0

Percent Bareground

Treatment	6/6/2007	8/16/2007	10/17/2007	5/20/2008	7/24/2008	11/11/2008
	%					
Litter Split N	23.0	63.0	78.0	0.0	14.0	5.0
Fertilizer Split N	18.0	48.0	65.0	0.0	20.0	8.0
Litter Single N	10.0	68.0	75.0	0.0	10.0	13.0
Fertilizer Single N	8.0	53.0	73.0	0.0	15.0	25.0
No Fert Control	30.0	58.0	80.0	3.0	18.0	18.0

Yield

	2007					**2008**			
Treatment	1st cut	2nd cut	3rd cut	4th cut	**2007 total**	1st cut	2nd cut	3rd cut	**2008 total**
	Mg/ha								
Litter Split N	1.9	1.3	0.1	-	**3.3**	3.7	0.5	1.0	**5.2**
Fertilizer Split N	2.4	1.5	0.1	-	**4.0**	4.0	0.4	0.8	**5.2**
Litter Single N	2.4	1.7	0.1	-	**4.2**	3.8	0.6	0.5	**4.9**
Fertilizer Single N	2.8	2.4	0.1	-	**5.3**	3.9	0.5	0.4	**4.8**
No Fert Control	1.8	0.9	0.1	-	**2.8**	2.2	0.3	0.2	**2.7**

Appendix 3. Shenandoah County Soil Data

pH

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month
Litter Split N	6.8	6.6	6.6	6.8	6.7	6.7	6.3	6.6
Fertilizer Split N	7.0	6.4	6.4	6.7	6.6	6.4	6.1	6.3
Litter Single N	6.9	6.7	6.7	7.0	6.8	6.5	6.3	6.7
Fertilizer Single N	6.9	6.3	6.3	6.7	6.6	6.3	5.9	6.3
No Fert Control	6.9	6.6	6.6	6.9	6.7	6.7	6.4	6.5

Organic Matter

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month
	%							
Litter Split N	4.9	3.8	5.3	5.0	5.3	3.6	6.0	4.9
Fertilizer Split N	4.9	3.8	5.8	5.0	5.4	3.7	6.5	4.2
Litter Single N	4.6	3.8	5.8	5.1	5.2	3.6	6.9	4.6
Fertilizer Single N	4.5	3.8	6.1	5.0	5.6	3.7	6.5	4.6
No Fert Control	4.6	3.9	5.7	4.9	5.0	3.5	6.3	4.1

M1P

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month
	mg/kg							
Litter Split N	10.3	11.0	12.5	15.5	14.8	13.9	24.5	25.8
Fertilizer Split N	6.3	10.3	15.8	17.8	16.5	17.7	27.0	18.9
Litter Single N	7.0	11.3	24.5	16.5	12.8	13.3	29.3	18.5
Fertilizer Single N	7.5	15.5	21.8	14.5	14.3	23.1	29.0	18.0
No Fert Control	6.3	8.5	9.0	10.3	9.0	9.6	11.5	8.0

WSP

Treatment	Before Application 2007	1 week	1 Month	6 Month	Before Application 2008	1 week	1 Month	6 Month
	mg/kg							
Litter Split N	1.4	1.1	2.2	3.7	3.7	1.8	2.6	3.8
Fertilizer Split N	1.0	1.2	4.3	4.5	4.5	2.7	3.8	2.8
Litter Single N	1.5	1.3	5.5	4.0	3.8	1.6	5.2	3.3
Fertilizer Single N	0.9	2.7	7.3	3.4	4.1	3.0	5.1	2.7
No Fert Control	1.2	0.9	1.8	2.1	2.6	1.3	1.5	1.3

Appendix 4. Shenandoah County Forage Data

Protein

	2007				2008		
Treatment	1st cut	2nd cut	3rd cut	4th cut	1st cut	2nd cut	3rd cut
%							
Litter Split N	12.3	12.2	18.2	13.4	3.3	2.7	1.7
Fertilizer Split N	13.7	11.4	20.3	13.7	3.3	2.5	3.6
Litter Single N	13.6	12.8	17.4	14.0	3.3	3.6	1.4
Fertilizer Single N	16.2	11.8	16.0	13.2	3.3	2.9	1.3
No Fert Control	9.8	11.6	15.3	12.9	2.1	2.0	1.5

Botanical Composition

Treatment	6/6/2007	8/16/2007	10/17/2007	5/20/2008	7/24/2008	11/11/2008
# of species						
Litter Split N	8.0	4.0	6.0	6.0	6.0	3.0
Fertilizer Split N	7.0	4.0	5.0	5.0	6.0	3.0
Litter Single N	7.0	5.0	7.0	6.0	6.0	4.0
Fertilizer Single N	7.0	4.0	6.0	6.0	6.0	4.0
No Fert Control	8.0	6.0	8.0	5.0	6.0	5.0

Percent Bareground

Treatment	6/6/2007	8/16/2007	10/17/2007	5/20/2008	7/24/2008	11/11/2008
%						
Litter Split N	38.0	33.0	18.0	0.0	0.0	0.0
Fertilizer Split N	23.0	28.0	13.0	0.0	0.0	0.0
Litter Single N	30.0	33.0	13.0	0.0	0.0	5.0
Fertilizer Single N	13.0	35.0	20.0	0.0	0.0	8.0
No Fert Control	30.0	43.0	20.0	14.0	5.0	8.0

Yield

	2007					**2008**			
Treatment	1st cut	2nd cut	3rd cut	4th cut	**2007 total**	1st cut	2nd cut	3rd cut	**2008 total**
	Mg/ha								
Litter Split N	2.5	0.7	0.2	0.5	**4.0**	3.3	2.7	1.7	**7.6**
Fertilizer Split N	2.9	0.8	0.4	0.8	**5.0**	3.3	2.5	3.6	**9.3**
Litter Single N	2.2	0.7	0.2	0.3	**3.7**	3.3	3.6	1.4	**8.3**
Fertilizer Single N	2.9	1.0	0.2	0.3	**4.4**	3.3	2.9	1.3	**7.5**
No Fert Control	2.2	0.7	0.2	0.2	**3.3**	2.1	2.0	1.5	**5.7**

Appendix 5. Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	1	D	Orchardgrass (*Dactylis glomerata)*	10	10	.	.	2	50.0	20	4.45	2.23	0.03	27.2	0.050
2007	June	1	D	Bluegrass (*Poa Annua)*	10	10	10	10	4	100.0	40	8.91	8.91	0.10	54.5	0.099
2007	June	1	D	Tall fescue (*Festuca arundinacea)*	20	40	20	10	4	100.0	90	20.04	20.04	0.23	60.0	0.109
2007	June	1	W	Yellow Foxtail (*Setaria glauca)*	10	10	20	10	4	100.0	50	11.14	11.14	0.13	55.6	0.101
2007	June	1	W	Witchgrass (*Panicum capillare)*	5	5	10	5	4	100.0	25	5.57	5.57	0.07	52.8	0.096
2007	June	1	W	Sweet vernal (*Anthoxanthum odoratum)*	10	20	20	10	4	100.0	60	13.36	13.36	0.16	56.7	0.103
2007	June	1	W	Crabgrass (*Digitaria sanguinalis)*	.	.	10	.	1	25.0	10	2.23	0.56	0.01	13.6	0.025
2007	June	1	W	Cinquefoil (*Potentilla simplex)*	10	5	1	5	4	100.0	21	4.68	4.68	0.05	52.3	0.095
2007	June	1	W	Coral-berry (Symphoricarpos orbiculatus)	.	5	.	.	1	25.0	5	1.11	0.28	0.00	13.1	0.024
2007	June	1	W	Horseweed (*Conyza canadensis)*	.	.	.	5	1	25.0	5	1.11	0.28	0.00	13.1	0.024
2007	June	1	W	Broadleaf Plantain (*Plantago major*)	.	.	.	1	1	25.0	1	0.22	0.06	0.00	12.6	0.023
2007	June	1	W	Narrowleaf Plantain (*Plantago lanceolata)*	5	.	.	.	1	25.0	5	1.11	0.28	0.00	13.1	0.024
2007	June	1	W	Wild Carrot (*Daucus carota)*	10	.	.	5	2	50.0	15	3.34	1.67	0.02	26.7	0.048
2007	June	1	W	Horsenettle (*Solanum carolinense)*	5	.	5	.	2	50.0	10	2.23	1.11	0.01	26.1	0.047
2007	June	1	W	Yarrow (*Achillea millefolium*)	1	.	.	.	1	25.0	1	0.22	0.06	0.00	12.6	0.023
2007	June	1	W	Composite	.	.	.	1	1	25.0	1	0.22	0.06	0.00	12.6	0.023
2007	June	1	B	Bareground Litter	.	30	30	30	3	75.0	90	20.04	15.03	0.18	47.5	0.086
2007	June	1		Total	96	135	126	92	4	1000.0	449	100.00	85.30	1.00	550.0	1.000

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	2	D	Orchardgrass (*Dactylis glomerata)*	10	10			*2*	*66.7*	*20*	*6.25*	*4.17*	*0.05*	*36.5*	*0.073*
2007	June	2	D	Bluegrass (*Poa Annua)*	10	10	10	.	*3*	*100.0*	*30*	*9.38*	*9.38*	*0.12*	*54.7*	*0.109*
2007	June	2	D	Tall fescue (*Festuca arundinacea)*	60		30		*2*	*66.7*	*90*	*28.13*	*18.75*	*0.24*	*47.4*	*0.095*
2007	June	2	W	Yellow Foxtail (*Setaria glauca)*		50	10		*2*	*66.7*	*60*	*18.75*	*12.50*	*0.16*	*42.7*	*0.085*
2007	June	2	W	Witchgrass (*Panicum capillare)*	1	1	1		*3*	*100.0*	*3*	*0.94*	*0.94*	*0.01*	*50.5*	*0.101*
2007	June	2	W	Sweet vernal (*Anthoxanthum odoratum)*	10	10	20		*3*	*100.0*	*40*	*12.50*	*12.50*	*0.16*	*56.3*	*0.113*
2007	June	2	W	Cinquefoil (*Potentilla simplex)*	1				*1*	*33.3*	*1*	*0.31*	*0.10*	*0.00*	*16.8*	*0.034*
2007	June	2	W	Horseweed (*Conyza canadensis)*		1			*1*	*33.3*	*1*	*0.31*	*0.10*	*0.00*	*16.8*	*0.034*
2007	June	2	W	Broadleaf Plantain (*Plantago major*)			1		*1*	*33.3*	*1*	*0.31*	*0.10*	*0.00*	*16.8*	*0.034*
2007	June	2	W	Ragweed (*Ambrosia artemisiifolia)*	1				*1*	*33.3*	*1*	*0.31*	*0.10*	*0.00*	*16.8*	*0.034*
2007	June	2	W	Black Medic (Medicago lupulina)		5			*1*	*33.3*	*5*	*1.56*	*0.52*	*0.01*	*17.4*	*0.035*
2007	June	2	W	Horsenettle (*Solanum carolinense)*		1	1		*2*	*66.7*	*2*	*0.63*	*0.42*	*0.01*	*33.6*	*0.067*
2007	June	2	W	Common Bramble (*Rubus)*			1		*1*	*33.3*	*1*	*0.31*	*0.10*	*0.00*	*16.8*	*0.034*
2007	June	2	W	Wild Grape (*Vitis)*			5		*1*	*33.3*	*5*	*1.56*	*0.52*	*0.01*	*17.4*	*0.035*
2007	June	2	B	Bareground Litter	20	20	20		*3*	*100.0*	*60*	*18.75*	*18.75*	*0.24*	*59.4*	*0.119*
2007	June	2	W	Total	113	108	99		*3*	*900.0*	*320*	*100.00*	*78.96*	*1.00*	*500.0*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	3	D	Orchardgrass (*Dactylis glomerata)*	30	5	10		*3*	*75.0*	*45*	*10.18*	*7.64*	*0.10*	*42.6*	*0.072*
2007	June	3	D	Bluegrass (*Poa Annua)*	10	10	5	10	*4*	*100.0*	*35*	*7.92*	*7.92*	*0.10*	*54.0*	*0.092*
2007	June	3	D	Tall fescue (*Festuca arundinacea)*	20	40	10	10	*4*	*100.0*	*80*	*18.10*	*18.10*	*0.23*	*59.0*	*0.101*
2007	June	3	W	Yellow Foxtail (*Setaria glauca)*			60	20	*2*	*50.0*	*80*	*18.10*	*9.05*	*0.12*	*34.0*	*0.058*
2007	June	3	W	Witchgrass (*Panicum capillare)*	1		1		*2*	*50.0*	*2*	*0.45*	*0.23*	*0.00*	*25.2*	*0.043*
2007	June	3	W	Sweet vernal (*Anthoxanthum odoratum)*	20	10	10	20	*4*	*100.0*	*60*	*13.57*	*13.57*	*0.17*	*56.8*	*0.097*
2007	June	3	W	Crabgrass (*Digitaria sanguinalis)*		1			*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	3	W	Cinquefoil (*Potentilla simplex)*	10	10	5		*3*	*75.0*	*25*	*5.66*	*4.24*	*0.05*	*40.3*	*0.069*
2007	June	3	W	Coral-berry (Symphoricarpos orbiculatus)	10				*1*	*25.0*	*10*	*2.26*	*0.57*	*0.01*	*13.6*	*0.023*
2007	June	3	W	Catchweed Bedstraw (*Galium aparine)*			1		*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	3	W	Horseweed (*Conyza canadensis)*		5		20	*2*	*50.0*	*25*	*5.66*	*2.83*	*0.04*	*27.8*	*0.047*
2007	June	3	W	Narrowleaf Plantain (*Plantago lanceolata)*	1				*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	3	W	Ragweed (*Ambrosia artemisiifolia)*	1	1			*2*	*50.0*	*2*	*0.45*	*0.23*	*0.00*	*25.2*	*0.043*
2007	June	3	W	Black Medic (Medicago lupulina)	10		5		*2*	*50.0*	*15*	*3.39*	*1.70*	*0.02*	*26.7*	*0.045*
2007	June	3	W	Horsenettle (*Solanum carolinense)*	1	1	1	1	*4*	*100.0*	*4*	*0.90*	*0.90*	*0.01*	*50.5*	*0.086*
2007	June	3	W	Common Bramble (*Rubus)*				1	*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	3	W	Yarrow (*Achillea millefolium*)		10		5	*2*	*50.0*	*15*	*3.39*	*1.70*	*0.02*	*26.7*	*0.045*
2007	June	3	B	Bareground Litter	10	10	10	10	*4*	*100.0*	*40*	*9.05*	*9.05*	*0.12*	*54.5*	*0.093*
2007	June	3		Total	124	103	118	97	*4*	*1075.0*	*442*	*100.00*	*77.94*	*1.00*	*587.5*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	4	D	Orchardgrass (*Dactylis glomerata)*	1	10			*2*	*50.0*	*11*	*2.56*	*1.28*	*0.02*	*26.3*	*0.054*
2007	June	4	D	Bluegrass (*Poa Annua)*		10		10	*2*	*50.0*	*20*	*4.65*	*2.33*	*0.03*	*27.3*	*0.056*
2007	June	4	D	Tall fescue (*Festuca arundinacea)*	40	60	10	50	*4*	*100.0*	*160*	*37.21*	*37.21*	*0.48*	*68.6*	*0.141*
2007	June	4	W	Yellow Foxtail (*Setaria glauca)*	50		50		*2*	*50.0*	*100*	*23.26*	*11.63*	*0.15*	*36.6*	*0.075*
2007	June	4	W	Witchgrass (*Panicum capillare)*			10	1	*2*	*50.0*	*11*	*2.56*	*1.28*	*0.02*	*26.3*	*0.054*
2007	June	4	W	Sweet vernal (*Anthoxanthum odoratum)*	10	10	10	20	*4*	*100.0*	*50*	*11.63*	*11.63*	*0.15*	*55.8*	*0.114*
2007	June	4	W	Cinquefoil (*Potentilla simplex)*		1	5	1	*3*	*75.0*	*7*	*1.63*	*1.22*	*0.02*	*38.3*	*0.079*
2007	June	4	W	Coral-berry (Symphoricarpos orbiculatus)			5		*1*	*25.0*	*5*	*1.16*	*0.29*	*0.00*	*13.1*	*0.027*
2007	June	4	W	Horseweed (*Conyza canadensis)*		1		1	*2*	*50.0*	*2*	*0.47*	*0.23*	*0.00*	*25.2*	*0.052*
2007	June	4	W	Narrowleaf Plantain (*Plantago lanceolata)*				5	*1*	*25.0*	*5*	*1.16*	*0.29*	*0.00*	*13.1*	*0.027*
2007	June	4	W	Nightshade (*Solanum ptycanthum)*		1			*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.026*
2007	June	4	W	Oxalis (*Oxalis stricta)*				1	*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.026*
2007	June	4	W	Horsenettle (*Solanum carolinense)*			5	1	*2*	*50.0*	*6*	*1.40*	*0.70*	*0.01*	*25.7*	*0.053*
2007	June	4	W	Common Bramble (*Rubus)*			10	5	*2*	*50.0*	*15*	*3.49*	*1.74*	*0.02*	*26.7*	*0.055*
2007	June	4	W	Yarrow (*Achillea millefolium*)				5	*1*	*25.0*	*5*	*1.16*	*0.29*	*0.00*	*13.1*	*0.027*
2007	June	4	W	Composite		1			*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.026*
2007	June	4	B	Bareground Litter	5	10	5	10	*4*	*100.0*	*30*	*6.98*	*6.98*	*0.09*	*53.5*	*0.110*
2007	June	4		Total	106	104	110	110	*4*	*875.0*	430	*100.00*	*77.27*	*1.00*	*487.5*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	5	D	Orchardgrass (*Dactylis glomerata)*	30				*1*	*25.0*	*30*	*6.70*	*1.67*	*0.02*	*15.8*	*0.026*
2007	June	5	D	Bluegrass (*Poa Annua)*	20	10	10	10	*4*	*100.0*	*50*	*11.16*	*11.16*	*0.14*	*55.6*	*0.093*
2007	June	5	D	Tall fescue (*Festuca arundinacea)*		10	10	30	*3*	*75.0*	*50*	*11.16*	*8.37*	*0.10*	*43.1*	*0.072*
2007	June	5	W	Yellow Foxtail (*Setaria glauca)*	5	20	20	10	*4*	*100.0*	*55*	*12.28*	*12.28*	*0.15*	*56.1*	*0.094*
2007	June	5	W	Witchgrass (*Panicum capillare)*	5	10		10	*3*	*75.0*	*25*	*5.58*	*4.19*	*0.05*	*40.3*	*0.067*
2007	June	5	W	Sweet vernal (*Anthoxanthum odoratum)*	10		20	10	*3*	*75.0*	*40*	*8.93*	*6.70*	*0.08*	*42.0*	*0.070*
2007	June	5	W	Cinquefoil (*Potentilla simplex)*		1	1	5	*3*	*75.0*	*7*	*1.56*	*1.17*	*0.01*	*38.3*	*0.064*
2007	June	5	W	Coral-berry (Symphoricarpos orbiculatus)	5		10		*2*	*50.0*	*15*	*3.35*	*1.67*	*0.02*	*26.7*	*0.044*
2007	June	5	W	Aster (*Aster pilosus)*	1				*1*	*25.0*	*1*	*0.22*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	5	W	Horseweed (*Conyza canadensis)*				1	*1*	*25.0*	*1*	*0.22*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	5	W	Oxalis (*Oxalis stricta)*		1			*1*	*25.0*	*1*	*0.22*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	5	W	Ragweed (*Ambrosia artemisiifolia)*				1	*1*	*25.0*	*1*	*0.22*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	5	W	Black Medic (Medicago lupulina)	10	5	1	1	*4*	*100.0*	*17*	*3.79*	*3.79*	*0.05*	*51.9*	*0.086*
2007	June	5	W	Sage (			10		*1*	*25.0*	*10*	*2.23*	*0.56*	*0.01*	*13.6*	*0.023*
2007	June	5	W	Horsenettle (*Solanum carolinense)*			1	1	*2*	*50.0*	*2*	*0.45*	*0.22*	*0.00*	*25.2*	*0.042*
2007	June	5	W	Yarrow (*Achillea millefolium*)				1	*1*	*25.0*	*1*	*0.22*	*0.06*	*0.00*	*12.6*	*0.021*
2007	June	5	W	Yellow hawkweed (*Hieracium pratense)*				5	*1*	*25.0*	*5*	*1.12*	*0.28*	*0.00*	*13.1*	*0.022*
2007	June	5	W	Red Cedar			1	1	*2*	*50.0*	*2*	*0.45*	*0.22*	*0.00*	*25.2*	*0.042*
2007	June	5	W	Sedge		10			*1*	*25.0*	*10*	*2.23*	*0.56*	*0.01*	*13.6*	*0.023*
2007	June	5	W	Composite				5	*1*	*25.0*	*5*	*1.12*	*0.28*	*0.00*	*13.1*	*0.022*
2007	June	5	B	Bareground Litter	20	30	40	30	*4*	*100.0*	*120*	*26.79*	*26.79*	*0.33*	*63.4*	*0.106*
2007	June	5		Total	106	97	124	121	*4*	*1100.0*	*448*	*100.00*	*80.19*	*1.00*	*600.0*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	August	1	D	Orchardgrass (*Dactylis glomerata)*	10	10	10		*3*	*75.0*	*30*	*7.59*	*5.70*	*0.07*	*41.3*	*0.150*
2007	August	1	D	Bluegrass (*Poa Annua)*	10		10		*2*	*50.0*	*20*	*5.06*	*2.53*	*0.03*	*27.5*	*0.100*
2007	August	1	D	Tall fescue (*Festuca arundinacea)*		10			*1*	*25.0*	*10*	*2.53*	*0.63*	*0.01*	*13.8*	*0.050*
2007	August	1	W	Broomsedge		10	10	20	*3*	*75.0*	*40*	*10.13*	*7.59*	*0.09*	*42.6*	*0.155*
2007	August	1	W	Sweet vernal (*Anthoxanthum odoratum)*			10	10	*2*	*50.0*	*20*	*5.06*	*2.53*	*0.03*	*27.5*	*0.100*
2007	August	1	W	Cinquefoil (*Potentilla simplex)*			10		*1*	*25.0*	*10*	*2.53*	*0.63*	*0.01*	*13.8*	*0.050*
2007	August	1	D	White Clover (*Trifolium repens*)	10				*1*	*25.0*	*10*	*2.53*	*0.63*	*0.01*	*13.8*	*0.050*
2007	August	1	W	Stickweed				5	*1*	*25.0*	*5*	*1.27*	*0.32*	*0.00*	*13.1*	*0.048*
2007	August	1	B	Bareground Litter	70	70	50	60	*4*	*100.0*	*250*	*63.29*	*63.29*	*0.75*	*81.6*	*0.297*
2007	August	1	W	Total	100	100	100	95	*4*	*450.0*	*395*	*100.00*	*83.86*	*1.00*	*275.0*	*1.000*
2007	August	2	D	Orchardgrass (*Dactylis glomerata)*				10	*1*	*25.0*	*10*	*2.50*	*0.63*	*0.01*	*13.8*	*0.052*
2007	August	2	D	Bluegrass (*Poa Annua)*	10	10	20	20	*4*	*100.0*	*60*	*15.00*	*15.00*	*0.18*	*57.5*	*0.219*
2007	August	2	D	Tall fescue (*Festuca arundinacea)*	10			40	*2*	*50.0*	*50*	*12.50*	*6.25*	*0.08*	*31.3*	*0.119*
2007	August	2	W	Broomsedge	10	20	20		*3*	*75.0*	*50*	*12.50*	*9.38*	*0.11*	*43.8*	*0.167*
2007	August	2	W	Sweet vernal (*Anthoxanthum odoratum)*	10	20			*2*	*50.0*	*30*	*7.50*	*3.75*	*0.05*	*28.8*	*0.110*
2007	August	2	W	Broadleaf Plantain (*Plantago major*)				10	*1*	*25.0*	*10*	*2.50*	*0.63*	*0.01*	*13.8*	*0.052*
2007	August	2	B	Bareground Litter	50	60	50	30	*4*	*100.0*	*190*	*47.50*	*47.50*	*0.57*	*73.8*	*0.281*
2007	August	2		Total	90	110	90	110	*4*	*425.0*	*400*	*100.00*	*83.13*	*1.00*	*262.5*	*1.000*
2007	August	3	D	Orchardgrass (*Dactylis glomerata)*	10		10		*2*	*50.0*	*20*	*5.13*	*2.56*	*0.03*	*27.6*	*0.110*
2007	August	3	D	Bluegrass (*Poa Annua)*			10	10	*2*	*50.0*	*20*	*5.13*	*2.56*	*0.03*	*27.6*	*0.110*
2007	August	3	D	Tall fescue (*Festuca arundinacea)*		10	20		*2*	*50.0*	*30*	*7.69*	*3.85*	*0.05*	*28.8*	*0.115*
2007	August	3	W	Broomsedge	10			10	*2*	*50.0*	*20*	*5.13*	*2.56*	*0.03*	*27.6*	*0.110*
2007	August	3	W	Sweet vernal (*Anthoxanthum odoratum)*				10	*1*	*25.0*	*10*	*2.56*	*0.64*	*0.01*	*13.8*	*0.055*
2007	August	3	W	Cinquefoil (*Potentilla simplex)*		5			*1*	*25.0*	*5*	*1.28*	*0.32*	*0.00*	*13.1*	*0.053*
2007	August	3	W	Purple top		10			*1*	*25.0*	*10*	*2.56*	*0.64*	*0.01*	*13.8*	*0.055*
2007	August	3	W	Broadleaf Plantain (*Plantago major*)			5		*1*	*25.0*	*5*	*1.28*	*0.32*	*0.00*	*13.1*	*0.053*
2007	August	3	B	Bareground Litter	80	80	50	60	*4*	*100.0*	*270*	*69.23*	*69.23*	*0.84*	*84.6*	*0.338*
2007	August	3		Total	100	105	95	90	*4*	*400.0*	*390*	*100.00*	*82.69*	*1.00*	*250.0*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	August	4	D	Orchardgrass (*Dactylis glomerata)*	10	10			*2*	*50.0*	*20*	*4.94*	*2.47*	*0.03*	*27.5*	*0.092*
2007	August	4	D	Bluegrass (*Poa Annua)*		20	10		*2*	*50.0*	*30*	*7.41*	*3.70*	*0.04*	*28.7*	*0.096*
2007	August	4	D	Tall fescue (*Festuca arundinacea)*	10	30	10	10	*4*	*100.0*	*60*	*14.81*	*14.81*	*0.17*	*57.4*	*0.191*
2007	August	4	W	Broomsedge	20		10	20	*3*	*75.0*	*50*	*12.35*	*9.26*	*0.11*	*43.7*	*0.146*
2007	August	4	W	Sweet vernal (*Anthoxanthum odoratum)*	10		10		*2*	*50.0*	*20*	*4.94*	*2.47*	*0.03*	*27.5*	*0.092*
2007	August	4	W	Crabgrass (*Digitaria sanguinalis)*	5				*1*	*25.0*	*5*	*1.23*	*0.31*	*0.00*	*13.1*	*0.044*
2007	August	4	W	Cinquefoil (*Potentilla simplex)*				5	*1*	*25.0*	*5*	*1.23*	*0.31*	*0.00*	*13.1*	*0.044*
2007	August	4	W	Broadleaf Plantain (*Plantago major*)		5			*1*	*25.0*	*5*	*1.23*	*0.31*	*0.00*	*13.1*	*0.044*
2007	August	4	B	Bareground Litter	50	30	60	70	*4*	*100.0*	*210*	*51.85*	*51.85*	*0.61*	*75.9*	*0.253*
2007	August	4		Total	105	95	100	105	*4*	*500.0*	*405*	*100.00*	*85.49*	*1.00*	*300.0*	*1.000*
2007	August	5	D	Orchardgrass (*Dactylis glomerata)*	10	10		10	*3*	*75.0*	*30*	*7.23*	*5.42*	*0.07*	*41.1*	*0.137*
2007	August	5	D	Bluegrass (*Poa Annua)*	20	10			*2*	*50.0*	*30*	*7.23*	*3.61*	*0.05*	*28.6*	*0.095*
2007	August	5	D	Tall fescue (*Festuca arundinacea)*	30				*1*	*25.0*	*30*	*7.23*	*1.81*	*0.02*	*16.1*	*0.054*
2007	August	5	W	Broomsedge		10	10	10	*3*	*75.0*	*30*	*7.23*	*5.42*	*0.07*	*41.1*	*0.137*
2007	August	5	W	Purple top		10			*1*	*25.0*	*10*	*2.41*	*0.60*	*0.01*	*13.7*	*0.046*
2007	August	5	W	Chicory *(Cichorium intybus)*		10			*1*	*25.0*	*10*	*2.41*	*0.60*	*0.01*	*13.7*	*0.046*
2007	August	5	W	Broadleaf Plantain (*Plantago major*)	5			10	*2*	*50.0*	*15*	*3.61*	*1.81*	*0.02*	*26.8*	*0.089*
2007	August	5	W	Nightshade (*Solanum ptycanthum)*	10				*1*	*25.0*	*10*	*2.41*	*0.60*	*0.01*	*13.7*	*0.046*
2007	August	5	D	White Clover (*Trifolium repens*)	15				*1*	*25.0*	*15*	*3.61*	*0.90*	*0.01*	*14.3*	*0.048*
2007	August	5	W	Wild Grape (*Vitis)*			5		*1*	*25.0*	*5*	*1.20*	*0.30*	*0.00*	*13.1*	*0.044*
2007	August	5	B	Bareground Litter	20	60	80	70	*4*	*100.0*	*230*	*55.42*	*55.42*	*0.72*	*77.7*	*0.259*
2007	August	5	W	Total	110	110	95	100	*4*	*500.0*	*415*	*100.00*	*76.51*	*1.00*	*300.0*	*1.000*
2007	October	1	D	Orchardgrass (*Dactylis glomerata)*	1				*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.037*
2007	October	1	D	Tall fescue (*Festuca arundinacea)*	10	20	10	10	*4*	*100.0*	*50*	*11.93*	*11.93*	*0.12*	*56.0*	*0.166*
2007	October	1	W	Broomsedge	10	10	10	10	*4*	*100.0*	*40*	*9.55*	*9.55*	*0.10*	*54.8*	*0.162*
2007	October	1	W	Cinquefoil (*Potentilla simplex)*	1		1		*2*	*50.0*	*2*	*0.48*	*0.24*	*0.00*	*25.2*	*0.075*
2007	October	1	W	Purple top	5	5	1	1	*4*	*100.0*	*12*	*2.86*	*2.86*	*0.03*	*51.4*	*0.152*
2007	October	1	W	Nightshade (*Solanum ptycanthum)*	1				*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.037*
2007	October	1	W	Horsenettle (*Solanum carolinense)*	1	1	1		*3*	*75.0*	*3*	*0.72*	*0.54*	*0.01*	*37.9*	*0.112*
2007	October	1	B	Bareground Litter	80	70	80	80	*4*	*100.0*	*310*	*73.99*	*73.99*	*0.75*	*87.0*	*0.258*
2007	October	1		Total:	109	106	103	101	*4*	*575.0*	*419*	*100.00*	*99.22*	*1.00*	*337.5*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	October	2	D	Tall fescue (*Festuca arundinacea)*	20	20	10	20	*4*	*100.0*	*70*	*16.95*	*16.95*	*0.17*	*58.5*	*0.180*
2007	October	2	W	Broomsedge	5	20	20	20	*4*	*100.0*	*65*	*15.74*	*15.74*	*0.16*	*57.9*	*0.178*
2007	October	2	W	Witchgrass (*Panicum capillare)*			1		*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.039*
2007	October	2	W	Cinquefoil (*Potentilla simplex)*		1		1	*2*	*50.0*	*2*	*0.48*	*0.24*	*0.00*	*25.2*	*0.078*
2007	October	2	W	Purple top	5	1	1	1	*4*	*100.0*	*8*	*1.94*	*1.94*	*0.02*	*51.0*	*0.157*
2007	October	2	W	Horsenettle (*Solanum carolinense)*			1	1	*2*	*50.0*	*2*	*0.48*	*0.24*	*0.00*	*25.2*	*0.078*
2007	October	2	W	Muliflora Rose			5		*1*	*25.0*	*5*	*1.21*	*0.30*	*0.00*	*13.1*	*0.040*
2007	October	2	B	Bareground Litter	70	60	70	60	*4*	*100.0*	*260*	*62.95*	*62.95*	*0.64*	*81.5*	*0.251*
2007	October	2		Total:	100	102	108	103	*4*	*550.0*	*413*	*100.00*	*98.43*	*1.00*	*325.0*	*1.000*
2007	October	3	D	Orchardgrass (*Dactylis glomerata)*	1	5			*2*	*50.0*	*6*	*1.35*	*0.68*	*0.01*	*25.7*	*0.068*
2007	October	3	D	Tall fescue (*Festuca arundinacea)*	10	20	10	20	*4*	*100.0*	*60*	*13.51*	*13.51*	*0.14*	*56.8*	*0.151*
2007	October	3	W	Broomsedge	5	20	10	10	*4*	*100.0*	*45*	*10.14*	*10.14*	*0.10*	*55.1*	*0.147*
2007	October	3	W	Witchgrass (*Panicum capillare)*				1	*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.034*
2007	October	3	W	Cinquefoil (*Potentilla simplex)*	1	1	1		*3*	*75.0*	*3*	*0.68*	*0.51*	*0.01*	*37.8*	*0.101*
2007	October	3	W	Purple top	1	10	1	5	*4*	*100.0*	*17*	*3.83*	*3.83*	*0.04*	*51.9*	*0.138*
2007	October	3	W	Oxalis (*Oxalis stricta)*		1			*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.034*
2007	October	3	W	Horsenettle (*Solanum carolinense)*	1	5			*2*	*50.0*	*6*	*1.35*	*0.68*	*0.01*	*25.7*	*0.068*
2007	October	3	W	Composite	5				*1*	*25.0*	*5*	*1.13*	*0.28*	*0.00*	*13.1*	*0.035*
2007	October	3	B	Bareground Litter	80	70	80	70	*4*	*100.0*	*300*	*67.57*	*67.57*	*0.69*	*83.8*	*0.223*
2007	October	3		Total:	104	132	102	106	*4*	*650.0*	*444*	*100.00*	*97.30*	*1.00*	*375.0*	*1.000*
2007	October	4	D	Orchardgrass (*Dactylis glomerata)*	10				*1*	*25.0*	*10*	*2.29*	*0.57*	*0.01*	*13.6*	*0.044*
2007	October	4	D	Tall fescue (*Festuca arundinacea)*	5	20	10	10	*4*	*100.0*	*45*	*10.30*	*10.30*	*0.11*	*55.1*	*0.176*
2007	October	4	W	Broomsedge	30	20	10	20	*4*	*100.0*	*80*	*18.31*	*18.31*	*0.19*	*59.2*	*0.189*
2007	October	4	W	Cinquefoil (*Potentilla simplex)*			1		*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.040*
2007	October	4	W	Purple top			1		*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.040*
2007	October	4	W	Nightshade (*Solanum ptycanthum)*		5			*1*	*25.0*	*5*	*1.14*	*0.29*	*0.00*	*13.1*	*0.042*
2007	October	4	W	Horsenettle (*Solanum carolinense)*	1	1	1	1	*4*	*100.0*	*4*	*0.92*	*0.92*	*0.01*	*50.5*	*0.161*
2007	October	4	W	Muliflora Rose				1	*1*	*25.0*	*1*	*0.23*	*0.06*	*0.00*	*12.6*	*0.040*
2007	October	4	B	Bareground Litter	70	70	80	70	*4*	*100.0*	*290*	*66.36*	*66.36*	*0.68*	*83.2*	*0.266*
2007	October	4		Total:	116	116	103	102	*4*	*525.0*	*437*	*100.00*	*96.91*	*1.00*	*312.5*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	October	5	D	Orchardgrass (*Dactylis glomerata)*	5				*1*	*25.0*	*5*	*1.20*	*0.30*	*0.00*	*13.1*	*0.042*
2007	October	5	D	Tall fescue (*Festuca arundinacea)*	10	10	10	10	*4*	*100.0*	*40*	*9.62*	*9.62*	*0.10*	*54.8*	*0.175*
2007	October	5	W	Broomsedge		10	10	10	*3*	*75.0*	*30*	*7.21*	*5.41*	*0.06*	*41.1*	*0.132*
2007	October	5	W	Witchgrass (*Panicum capillare)*		5			*1*	*25.0*	*5*	*1.20*	*0.30*	*0.00*	*13.1*	*0.042*
2007	October	5	W	Sweet vernal (*Anthoxanthum odoratum)*	.				*0*	*0.0*	*0*	*0.00*	*0.00*	*0.00*	*0.0*	*0.000*
2007	October	5	W	Cinquefoil (*Potentilla simplex)*			1		*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.040*
2007	October	5	W	Purple top	5		1	1	*3*	*75.0*	*7*	*1.68*	*1.26*	*0.01*	*38.3*	*0.123*
2007	October	5	W	Nightshade (*Solanum ptycanthum)*		1			*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.040*
2007	October	5	W	Sage		5			*1*	*25.0*	*5*	*1.20*	*0.30*	*0.00*	*13.1*	*0.042*
2007	October	5	W	Horsenettle (*Solanum carolinense)*			1	1	*2*	*50.0*	*2*	*0.48*	*0.24*	*0.00*	*25.2*	*0.081*
2007	October	5	B	Bareground Litter	80	80	80	80	*4*	*100.0*	*320*	*76.92*	*76.92*	*0.81*	*88.5*	*0.283*
2007	October	5		Total:	100	111	103	102	*4*	*525.0*	*416*	*100.00*	*94.47*	*1.00*	*312.5*	*1.000*
2008	May	1	D	Orchardgrass (*Dactylis glomerata)*	10	10	10		*3*	*75.0*	*30*	*7.21*	*5.41*	*0.06*	*41.1*	*0.137*
2008	May	1	D	Tall fescue (*Festuca arundinacea)*	40	30	40	60	*4*	*100.0*	*170*	*40.87*	*40.87*	*0.43*	*70.4*	*0.235*
2008	May	1	W	Quackgrass	10	1	10		*3*	*75.0*	*21*	*5.05*	*3.79*	*0.04*	*40.0*	*0.133*
2008	May	1	W	Cinquefoil (*Potentilla simplex)*	1		1	10	*3*	*75.0*	*12*	*2.88*	*2.16*	*0.02*	*38.9*	*0.130*
2008	May	1	W	Black Medic (Medicago lupulina)	50	60	40	30	*4*	*100.0*	*180*	*43.27*	*43.27*	*0.45*	*71.6*	*0.239*
2008	May	1	W	Yarrow (*Achillea millefolium*)	1				*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.042*
2008	May	1	W	Muliflora Rose		1			*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.042*
2008	May	1	W	Daisy				1	*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.042*
2008	May	1		Total:	112	102	101	101	*4*	*500.0*	*416*	*100.00*	*95.67*	*1.00*	*300.0*	*1.000*
2008	May	2	D	Orchardgrass (*Dactylis glomerata)*	10	10	10	1	*4*	*100.0*	*31*	*7.69*	*7.69*	*0.08*	*53.8*	*0.227*
2008	May	2	D	Bluegrass (*Poa Annua)*					*0*	*0.0*	*0*	*0.00*	*0.00*	*0.00*	*0.0*	*0.000*
2008	May	2	D	Tall fescue (*Festuca arundinacea)*	50	30	70	70	*4*	*100.0*	*220*	*54.59*	*54.59*	*0.55*	*77.3*	*0.325*
2008	May	2	W	Quackgrass		10		1	*2*	*50.0*	*11*	*2.73*	*1.36*	*0.01*	*26.4*	*0.111*
2008	May	2	W	Wild Carrot (*Daucus carota)*			1		*1*	*25.0*	*1*	*0.25*	*0.06*	*0.00*	*12.6*	*0.053*
2008	May	2	W	Black Medic (Medicago lupulina)	40	50	20	30	*4*	*100.0*	*140*	*34.74*	*34.74*	*0.35*	*67.4*	*0.284*
2008	May	2		Total:	100	100	101	102	*4*	*375.0*	*403*	*100.00*	*98.45*	*1.00*	*237.5*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	May	3	D	Orchardgrass (*Dactylis glomerata)*	20	10	10		3	75.0	40	10.70	8.02	0.09	42.8	0.163
2008	May	3	D	Tall fescue (*Festuca arundinacea)*	20	30	20	50	4	100.0	120	32.09	32.09	0.35	66.0	0.252
2008	May	3	W	Cinquefoil (*Potentilla simplex)*	1		1		2	50.0	2	0.53	0.27	0.00	25.3	0.096
2008	May	3	W	Narrowleaf Plantain (*Plantago lanceolata)*				1	1	25.0	1	0.27	0.07	0.00	12.6	0.048
2008	May	3	W	Wild Carrot (*Daucus carota)*			1		1	25.0	1	0.27	0.07	0.00	12.6	0.048
2008	May	3	W	Black Medic (Medicago lupulina)	60	30	70	30	4	100.0	190	50.80	50.80	0.55	75.4	0.287
2008	May	3	W	Yarrow (*Achillea millefolium*)				10	1	25.0	10	2.67	0.67	0.01	13.8	0.053
2008	May	3	W	Daisy				10	1	25.0	10	2.67	0.67	0.01	13.8	0.053
2008	May	3		Total:	101	70	102	101	4	425.0	374	100.00	92.65	1.00	262.5	1.000
2008	May	4	D	Orchardgrass (*Dactylis glomerata)*	20	20	20	10	4	100.0	70	17.33	17.33	0.17	58.7	0.235
2008	May	4	D	Tall fescue (*Festuca arundinacea)*	20	20	40	60	4	100.0	140	34.65	34.65	0.35	67.3	0.269
2008	May	4	W	Quackgrass	1		1		2	50.0	2	0.50	0.25	0.00	25.2	0.101
2008	May	4	W	Cinquefoil (*Potentilla simplex)*				1	1	25.0	1	0.25	0.06	0.00	12.6	0.050
2008	May	4	W	Black Medic (Medicago lupulina)	60	60	40	30	4	100.0	190	47.03	47.03	0.47	73.5	0.294
2008	May	4	W	Muliflora Rose				1	1	25.0	1	0.25	0.06	0.00	12.6	0.050
2008	May	4		Total:	101	100	101	102	4	400.0	404	100.00	99.38	1.00	250.0	1.000
2008	May	5	D	Orchardgrass (*Dactylis glomerata)*	1	1	1	1	4	100.0	4	1.01	1.01	0.01	50.5	0.162
2008	May	5	D	Tall fescue (*Festuca arundinacea)*	20	30	20	20	4	100.0	90	22.67	22.67	0.26	61.3	0.196
2008	May	5	W	Quackgrass	10	10	30		3	75.0	50	12.59	9.45	0.11	43.8	0.140
2008	May	5	W	Cinquefoil (*Potentilla simplex)*			1		1	25.0	1	0.25	0.06	0.00	12.6	0.040
2008	May	5	W	Black Medic (Medicago lupulina)	70	50	30	60	4	100.0	210	52.90	52.90	0.60	76.4	0.245
2008	May	5	W	Muliflora Rose	1			1	2	50.0	2	0.50	0.25	0.00	25.3	0.081
2008	May	5	W	Sedge		10			1	25.0	10	2.52	0.63	0.01	13.8	0.044
2008	May	5	W	Daisy				20	1	25.0	20	5.04	1.26	0.01	15.0	0.048
2008	May	5	B	Bareground Litter			10		1	25.0	10	2.52	0.63	0.01	13.8	0.044
2008	May	5		Total:	102	101	92	102	4	525.0	397	100.00	88.85	1.00	312.5	1.000

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	July	1	D	Orchardgrass (*Dactylis glomerata)*	20	20	20	20	*4*	*100.0*	*80*	*20.20*	*20.20*	*0.26*	*60.1*	*0.166*
2008	July	1	D	Bluegrass (*Poa Annua)*		10	10	30	*3*	*75.0*	*50*	*12.63*	*9.47*	*0.12*	*43.8*	*0.121*
2008	July	1	D	Tall fescue (*Festuca arundinacea)*			30	20	*2*	*50.0*	*50*	*12.63*	*6.31*	*0.08*	*31.3*	*0.086*
2008	July	1	W	Witchgrass (*Panicum capillare)*		10			*1*	*25.0*	*10*	*2.53*	*0.63*	*0.01*	*13.8*	*0.038*
2008	July	1	W	Sweet vernal (*Anthoxanthum odoratum)*	20				*1*	*25.0*	*20*	*5.05*	*1.26*	*0.02*	*15.0*	*0.041*
2008	July	1	W	Cinquefoil (*Potentilla simplex)*				1	*1*	*25.0*	*1*	*0.25*	*0.06*	*0.00*	*12.6*	*0.035*
2008	July	1	W	Wild Carrot (*Daucus carota)*	10				*1*	*25.0*	*10*	*2.53*	*0.63*	*0.01*	*13.8*	*0.038*
2008	July	1	W	Ragweed (*Ambrosia artemisiifolia)*	20	20	20	10	*4*	*100.0*	*70*	*17.68*	*17.68*	*0.23*	*58.8*	*0.162*
2008	July	1	W	Muliflora Rose	20	10		10	*3*	*75.0*	*40*	*10.10*	*7.58*	*0.10*	*42.6*	*0.117*
2008	July	1	W	Ground cherry			10		*1*	*25.0*	*10*	*2.53*	*0.63*	*0.01*	*13.8*	*0.038*
2008	July	1	B	Bareground Litter	5	30	10	10	*4*	*100.0*	*55*	*13.89*	*13.89*	*0.18*	*56.9*	*0.157*
2008	July	1		Total:	95	100	100	101	*4*	*625.0*	*396*	*100.00*	*78.35*	*1.00*	*362.5*	*1.000*
2008	July	2	D	Orchardgrass (*Dactylis glomerata)*	30	30	10	20	*4*	*100.0*	*90*	*23.32*	*23.32*	*0.29*	*61.7*	*0.170*
2008	July	2	D	Bluegrass (*Poa Annua)*			20	20	*2*	*50.0*	*40*	*10.36*	*5.18*	*0.06*	*30.2*	*0.083*
2008	July	2	D	Tall fescue (*Festuca arundinacea)*	20	10	10	20	*4*	*100.0*	*60*	*15.54*	*15.54*	*0.19*	*57.8*	*0.159*
2008	July	2	W	Witchgrass (*Panicum capillare)*		10			*1*	*25.0*	*10*	*2.59*	*0.65*	*0.01*	*13.8*	*0.038*
2008	July	2	W	Cinquefoil (*Potentilla simplex)*	10			1	*2*	*50.0*	*11*	*2.85*	*1.42*	*0.02*	*26.4*	*0.073*
2008	July	2	W	Oxalis (*Oxalis stricta)*	5				*1*	*25.0*	*5*	*1.30*	*0.32*	*0.00*	*13.1*	*0.036*
2008	July	2	W	Ragweed (*Ambrosia artemisiifolia)*	10	10	10		*3*	*75.0*	*30*	*7.77*	*5.83*	*0.07*	*41.4*	*0.114*
2008	July	2	W	Muliflora Rose		10	20		*2*	*50.0*	*30*	*7.77*	*3.89*	*0.05*	*28.9*	*0.080*
2008	July	2	W	Ground cherry			10	20	*2*	*50.0*	*30*	*7.77*	*3.89*	*0.05*	*28.9*	*0.080*
2008	July	2	B	Bareground Litter	20	20	20	20	*4*	*100.0*	*80*	*20.73*	*20.73*	*0.26*	*60.4*	*0.167*
2008	July	2		Total:	95	90	100	101	*4*	*625.0*	*386*	*100.00*	*80.76*	*1.00*	*362.5*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	July	3	D	Orchardgrass (*Dactylis glomerata)*	60	30	20	30	*4*	*100.0*	*140*	*33.98*	*33.98*	*0.41*	*67.0*	*0.173*
2008	July	3	D	Bluegrass (*Poa Annua)*	10	10	10	20	*4*	*100.0*	*50*	*12.14*	*12.14*	*0.15*	*56.1*	*0.145*
2008	July	3	D	Tall fescue (*Festuca arundinacea)*		10	30	20	*3*	*75.0*	*60*	*14.56*	*10.92*	*0.13*	*44.8*	*0.116*
2008	July	3	W	Wild Carrot (*Daucus carota)*			1		*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.033*
2008	July	3	W	Oxalis (*Oxalis stricta)*	10	10	10		*3*	*75.0*	*30*	*7.28*	*5.46*	*0.07*	*41.1*	*0.106*
2008	July	3	W	Ragweed (*Ambrosia artemisiifolia)*	1	10		10	*3*	*75.0*	*21*	*5.10*	*3.82*	*0.05*	*40.0*	*0.103*
2008	July	3	W	Yarrow (*Achillea millefolium*)				10	*1*	*25.0*	*10*	*2.43*	*0.61*	*0.01*	*13.7*	*0.035*
2008	July	3	W	Muliflora Rose	10	20			*2*	*50.0*	*30*	*7.28*	*3.64*	*0.04*	*28.6*	*0.074*
2008	July	3	W	Spurge			10		*1*	*25.0*	*10*	*2.43*	*0.61*	*0.01*	*13.7*	*0.035*
2008	July	3	W	Ground cherry			20		*1*	*25.0*	*20*	*4.85*	*1.21*	*0.01*	*14.9*	*0.039*
2008	July	3	B	Bareground Litter	10	10	10	10	*4*	*100.0*	*40*	*9.71*	*9.71*	*0.12*	*54.9*	*0.142*
2008	July	3		Total:	101	100	111	100	*4*	*675.0*	*412*	*100.00*	*82.16*	*1.00*	*387.5*	*1.000*
2008	July	4	D	Orchardgrass (*Dactylis glomerata)*	30	40	20	10	*4*	*100.0*	*100*	*25.38*	*25.38*	*0.31*	*62.7*	*0.157*
2008	July	4	D	Bluegrass (*Poa Annua)*	10	10	20	20	*4*	*100.0*	*60*	*15.23*	*15.23*	*0.19*	*57.6*	*0.144*
2008	July	4	D	Tall fescue (*Festuca arundinacea)*		10		20	*2*	*50.0*	*30*	*7.61*	*3.81*	*0.05*	*28.8*	*0.072*
2008	July	4	W	Sweet vernal (*Anthoxanthum odoratum)*		10			*1*	*25.0*	*10*	*2.54*	*0.63*	*0.01*	*13.8*	*0.034*
2008	July	4	W	Cinquefoil (*Potentilla simplex)*			10		*1*	*25.0*	*10*	*2.54*	*0.63*	*0.01*	*13.8*	*0.034*
2008	July	4	W	Wild Carrot (*Daucus carota)*				1	*1*	*25.0*	*1*	*0.25*	*0.06*	*0.00*	*12.6*	*0.032*
2008	July	4	W	Oxalis (*Oxalis stricta)*	5		10	1	*3*	*75.0*	*16*	*4.06*	*3.05*	*0.04*	*39.5*	*0.099*
2008	July	4	W	Ragweed (*Ambrosia artemisiifolia)*	30		20	10	*3*	*75.0*	*60*	*15.23*	*11.42*	*0.14*	*45.1*	*0.113*
2008	July	4	W	Muliflora Rose				10	*1*	*25.0*	*10*	*2.54*	*0.63*	*0.01*	*13.8*	*0.034*
2008	July	4	W	Spurge	5			1	*2*	*50.0*	*6*	*1.52*	*0.76*	*0.01*	*25.8*	*0.064*
2008	July	4	W	Ground cherry		30	1		*2*	*50.0*	*31*	*7.87*	*3.93*	*0.05*	*28.9*	*0.072*
2008	July	4	B	Bareground Litter	10	10	20	20	*4*	*100.0*	*60*	*15.23*	*15.23*	*0.19*	*57.6*	*0.144*
2008	July	4		Total:	90	110	101	93	*4*	*700.0*	*394*	*100.00*	*80.77*	*1.00*	*400.0*	*1.000*

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	July	5	D	Orchardgrass (*Dactylis glomerata)*	20	10	10	1	4	100.0	41	10.07	10.07	0.14	55.0	0.142
2008	July	5	D	Bluegrass (*Poa Annua)*			20	10	2	50.0	30	7.37	3.69	0.05	28.7	0.074
2008	July	5	D	Tall fescue (*Festuca arundinacea)*			10	20	2	50.0	30	7.37	3.69	0.05	28.7	0.074
2008	July	5	W	Witchgrass (*Panicum capillare)*	20	10			2	50.0	30	7.37	3.69	0.05	28.7	0.074
2008	July	5	W	Sweet vernal (*Anthoxanthum odoratum)*		10	1		2	50.0	11	2.70	1.35	0.02	26.4	0.068
2008	July	5	W	Chicory *(Cichorium intybus)*		30			1	25.0	30	7.37	1.84	0.03	16.2	0.042
2008	July	5	W	Broadleaf Plantain (*Plantago major*)				10	1	25.0	10	2.46	0.61	0.01	13.7	0.035
2008	July	5	W	Oxalis (*Oxalis stricta)*	5				1	25.0	5	1.23	0.31	0.00	13.1	0.034
2008	July	5	W	Ragweed (*Ambrosia artemisiifolia)*	30	20	20	30	4	100.0	100	24.57	24.57	0.34	62.3	0.161
2008	July	5	W	Muliflora Rose	10				1	25.0	10	2.46	0.61	0.01	13.7	0.035
2008	July	5	W	Spurge	10			20	2	50.0	30	7.37	3.69	0.05	28.7	0.074
2008	July	5	W	Ground cherry			10		1	25.0	10	2.46	0.61	0.01	13.7	0.035
2008	July	5	B	Bareground Litter	10	20	30	10	4	100.0	70	17.20	17.20	0.24	58.6	0.151
2008	July	5		Total:	105	100	101	101	4	675.0	407	100.00	71.93	1.00	387.5	1.000
2008	Nov	1	D	Bluegrass (*Poa Annua)*	10	20	30	70	4	100.0	130	32.42	32.42	0.35	66.2	0.265
2008	Nov	1	D	Tall fescue (*Festuca arundinacea)*	80	60	30	20	4	100.0	190	47.38	47.38	0.52	73.7	0.295
2008	Nov	1	W	Broomsedge	10		20		2	50.0	30	7.48	3.74	0.04	28.7	0.115
2008	Nov	1	W	Cinquefoil (*Potentilla simplex)*				1	1	25.0	1	0.25	0.06	0.00	12.6	0.050
2008	Nov	1	W	Purple top		10	10	10	3	75.0	30	7.48	5.61	0.06	41.2	0.165
2008	Nov	1	B	Bareground Litter		10	10		2	50.0	20	4.99	2.49	0.03	27.5	0.110
2008	Nov	1		Total:	100	100	100	101	4	400.0	401	100.00	91.71	1.00	250.0	1.000
2008	Nov	2	D	Orchardgrass (*Dactylis glomerata)*	10				1	25.0	10	2.54	0.63	0.01	13.8	0.041
2008	Nov	2	D	Bluegrass (*Poa Annua)*	10	20	30	30	4	100.0	90	22.84	22.84	0.24	61.4	0.182
2008	Nov	2	D	Tall fescue (*Festuca arundinacea)*	40	60	20	40	4	100.0	160	40.61	40.61	0.42	70.3	0.208
2008	Nov	2	W	Broomsedge	20	10	20	10	4	100.0	60	15.23	15.23	0.16	57.6	0.171
2008	Nov	2	W	Purple top	10	10	10	10	4	100.0	40	10.15	10.15	0.11	55.1	0.163
2008	Nov	2	W	Horsenettle (*Solanum carolinense)*		1		1	2	50.0	2	0.51	0.25	0.00	25.3	0.075
2008	Nov	2	W	Mullien		1			1	25.0	1	0.25	0.06	0.00	12.6	0.037
2008	Nov	2	B	Bareground Litter	10		20	1	3	75.0	31	7.87	5.90	0.06	41.4	0.123
2008	Nov	2		Total:	100	102	100	92	4	575.0	394	100.00	95.69	1.00	337.5	1.000

Rockbridge County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	Nov	3	D	Bluegrass (*Poa Annua)*	20	20	20	30	*4*	*100.0*	*90*	*23.38*	*23.38*	*0.26*	*61.7*	*0.206*
2008	Nov	3	D	Tall fescue (*Festuca arundinacea)*	70	20	30	40	*4*	*100.0*	*160*	*41.56*	*41.56*	*0.46*	*70.8*	*0.236*
2008	Nov	3	W	Broomsedge	10	30	20		*3*	*75.0*	*60*	*15.58*	*11.69*	*0.13*	*45.3*	*0.151*
2008	Nov	3	W	Purple top	1		20		*2*	*50.0*	*21*	*5.45*	*2.73*	*0.03*	*27.7*	*0.092*
2008	Nov	3	W	Horsenettle (*Solanum carolinense)*	1	1			*2*	*50.0*	*2*	*0.52*	*0.26*	*0.00*	*25.3*	*0.084*
2008	Nov	3	W	Yarrow (*Achillea millefolium*)				1	*1*	*25.0*	*1*	*0.26*	*0.06*	*0.00*	*12.6*	*0.042*
2008	Nov	3	W	Yellow nutsedge (*Cyperus esculentus)*				1	*1*	*25.0*	*1*	*0.26*	*0.06*	*0.00*	*12.6*	*0.042*
2008	Nov	3	B	Bareground Litter		20	10	20	*3*	*75.0*	*50*	*12.99*	*9.74*	*0.11*	*44.0*	*0.147*
2008	Nov	3		Total:	102	91	100	92	*4*	*500.0*	*385*	*100.00*	*89.48*	*1.00*	*300.0*	*1.000*
2008	Nov	4	D	Bluegrass (*Poa Annua)*	20	20	20	40	*4*	*100.0*	*100*	*24.75*	*24.75*	*0.25*	*62.4*	*0.208*
2008	Nov	4	D	Tall fescue (*Festuca arundinacea)*	40	40	20	40	*4*	*100.0*	*140*	*34.65*	*34.65*	*0.35*	*67.3*	*0.224*
2008	Nov	4	W	Broomsedge	10	10	20	10	*4*	*100.0*	*50*	*12.38*	*12.38*	*0.13*	*56.2*	*0.187*
2008	Nov	4	W	Purple top		10		1	*2*	*50.0*	*11*	*2.72*	*1.36*	*0.01*	*26.4*	*0.088*
2008	Nov	4	W	Oxalis (*Oxalis stricta)*	1				*1*	*25.0*	*1*	*0.25*	*0.06*	*0.00*	*12.6*	*0.042*
2008	Nov	4	W	Mullien		1			*1*	*25.0*	*1*	*0.25*	*0.06*	*0.00*	*12.6*	*0.042*
2008	Nov	4	B	Bareground Litter	30	30	40	1	*4*	*100.0*	*101*	*25.00*	*25.00*	*0.25*	*62.5*	*0.208*
2008	Nov	4		Total:	101	111	100	92	*4*	*500.0*	*404*	*100.00*	*98.27*	*1.00*	*300.0*	*1.000*
2008	Nov	5	D	Bluegrass (*Poa Annua)*	10	20	20	40	*4*	*100.0*	*90*	*21.90*	*21.90*	*0.25*	*60.9*	*0.203*
2008	Nov	5	D	Tall fescue (*Festuca arundinacea)*	30	60	30	20	*4*	*100.0*	*140*	*34.06*	*34.06*	*0.39*	*67.0*	*0.223*
2008	Nov	5	W	Broomsedge	20		20	10	*3*	*75.0*	*50*	*12.17*	*9.12*	*0.11*	*43.6*	*0.145*
2008	Nov	5	W	Cinquefoil (*Potentilla simplex)*			10		*1*	*25.0*	*10*	*2.43*	*0.61*	*0.01*	*13.7*	*0.046*
2008	Nov	5	W	Purple top	10	10	20		*3*	*75.0*	*40*	*9.73*	*7.30*	*0.08*	*42.4*	*0.141*
2008	Nov	5	W	Horsenettle (*Solanum carolinense)*	1				*1*	*25.0*	*1*	*0.24*	*0.06*	*0.00*	*12.6*	*0.042*
2008	Nov	5	W	Mullien				10	*1*	*25.0*	*10*	*2.43*	*0.61*	*0.01*	*13.7*	*0.046*
2008	Nov	5	B	Bareground Litter	30	10		30	*3*	*75.0*	*70*	*17.03*	*12.77*	*0.15*	*46.0*	*0.153*
2008	Nov	5		Total:	101	100	100	110	*4*	*500.0*	*411*	*100.00*	*86.44*	*1.00*	*300.0*	*1.000*

Appendix 6. Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	1	D	Orchardgrass (*Dactylis glomerata)*	10	5	20	20	4	100	55	11.36	11.4	0.1218	55.7	0.111
2007	June	1	D	Bluegrass (*Poa Annua)*	30	20	20	30	4	100	100	20.66	20.7	0.22145	60.3	0.121
2007	June	1	D	Tall fescue (*Festuca arundinacea)*	30	30	30	30	4	100	120	24.79	24.8	0.26574	62.4	0.125
2007	June	1	W	Yellow Foxtail (*Setaria glauca)*		1			1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Cinquefoil (*Potentilla simplex)*		1			1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Mouseear Chickweed (*Cerastium vulgatum)*	1				1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Chicory *(Cichorium intybus)*				1	1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Aster (*Aster pilosus)*		1	1		2	50	2	0.41	0.2	0.00221	25.2	0.050
2007	June	1	W	Nightshade (*Solanum ptycanthum)*	1				1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	D	Red Clover (*Trifolium pratense)*		10	5		2	50	15	3.10	1.5	0.01661	26.5	0.053
2007	June	1	D	White Clover (*Trifolium repens*)			1		1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Wild Carrot (*Daucus carota)*			1		1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Oxalis (*Oxalis stricta)*	5				1	25	5	1.03	0.3	0.00277	13	0.026
2007	June	1	W	Black Medic (Medicago lupulina)	10	1	1		3	75	12	2.48	1.9	0.01993	38.7	0.077
2007	June	1	W	Speedwell (*Veronica arvensis)*	1				1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Horsenettle (*Solanum carolinense)*			1		1	25	1	0.21	0.1	0.00055	12.6	0.025
2007	June	1	W	Common Bramble (*Rubus)*	5	1			2	50	6	1.24	0.6	0.00664	25.6	0.051
2007	June	1	W	Wild Grape (*Vitis)*		10			1	25	10	2.07	0.5	0.00554	13.5	0.027
2007	June	1	B	Bareground Litter	10	40	50	50	4	100	150	30.99	31.0	0.33217	65.5	0.131
2007	June	1		Total:	103	120	130	131	4	900	484	100.00	93.3	0.99984	500	1.000

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	2	D	Orchardgrass (*Dactylis glomerata)*	10		20	10	3	100	40	11.94	11.9	0.14369	56	0.120
2007	June	2	D	Bluegrass (*Poa Annua)*	20		30	20	3	100	70	20.90	20.9	0.25145	60.4	0.129
2007	June	2	D	Tall fescue (*Festuca arundinacea)*			30	40	2	67	70	20.90	13.9	0.16763	43.8	0.094
2007	June	2	W	Yellow Foxtail (*Setaria glauca)*	10			10	2	67	20	5.97	4.0	0.0479	36.3	0.078
2007	June	2	W	Chicory *(Cichorium intybus)*	10				1	33	10	2.99	1.0	0.01197	18.2	0.039
2007	June	2	W	Aster (*Aster pilosus)*				1	1	33	1	0.30	0.1	0.0012	16.8	0.036
2007	June	2	W	Narrowleaf Plantain (*Plantago lanceolata)*	5				1	33	5	1.49	0.5	0.00599	17.4	0.037
2007	June	2	D	Red Clover (*Trifolium pratense)*	5				1	33	5	1.49	0.5	0.00599	17.4	0.037
2007	June	2	D	White Clover (*Trifolium repens*)			1		1	33	1	0.30	0.1	0.0012	16.8	0.036
2007	June	2	W	Wild Carrot (*Daucus carota)*			1		1	33	1	0.30	0.1	0.0012	16.8	0.036
2007	June	2	W	Oxalis (*Oxalis stricta)*	1				1	33	1	0.30	0.1	0.0012	16.8	0.036
2007	June	2	W	Black Medic (Medicago lupulina)	5		5		2	67	10	2.99	2.0	0.02395	34.8	0.075
2007	June	2	W	Common Bramble (*Rubus)*	1				1	33	1	0.30	0.1	0.0012	16.8	0.036
2007	June	2	W	Poison Ivy (*Toxicodendron radicans)*			5		1	33	5	1.49	0.5	0.00599	17.4	0.037
2007	June	2	W	Yellow nutsedge (*Cyperus esculentus)*			5		1	33	5	1.49	0.5	0.00599	17.4	0.037
2007	June	2	B	Bareground Litter	20		30	40	3	100	90	26.87	26.9	0.32329	63.4	0.136
2007	June	2		Total:	87		127	121	3	833	335	100.00	83.1	0.99981	467	0.999

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	3	D	Orchardgrass (*Dactylis glomerata)*		10	10	10	3	75	30	7.03	5.3	0.05954	41	0.089
2007	June	3	D	Bluegrass (*Poa Annua)*	20	40	20	20	4	100	100	23.42	23.4	0.26462	61.7	0.133
2007	June	3	D	Tall fescue (*Festuca arundinacea)*	30	20	20	30	4	100	100	23.42	23.4	0.26462	61.7	0.133
2007	June	3	W	Yellow Foxtail (*Setaria glauca)*			10		1	25	10	2.34	0.6	0.00662	13.7	0.030
2007	June	3	W	Cinquefoil (*Potentilla simplex)*	1				1	25	1	0.23	0.1	0.00066	12.6	0.027
2007	June	3	W	Mouseear Chickweed (*Cerastium vulgatum)*		5			1	25	5	1.17	0.3	0.00331	13.1	0.028
2007	June	3	W	Chicory *(Cichorium intybus)*	5				1	25	5	1.17	0.3	0.00331	13.1	0.028
2007	June	3	W	Broadleaf Plantain (*Plantago major*)				1	1	25	1	0.23	0.1	0.00066	12.6	0.027
2007	June	3	W	Narrowleaf Plantain (*Plantago lanceolata)*		5			1	25	5	1.17	0.3	0.00331	13.1	0.028
2007	June	3	D	Red Clover (*Trifolium pratense)*	5	10		1	3	75	16	3.75	2.8	0.03175	39.4	0.085
2007	June	3	D	White Clover (*Trifolium repens*)			5		1	25	5	1.17	0.3	0.00331	13.1	0.028
2007	June	3	W	Wild Carrot (*Daucus carota)*		1		1	2	50	2	0.47	0.2	0.00265	25.2	0.055
2007	June	3	W	Black Medic (Medicago lupulina)	5	5	5		3	75	15	3.51	2.6	0.02977	39.3	0.085
2007	June	3	W	Common Bramble (*Rubus)*	1				1	25	1	0.23	0.1	0.00066	12.6	0.027
2007	June	3	W	Poison Ivy (*Toxicodendron radicans)*	10				1	25	10	2.34	0.6	0.00662	13.7	0.030
2007	June	3	W	Red Cedar			1		1	25	1	0.23	0.1	0.00066	12.6	0.027
2007	June	3	B	Bareground Litter	20	20	40	40	4	100	120	28.10	28.1	0.31755	64.1	0.138
2007	June	3		Total:	97	116	111	103	4	825	427	100.00	88.5	0.99962	463	0.999
2007	June	4	D	Orchardgrass (*Dactylis glomerata)*	20	20	20		3	100	60	21.66	21.7	0.23068	60.8	0.159
2007	June	4	D	Bluegrass (*Poa Annua)*	20	20	20		3	100	60	21.66	21.7	0.23068	60.8	0.159
2007	June	4	D	Tall fescue (*Festuca arundinacea)*	40	40	40		3	100	120	43.32	43.3	0.46136	71.7	0.187
2007	June	4	W	Yellow Foxtail (*Setaria glauca)*			10		1	33	10	3.61	1.2	0.01282	18.5	0.048
2007	June	4	W	Mouseear Chickweed (*Cerastium vulgatum)*		1			1	33	1	0.36	0.1	0.00128	16.8	0.044
2007	June	4	W	Narrowleaf Plantain (*Plantago lanceolata)*			1		1	33	1	0.36	0.1	0.00128	16.8	0.044
2007	June	4	W	Nightshade (*Solanum ptycanthum)*	1				1	33	1	0.36	0.1	0.00128	16.8	0.044
2007	June	4	D	Red Clover (*Trifolium pratense)*		5	5		2	67	10	3.61	2.4	0.02563	35.1	0.092
2007	June	4	D	White Clover (*Trifolium repens*)	1		1		2	67	2	0.72	0.5	0.00513	33.7	0.088
2007	June	4	W	Wild Carrot (*Daucus carota)*		1			1	33	1	0.36	0.1	0.00128	16.8	0.044
2007	June	4	W	Black Medic (Medicago lupulina)	1	10			2	67	11	3.97	2.6	0.02819	35.3	0.092
2007	June	4		total:	83	97	97	0		667	277	100.00	93.9	0.9996	383	1.001

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	June	5	W	Broadleaf Plantain (*Plantago major*)	1			1	2	67	2	1.03	0.7	0.00738	33.8	0.120
2007	June	5	D	Red Clover (*Trifolium pratense)*	20	5		20	3	100	45	23.08	23.1	0.24921	61.5	0.217
2007	June	5	W	White Clover (*Trifolium repens*)	1				1	33	1	0.51	0.2	0.00185	16.9	0.060
2007	June	5	W	Wild Carrot (*Daucus carota)*	1				1	33	1	0.51	0.2	0.00185	16.9	0.060
2007	June	5	W	Black Medic (Medicago lupulina)	10	5			2	67	15	7.69	5.1	0.05538	37.2	0.131
2007	June	5	W	Horsenettle (*Solanum carolinense)*				1	1	33	1	0.51	0.2	0.00185	16.9	0.060
2007	June	5	W	Poison Ivy (*Toxicodendron radicans)*				10	1	33	10	5.13	1.7	0.01846	19.2	0.068
2007	June	5	B	Bareground Litter	30	50		40	3	100	120	61.54	61.5	0.66456	80.8	0.285
2007	June	5		Total:	129	121		122	3	467	195	100.00	92.6	1.00054	283	1.001
2007	August	1	D	Orchardgrass (*Dactylis glomerata)*	10	10	10	30	4	100	60	14.29	14.3	0.14819	57.1	0.190
2007	August	1	D	Bluegrass (*Poa Annua)*	30	30	30	30	4	100	120	28.57	28.6	0.29638	64.3	0.214
2007	August	1	D	Tall fescue (*Festuca arundinacea)*	20	30	30	10	4	100	90	21.43	21.4	0.22229	60.7	0.202
2007	August	1	W	Narrowleaf Plantain (*Plantago lanceolata)*				5	1	25	5	1.19	0.3	0.00309	13.1	0.044
2007	August	1	W	Wild Carrot (*Daucus carota)*			5		1	25	5	1.19	0.3	0.00309	13.1	0.044
2007	August	1	W	Wild Grape (*Vitis)*		5			1	25	5	1.19	0.3	0.00309	13.1	0.044
2007	August	1	W	Chickweed	5				1	25	5	1.19	0.3	0.00309	13.1	0.044
2007	August	1	B	Bareground Litter	40	30	30	30	4	100	130	30.95	31.0	0.32108	65.5	0.218
2007	August	1		Total:	105	105	105	105	4	500	420	100.00	96.4	1.0003	300	1.000
2007	August	2	D	Orchardgrass (*Dactylis glomerata)*	20	10	10	10	4	100	50	11.90	11.9	0.12815	56	0.179
2007	August	2	D	Bluegrass (*Poa Annua)*	20	10	30	20	4	100	80	19.05	19.0	0.20503	59.5	0.190
2007	August	2	D	Tall fescue (*Festuca arundinacea)*	30	40	30	40	4	100	140	33.33	33.3	0.35881	66.7	0.213
2007	August	2	W	Chicory *(Cichorium intybus)*	10				1	25	10	2.38	0.6	0.00641	13.7	0.044
2007	August	2	W	Narrowleaf Plantain (*Plantago lanceolata)*				10	1	25	10	2.38	0.6	0.00641	13.7	0.044
2007	August	2	D	White Clover (*Trifolium repens*)		5			1	25	5	1.19	0.3	0.0032	13.1	0.042
2007	August	2	W	Oxalis (*Oxalis stricta)*		5			1	25	5	1.19	0.3	0.0032	13.1	0.042
2007	August	2	W	Poison Ivy (*Toxicodendron radicans)*		10			1	25	10	2.38	0.6	0.00641	13.7	0.044
2007	August	2	B	Bareground Litter	20	20	40	30	4	100	110	26.19	26.2	0.28192	63.1	0.202
2007	August	2		Total:	100	100	110	110	4	525	420	100.00	92.9	0.99954	313	0.998

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	August	3	D	Orchardgrass (*Dactylis glomerata)*	10	5	10	10	4	100	35	9.21	9.2	0.09893	54.6	0.168
2007	August	3	D	Bluegrass (*Poa Annua)*	20	30	10	30	4	100	90	23.68	23.7	0.2544	61.8	0.190
2007	August	3	D	Tall fescue (*Festuca arundinacea)*	20	20	20	30	4	100	90	23.68	23.7	0.2544	61.8	0.190
2007	August	3	W	Cinquefoil (*Potentilla simplex)*	5				1	25	5	1.32	0.3	0.00353	13.2	0.040
2007	August	3	W	Chicory *(Cichorium intybus)*		5			1	25	5	1.32	0.3	0.00353	13.2	0.040
2007	August	3	W	Broadleaf Plantain (*Plantago major*)			5		1	25	5	1.32	0.3	0.00353	13.2	0.040
2007	August	3	W	Narrowleaf Plantain (*Plantago lanceolata)*	10				1	25	10	2.63	0.7	0.00707	13.8	0.043
2007	August	3	D	White Clover (*Trifolium repens*)		5			1	25	5	1.32	0.3	0.00353	13.2	0.040
2007	August	3	W	Oxalis (*Oxalis stricta)*	5				1	25	5	1.32	0.3	0.00353	13.2	0.040
2007	August	3	B	Bareground Litter	30	20	50	30	4	100	130	34.21	34.2	0.36746	67.1	0.206
2007	August	3		Total:	100	85	95	100	4	550	380	100.00	93.1	0.99992	325	1.000
2007	August	4	D	Orchardgrass (*Dactylis glomerata)*	10	10	30	10	4	100	60	14.81	14.8	0.15242	57.4	0.199
2007	August	4	D	Bluegrass (*Poa Annua)*	20	20	20	30	4	100	90	22.22	22.2	0.22862	61.1	0.212
2007	August	4	D	Tall fescue (*Festuca arundinacea)*	30	30	20	20	4	100	100	24.69	24.7	0.25403	62.3	0.216
2007	August	4	W	Chicory *(Cichorium intybus)*	5				1	25	5	1.23	0.3	0.00318	13.1	0.046
2007	August	4	W	Narrowleaf Plantain (*Plantago lanceolata)*		5			1	25	5	1.23	0.3	0.00318	13.1	0.046
2007	August	4	W	Oxalis (*Oxalis stricta)*				5	1	25	5	1.23	0.3	0.00318	13.1	0.046
2007	August	4	B	Bareground Litter	40	30	40	30	4	100	140	34.57	34.6	0.35564	67.3	0.234
2007	August	4		Total:	105	95	110	95	4	475	405	100.00	97.2	1.00023	288	0.998
2007	August	5	D	Orchardgrass (*Dactylis glomerata)*	10	10	20	20	4	100	60	13.33	13.3	0.14684	56.7	0.168
2007	August	5	D	Bluegrass (*Poa Annua)*	20	20	30	20	4	100	90	20.00	20.0	0.22026	60	0.178
2007	August	5	D	Tall fescue (*Festuca arundinacea)*	30	20	10	10	4	100	70	15.56	15.6	0.17132	57.8	0.171
2007	August	5	W	Chicory *(Cichorium intybus)*				5	1	25	5	1.11	0.3	0.00306	13.1	0.039
2007	August	5	W	Narrowleaf Plantain (*Plantago lanceolata)*	5				1	25	5	1.11	0.3	0.00306	13.1	0.039
2007	August	5	D	White Clover (*Trifolium repens*)	10		5		2	50	15	3.33	1.7	0.01836	26.7	0.079
2007	August	5	W	Wild Carrot (*Daucus carota)*	15				1	25	15	3.33	0.8	0.00918	14.2	0.042
2007	August	5	W	Poison Ivy (*Toxicodendron radicans)*				15	1	25	15	3.33	0.8	0.00918	14.2	0.042
2007	August	5	W	Chickweed		5			1	25	5	1.11	0.3	0.00306	13.1	0.039
2007	August	5	B	Bareground Litter	20	60	40	50	4	100	170	37.78	37.8	0.41605	68.9	0.204
2007	August	5	W	Total:	110	115	105	120	4	575	450	100.00	90.8	1.00037	338	0.999

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	October	1	D	Orchardgrass (*Dactylis glomerata)*		5	20	5	3	75	30	7.56	5.7	0.0614	41.3	0.103
2007	October	1	D	Bluegrass (*Poa Annua)*	30	20	30	40	4	100	120	30.23	30.2	0.32748	65.1	0.163
2007	October	1	D	Tall fescue (*Festuca arundinacea)*	30	40	40	30	4	100	140	35.26	35.3	0.38206	67.6	0.169
2007	October	1	W	Cinquefoil (*Potentilla simplex)*	5	1			2	50	6	1.51	0.8	0.00819	25.8	0.064
2007	October	1	W	Chicory *(Cichorium intybus)*				5	1	25	5	1.26	0.3	0.00341	13.1	0.033
2007	October	1	W	Broadleaf Plantain (*Plantago major*)		5			1	25	5	1.26	0.3	0.00341	13.1	0.033
2007	October	1	W	Narrowleaf Plantain (*Plantago lanceolata)*	1				1	25	1	0.25	0.1	0.00068	12.6	0.032
2007	October	1	D	Red Clover (*Trifolium pratense)*			1		1	25	1	0.25	0.1	0.00068	12.6	0.032
2007	October	1	D	White Clover (*Trifolium repens*)			5	1	2	50	6	1.51	0.8	0.00819	25.8	0.064
2007	October	1	W	Oxalis (*Oxalis stricta)*	5				1	25	5	1.26	0.3	0.00341	13.1	0.033
2007	October	1	W	Horsenettle (*Solanum carolinense)*		1			1	25	1	0.25	0.1	0.00068	12.6	0.032
2007	October	1	W	Wild Grape (*Vitis)*	5	1			2	50	6	1.51	0.8	0.00819	25.8	0.064
2007	October	1	W	Dandelion	1				1	25	1	0.25	0.1	0.00068	12.6	0.032
2007	October	1	B	Bareground Litter	10	30	10	20	4	100	70	17.63	17.6	0.19103	58.8	0.147
2007	October	1	W	Total:	87	103	106	101	4	700	397	100.00	92.3	0.99951	400	1.000
2007	October	2	D	Orchardgrass (*Dactylis glomerata)*	5	5	40	5	4	100	55	12.47	12.5	0.13705	56.2	0.155
2007	October	2	D	Bluegrass (*Poa Annua)*	20	10		20	3	75	50	11.34	8.5	0.09344	43.2	0.119
2007	October	2	D	Tall fescue (*Festuca arundinacea)*	60	80	40	60	4	100	240	54.42	54.4	0.59804	77.2	0.213
2007	October	2	W	Yellow Foxtail (*Setaria glauca)*			5		1	25	5	1.13	0.3	0.00311	13.1	0.036
2007	October	2	W	Chicory *(Cichorium intybus)*	10				1	25	10	2.27	0.6	0.00623	13.6	0.038
2007	October	2	W	Broadleaf Plantain (*Plantago major*)				1	1	25	1	0.23	0.1	0.00062	12.6	0.035
2007	October	2	W	Oxalis (*Oxalis stricta)*	1	10			2	50	11	2.49	1.2	0.01371	26.2	0.072
2007	October	2	W	Poison Ivy (*Toxicodendron radicans)*		1			1	25	1	0.23	0.1	0.00062	12.6	0.035
2007	October	2	W	Wild Grape (*Vitis)*		1			1	25	1	0.23	0.1	0.00062	12.6	0.035
2007	October	2	W	Red Cedar	1				1	25	1	0.23	0.1	0.00062	12.6	0.035
2007	October	2	W	Dandelion	10			5	2	50	15	3.40	1.7	0.01869	26.7	0.074
2007	October	2	B	Bareground Litter	10	1	20	20	4	100	51	11.56	11.6	0.12708	55.8	0.154
2007	October	2		Total:	117	108	105	111	4	625	441	100.00	91.0	0.99985	363	0.999

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	October	3	D	Orchardgrass (*Dactylis glomerata)*	10	10	10	20	4	100	50	11.60	11.6	0.12022	55.8	0.127
2007	October	3	D	Bluegrass (*Poa Annua)*	20	70	40	50	4	100	180	41.76	41.8	0.43278	70.9	0.162
2007	October	3	D	Tall fescue (*Festuca arundinacea)*	40	10	40	20	4	100	110	25.52	25.5	0.26448	62.8	0.143
2007	October	3	W	Cinquefoil (*Potentilla simplex)*	5				1	25	5	1.16	0.3	0.00301	13.1	0.030
2007	October	3	W	Chicory *(Cichorium intybus)*	10	1		10	3	75	21	4.87	3.7	0.03787	39.9	0.091
2007	October	3	W	Broadleaf Plantain (*Plantago major*)	1		1		2	50	2	0.46	0.2	0.0024	25.2	0.058
2007	October	3	W	Narrowleaf Plantain (*Plantago lanceolata)*		1			1	25	1	0.23	0.1	0.0006	12.6	0.029
2007	October	3	D	Red Clover (*Trifolium pratense)*	5	1	1		3	75	7	1.62	1.2	0.01262	38.3	0.087
2007	October	3	D	White Clover (*Trifolium repens*)		1	1		2	50	2	0.46	0.2	0.0024	25.2	0.058
2007	October	3	W	Oxalis (*Oxalis stricta)*	1				1	25	1	0.23	0.1	0.0006	12.6	0.029
2007	October	3	W	Horsenettle (*Solanum carolinense)*	1			1	2	50	2	0.46	0.2	0.0024	25.2	0.058
2007	October	3	B	Bareground Litter	10	10	20	10	4	100	50	11.60	11.6	0.12022	55.8	0.127
2007	October	3		Total:	103	104	113	111	4	775	431	100.00	96.5	0.9996	438	0.999
2007	October	4	D	Orchardgrass (*Dactylis glomerata)*	10	10	20	10	4	100	50	11.49	11.5	0.12333	55.7	0.149
2007	October	4	D	Bluegrass (*Poa Annua)*	20	20	20	20	4	100	80	18.39	18.4	0.19733	59.2	0.158
2007	October	4	D	Tall fescue (*Festuca arundinacea)*	60	50	30	40	4	100	180	41.38	41.4	0.44398	70.7	0.189
2007	October	4	W	Yellow Foxtail (*Setaria glauca)*			10		1	25	10	2.30	0.6	0.00617	13.6	0.036
2007	October	4	W	Cinquefoil (*Potentilla simplex)*	10				1	25	10	2.30	0.6	0.00617	13.6	0.036
2007	October	4	W	Chicory *(Cichorium intybus)*		10		5	2	50	15	3.45	1.7	0.0185	26.7	0.071
2007	October	4	W	Broadleaf Plantain (*Plantago major*)		1		1	2	50	2	0.46	0.2	0.00247	25.2	0.067
2007	October	4	W	Narrowleaf Plantain (*Plantago lanceolata)*			1		1	25	1	0.23	0.1	0.00062	12.6	0.034
2007	October	4	D	Red Clover (*Trifolium pratense)*		1			1	25	1	0.23	0.1	0.00062	12.6	0.034
2007	October	4	W	Oxalis (*Oxalis stricta)*			1		1	25	1	0.23	0.1	0.00062	12.6	0.034
2007	October	4	W	Dandelion		5			1	25	5	1.15	0.3	0.00308	13.1	0.035
2007	October	4	B	Bareground Litter	20	20	20	20	4	100	80	18.39	18.4	0.19733	59.2	0.158
2007	October	4		Total:	120	117	102	96	4	650	435	100.00	93.2	1.0002	375	1.000

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2007	October	5	D	Orchardgrass (*Dactylis glomerata)*	5	20	10	5	4	100	40	9.20	9.2	0.09952	54.6	0.115
2007	October	5	D	Bluegrass (*Poa Annua)*	10	20	30	20	4	100	80	18.39	18.4	0.19903	59.2	0.125
2007	October	5	D	Tall fescue (*Festuca arundinacea)*	70	30	40	30	4	100	170	39.08	39.1	0.42295	69.5	0.146
2007	October	5	W	Chicory *(Cichorium intybus)*		10			1	25	10	2.30	0.6	0.00622	13.6	0.029
2007	October	5	W	Broadleaf Plantain (*Plantago major*)		1	1		2	50	2	0.46	0.2	0.00249	25.2	0.053
2007	October	5	W	Narrowleaf Plantain (*Plantago lanceolata)*		1	10		2	50	11	2.53	1.3	0.01368	26.3	0.055
2007	October	5	D	Red Clover (*Trifolium pratense)*	1	1	5	5	4	100	12	2.76	2.8	0.02986	51.4	0.108
2007	October	5	D	White Clover (*Trifolium repens*)	1				1	25	1	0.23	0.1	0.00062	12.6	0.027
2007	October	5	W	Oxalis (*Oxalis stricta)*			1	1	2	50	2	0.46	0.2	0.00249	25.2	0.053
2007	October	5	W	Horsenettle (*Solanum carolinense)*			1	5	2	50	6	1.38	0.7	0.00746	25.7	0.054
2007	October	5	W	Poison Ivy (*Toxicodendron radicans)*				10	1	25	10	2.30	0.6	0.00622	13.6	0.029
2007	October	5	W	Red Cedar	5				1	25	5	1.15	0.3	0.00311	13.1	0.028
2007	October	5	W	Dandelion	5		1		2	50	6	1.38	0.7	0.00746	25.7	0.054
2007	October	5	B	Bareground Litter	10	20	30	20	4	100	80	18.39	18.4	0.19903	59.2	0.125
2007	October	5		Total:	107	103	129	96	4	850	435	100.00	92.4	1.00015	475	1.000
2008	May	1	D	Orchardgrass (*Dactylis glomerata)*	20	10	10	20	4	100	60	14.12	14.1	0.15531	57.1	0.176
2008	May	1	D	Bluegrass (*Poa Annua)*	30	60	50	20	4	100	160	37.65	37.6	0.41416	68.8	0.212
2008	May	1	D	Tall fescue (*Festuca arundinacea)*	30	20	30	30	4	100	110	25.88	25.9	0.28473	62.9	0.194
2008	May	1	W	Narrowleaf Plantain (*Plantago lanceolata)*	10				1	25	10	2.35	0.6	0.00647	13.7	0.042
2008	May	1	D	Red Clover (*Trifolium pratense)*		10	10	10	3	75	30	7.06	5.3	0.05824	41	0.126
2008	May	1	D	White Clover (*Trifolium repens*)			10	10	2	50	20	4.71	2.4	0.02588	27.4	0.084
2008	May	1	W	Black Medic (Medicago lupulina)	5	10		10	3	75	25	5.88	4.4	0.04853	40.4	0.124
2008	May	1	W	Chickweed				10	1	25	10	2.35	0.6	0.00647	13.7	0.042
2008	May	1		Total:	95	110	110	110	4	550	425	100.00	90.9	0.99981	325	1.000

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	May	2	D	Orchardgrass (*Dactylis glomerata)*	40	10	10	10	4	100	70	17.20	17.2	0.182	58.6	0.187
2008	May	2	D	Bluegrass (*Poa Annua)*	20	40	60	20	4	100	140	34.40	34.4	0.364	67.2	0.215
2008	May	2	D	Tall fescue (*Festuca arundinacea)*	30	30	30	50	4	100	140	34.40	34.4	0.364	67.2	0.215
2008	May	2	W	Narrowleaf Plantain (*Plantago lanceolata)*	5				1	25	5	1.23	0.3	0.00325	13.1	0.042
2008	May	2	D	Red Clover (*Trifolium pratense)*	5	5		10	3	75	20	4.91	3.7	0.039	40	0.128
2008	May	2	D	White Clover (*Trifolium repens*)		10	1	10	3	75	21	5.16	3.9	0.04095	40.1	0.128
2008	May	2	W	Black Medic (Medicago lupulina)		10			1	25	10	2.46	0.6	0.0065	13.7	0.044
2008	May	2	W	Chickweed				1	1	25	1	0.25	0.1	0.00065	12.6	0.040
2008	May	2		Total:	100	105	101	101	4	525	407	100.00	94.5	1.00035	313	0.998
2008	May	3	D	Orchardgrass (*Dactylis glomerata)*	20	10	20	20	4	100	70	17.41	17.4	0.18623	58.7	0.181
2008	May	3	D	Bluegrass (*Poa Annua)*	10	20	50	40	4	100	120	29.85	29.9	0.31926	64.9	0.200
2008	May	3	D	Tall fescue (*Festuca arundinacea)*	60	50	20	20	4	100	150	37.31	37.3	0.39907	68.7	0.211
2008	May	3	W	Narrowleaf Plantain (*Plantago lanceolata)*	1				1	25	1	0.25	0.1	0.00067	12.6	0.039
2008	May	3	D	Red Clover (*Trifolium pratense)*			10	10	2	50	20	4.98	2.5	0.0266	27.5	0.085
2008	May	3	D	White Clover (*Trifolium repens*)		5		10	2	50	15	3.73	1.9	0.01995	26.9	0.083
2008	May	3	W	Black Medic (Medicago lupulina)		5	10	5	3	75	20	4.98	3.7	0.03991	40	0.123
2008	May	3	W	Chickweed	5		1		2	50	6	1.49	0.7	0.00798	25.7	0.079
2008	May	3		Total:	96	90	111	105	4	550	402	100.00	93.5	0.99968	325	1.000
2008	May	4	D	Orchardgrass (*Dactylis glomerata)*	40	20	20	40	4	100	120	30.08	30.1	0.31758	65	0.179
2008	May	4	D	Bluegrass (*Poa Annua)*	10	20	10	10	4	100	50	12.53	12.5	0.13233	56.3	0.155
2008	May	4	D	Tall fescue (*Festuca arundinacea)*	40	20	60	30	4	100	150	37.59	37.6	0.39698	68.8	0.190
2008	May	4	W	Narrowleaf Plantain (*Plantago lanceolata)*	5				1	25	5	1.25	0.3	0.00331	13.1	0.036
2008	May	4	D	Red Clover (*Trifolium pratense)*		5	10	1	3	75	16	4.01	3.0	0.03176	39.5	0.109
2008	May	4	D	White Clover (*Trifolium repens*)		5			1	25	5	1.25	0.3	0.00331	13.1	0.036
2008	May	4	W	Wild Carrot (*Daucus carota)*				1	1	25	1	0.25	0.1	0.00066	12.6	0.035
2008	May	4	W	Black Medic (Medicago lupulina)	5	20		10	3	75	35	8.77	6.6	0.06947	41.9	0.115
2008	May	4	W	Chickweed	5	10	1	1	4	100	17	4.26	4.3	0.04499	52.1	0.144
2008	May	4		Total:	105	100	101	93	4	625	399	100.00	94.7	1.00039	363	0.999

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	May	5	D	Orchardgrass (*Dactylis glomerata)*	5	10	10	20	4	100	45	10.71	10.7	0.11326	55.4	0.152
2008	May	5	D	Bluegrass (*Poa Annua)*	50	40	40	30	4	100	160	38.10	38.1	0.4027	69	0.190
2008	May	5	D	Tall fescue (*Festuca arundinacea)*	10	10	10	20	4	100	50	11.90	11.9	0.12584	56	0.154
2008	May	5	D	Red Clover (*Trifolium pratense)*	20		10		2	50	30	7.14	3.6	0.03775	28.6	0.079
2008	May	5	D	White Clover (*Trifolium repens*)	10		10	10	3	75	30	7.14	5.4	0.05663	41.1	0.113
2008	May	5	W	Black Medic (Medicago lupulina)	10	20	10	10	4	100	50	11.90	11.9	0.12584	56	0.154
2008	May	5	B	Bareground Litter	5	20	20	10	4	100	55	13.10	13.1	0.13843	56.5	0.156
2008	May	5		Total:	110	100	110	100	4	625	420	100.00	94.6	1.00045	363	0.999
2008	July	1	D	Orchardgrass (*Dactylis glomerata)*	10	10	10	10	4	100	40	9.90	9.9	0.10249	55	0.157
2008	July	1	D	Bluegrass (*Poa Annua)*	10	20	20	20	4	100	70	17.33	17.3	0.17937	58.7	0.168
2008	July	1	D	Tall fescue (*Festuca arundinacea)*	50	70	40	30	4	100	190	47.03	47.0	0.48685	73.5	0.210
2008	July	1	W	Chicory *(Cichorium intybus)*	20	1	10	20	4	100	51	12.62	12.6	0.13068	56.3	0.161
2008	July	1	W	Aster (*Aster pilosus)*		1	10	10	3	75	21	5.20	3.9	0.04036	40.1	0.115
2008	July	1	D	Red Clover (*Trifolium pratense)*	10		10	10	3	75	30	7.43	5.6	0.05765	41.2	0.118
2008	July	1	W	Wild Grape (*Vitis)*	1	1			2	50	2	0.50	0.2	0.00256	25.2	0.072
2008	July	1		Total:	101	103	100	100	4	600	404	100.00	96.6	0.99996	350	1.000
2008	July	2	D	Orchardgrass (*Dactylis glomerata)*	10	10	10	10	4	100	40	9.71	9.7	0.09857	54.9	0.162
2008	July	2	D	Bluegrass (*Poa Annua)*	10	10	20	10	4	100	50	12.14	12.1	0.12321	56.1	0.166
2008	July	2	D	Tall fescue (*Festuca arundinacea)*	60	50	40	30	4	100	180	43.69	43.7	0.44355	71.8	0.213
2008	July	2	W	Chicory *(Cichorium intybus)*	20	10	10	10	4	100	50	12.14	12.1	0.12321	56.1	0.166
2008	July	2	W	Aster (*Aster pilosus)*		1		10	2	50	11	2.67	1.3	0.01355	26.3	0.078
2008	July	2	D	Red Clover (*Trifolium pratense)*	10	20	20	30	4	100	80	19.42	19.4	0.19713	59.7	0.177
2008	July	2	W	Wild Grape (*Vitis)*				1	1	25	1	0.24	0.1	0.00062	12.6	0.037
2008	July	2		Total:	110	101	100	101	4	575	412	100.00	98.5	0.99983	338	0.999
2008	July	3	D	Orchardgrass (*Dactylis glomerata)*	20	10		10	3	75	40	9.71	7.3	0.07601	42.4	0.130
2008	July	3	D	Bluegrass (*Poa Annua)*	10	30	10	20	4	100	70	16.99	17.0	0.17735	58.5	0.180
2008	July	3	D	Tall fescue (*Festuca arundinacea)*	50	20	80	40	4	100	190	46.12	46.1	0.48138	73.1	0.225
2008	July	3	W	Chicory *(Cichorium intybus)*	10	20	1	10	4	100	41	9.95	10.0	0.10388	55	0.169
2008	July	3	W	Aster (*Aster pilosus)*		10	10	10	3	75	30	7.28	5.5	0.05701	41.1	0.127
2008	July	3	D	Red Clover (*Trifolium pratense)*	20	10	1	10	4	100	41	9.95	10.0	0.10388	55	0.169
2008	July	3		Total:	110	100	102	100	4	550	412	100.00	95.8	0.9995	325	1.000
2008	July	4	D	Orchardgrass (*Dactylis glomerata)*	10	10	10	10	4	100	40	9.20	9.2	0.09629	54.6	0.162

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	July	4	D	Bluegrass (*Poa Annua)*	10	20	10	10	4	100	50	11.49	11.5	0.12036	55.7	0.165
2008	July	4	D	Tall fescue (*Festuca arundinacea)*	80	60	50	60	4	100	250	57.47	57.5	0.60179	78.7	0.233
2008	July	4	W	Chicory *(Cichorium intybus)*	1	10	20	20	4	100	51	11.72	11.7	0.12277	55.9	0.165
2008	July	4	W	Aster (*Aster pilosus)*	10		1	1	3	75	12	2.76	2.1	0.02166	38.9	0.115
2008	July	4	D	Red Clover (*Trifolium pratense)*		10	20		2	50	30	6.90	3.4	0.03611	28.4	0.084
2008	July	4	D	White Clover (*Trifolium repens*)			1		1	25	1	0.23	0.1	0.0006	12.6	0.037
2008	July	4	W	Wild Carrot (*Daucus carota)*			1		1	25	1	0.23	0.1	0.0006	12.6	0.037
2008	July	4		Total:	111	110	113	101	4	575	435	100.00	95.5	1.00018	338	0.999
2008	July	5	D	Orchardgrass (*Dactylis glomerata)*	20	10	10	10	4	100	50	12.17	12.2	0.14279	56.1	0.154
2008	July	5	D	Bluegrass (*Poa Annua)*	10	20	20	10	4	100	60	14.60	14.6	0.17134	57.3	0.158
2008	July	5	D	Tall fescue (*Festuca arundinacea)*	10	20	20	30	4	100	80	19.46	19.5	0.22846	59.7	0.165
2008	July	5	W	Chicory *(Cichorium intybus)*			20		1	25	20	4.87	1.2	0.01428	14.9	0.041
2008	July	5	W	Aster (*Aster pilosus)*	10	20		20	3	75	50	12.17	9.1	0.10709	43.6	0.120
2008	July	5	D	Red Clover (*Trifolium pratense)*	30	20	30	20	4	100	100	24.33	24.3	0.28557	62.2	0.171
2008	July	5	D	White Clover (*Trifolium repens*)	20				1	25	20	4.87	1.2	0.01428	14.9	0.041
2008	July	5	W	Wild Carrot (*Daucus carota)*	10				1	25	10	2.43	0.6	0.00714	13.7	0.038
2008	July	5	W	Wild Grape (*Vitis)*			1		1	25	1	0.24	0.1	0.00071	12.6	0.035
2008	July	5	B	Bareground Litter		10		10	2	50	20	4.87	2.4	0.02856	27.4	0.076
2008	July	5		Total:	110	100	101	100	4	625	411	100.00	85.2	1.00022	363	0.999

Shenandoah County Botanical Composition

Year	Sample Date	Trt	Desirable (D), Weedy (W), Bareground (B)	Species:	1	2	3	4	frequency	relative frequency(rf)	cumulative value(cv)	relative cv	Importance Value (IV)	relative IV	%IV	relative Importance value (RIV)
2008	Nov	1	D	Orchardgrass (*Dactylis glomerata)*	5	10			2	50	15	3.86	1.9	0.01973	26.9	0.120
2008	Nov	1	D	Bluegrass (*Poa Annua)*	30	20	20	40	4	100	110	28.28	28.3	0.28943	64.1	0.285
2008	Nov	1	D	Tall fescue (*Festuca arundinacea)*	60	60	80	60	4	100	260	66.84	66.8	0.68412	83.4	0.371
2008	Nov	1	D	White Clover (*Trifolium repens*)	1		1	1	3	75	3	0.77	0.6	0.00592	37.9	0.168
2008	Nov	1	B	Bareground Litter		1			1	25	1	0.26	0.1	0.00066	12.6	0.056
2008	Nov	1		Total:	96	91	101	101	4	350	389	100.00	97.7	0.99986	225	1.000
2008	Nov	2	D	Orchardgrass (*Dactylis glomerata)*	10	1	10		3	75	21	5.34	4.0	0.04077	40.2	0.189
2008	Nov	2	D	Bluegrass (*Poa Annua)*	30	20	30	10	4	100	90	22.90	22.9	0.23297	61.5	0.288
2008	Nov	2	D	Tall fescue (*Festuca arundinacea)*	50	80	60	90	4	100	280	71.25	71.2	0.72479	85.6	0.402
2008	Nov	2	D	White Clover (*Trifolium repens*)	1				1	25	1	0.25	0.1	0.00065	12.6	0.059
2008	Nov	2	W	Dandelion	1				1	25	1	0.25	0.1	0.00065	12.6	0.059
2008	Nov	2	B	Bareground Litter					0	0	0	0.00	0.0	0	0	0.000
2008	Nov	2		Total:	92	101	100	100	4	325	393	100.00	98.3	0.99982	213	0.998
2008	Nov	3	D	Orchardgrass (*Dactylis glomerata)*	10	10	10	1	4	100	31	8.07	8.1	0.08453	54	0.216
2008	Nov	3	D	Bluegrass (*Poa Annua)*	20	50	20	50	4	100	140	36.46	36.5	0.38176	68.2	0.273
2008	Nov	3	D	Tall fescue (*Festuca arundinacea)*	70	20	60	40	4	100	190	49.48	49.5	0.51811	74.7	0.299
2008	Nov	3	D	Red Clover (*Trifolium pratense)*			1		1	25	1	0.26	0.1	0.00068	12.6	0.051
2008	Nov	3	D	White Clover (*Trifolium repens*)			1		1	25	1	0.26	0.1	0.00068	12.6	0.051
2008	Nov	3	W	Oxalis (*Oxalis stricta)*			1		1	25	1	0.26	0.1	0.00068	12.6	0.051
2008	Nov	3	B	Bareground Litter		20			1	25	20	5.21	1.3	0.01363	15.1	0.060
2008	Nov	3		Total:	100	100	93	91	4	400	384	100.00	95.5	1.00008	250	1.000
2008	Nov	4	D	Orchardgrass (*Dactylis glomerata)*	10	1	1		3	75	12	3.05	2.3	0.0247	39	0.142
2008	Nov	4	D	Bluegrass (*Poa Annua)*	40	30	60	30	4	100	160	40.71	40.7	0.43919	70.4	0.256
2008	Nov	4	D	Tall fescue (*Festuca arundinacea)*	40	40	20	60	4	100	160	40.71	40.7	0.43919	70.4	0.256
2008	Nov	4	W	Cinquefoil (*Potentilla simplex)*	5				1	25	5	1.27	0.3	0.00343	13.1	0.048
2008	Nov	4	D	White Clover (*Trifolium repens*)	5	10		10	3	75	25	6.36	4.8	0.05147	40.7	0.148
2008	Nov	4	W	Dandelion				1	1	25	1	0.25	0.1	0.00069	12.6	0.046
2008	Nov	4	B	Bareground Litter		10	20		2	50	30	7.63	3.8	0.04117	28.8	0.105
2008	Nov	4		Total:	100	91	101	101	4	450	393	100.00	92.7	0.99983	275	1.000

Shenandoah County Botanical Composition

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2008	Nov	5	D	Orchardgrass (*Dactylis glomerata)*	10	10	10		3	75	30	7.65	5.7	0.06192	41.3	0.127
2008	Nov	5	D	Bluegrass (*Poa Annua)*	30	40	40	40	4	100	150	38.27	38.3	0.41279	69.1	0.213
2008	Nov	5	D	Tall fescue (*Festuca arundinacea)*	30	30	20	40	4	100	120	30.61	30.6	0.33023	65.3	0.201
2008	Nov	5	W	Cinquefoil (*Potentilla simplex)*	1				1	25	1	0.26	0.1	0.00069	12.6	0.039
2008	Nov	5	D	Red Clover (*Trifolium pratense)*	10				1	25	10	2.55	0.6	0.00688	13.8	0.042
2008	Nov	5	D	White Clover (*Trifolium repens*)	10	10	10	10	4	100	40	10.20	10.2	0.11008	55.1	0.170
2008	Nov	5	W	Dandelion	1		10		2	50	11	2.81	1.4	0.01514	26.4	0.081
2008	Nov	5	B	Bareground Litter		10	10	10	3	75	30	7.65	5.7	0.06192	41.3	0.127
2008	Nov	5		Total:	92	100	100	100	4	550	392	100.00	92.7	0.99963	325	1.000