PHOSPHORUS PARTITIONING AMONG PLANT PARTS OF FORAGES FERTILIZED WITH POULTRY LITTER OR SWINE EFFLUENT

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INTRODUCTION

Poultry litter and swine effluent are often used as fertilizers on forages grown in the southeastern U.S. Application rates of animal waste on forages usually are based on the nitrogen requirement of the plants. However, poultry litter or swine effluent applied to meet the plant's nitrogen requirement contain more phosphorus than is required by the plant and P buildup in the soil will occur (Kingery et al. 1993; Sharpley, Gburck, and Heathwaite 1998; Smith et al. 1998). This excess P may be lost via surface runoff, erosion, or leaching (Smith et al. 1998). Harvesting of forages as hay is one management technique that will help remove excess P from poultry litter- or swine effluent-fertilized soils.

Proper management of forages is essential to maximize P uptake from hayfields fertilized with poultry litter or swine effluent. Traditionally, producers have managed hay fields for maximum yields of high-quality forage (Albrecht and Hall 1995). To achieve high quality forage, plants are often harvested prior to full maturity when leaves comprise a greater proportion of the hay. Higher yields can be obtained by letting the plants reach full maturity, however forage quality decreases (Ball, Hoveland, and Lacefield 1991). To maximize P uptake and removal via hay, plants should be harvested at full maturity. Nutrient uptake is based on both the concentration of nutrient within the forage and the total dry matter yield of that forage. When nutrient uptake becomes the main goal of a hay production system, forage quality is of less importance than maximizing dry matter yield.

Producers affect nutrient uptake by altering management techniques such as animal waste application rates, application time, or plant maturity at harvest. To select the proper management techniques, producers must first know where within the plant P is located. Then forages can be managed to optimize growth and yield of that particular plant part. In this paper, results are presented from three studies showing phosphorus distribution within plant parts of annual and perennial legumes, annual grasses, and bermudagrass.

MATERIALS AND METHODS

Legumes and Grasses under Poultry Litter

Four grasses, three perennial legumes, and 10 annual legumes were grown under poultry litter fertilization at Collins, MS. The grasses were annual ryegrass (*Lolium multiflorum* Lam.), oat (*Avena sativa* L.), rye (*Secale cereale* L.), and wheat (*Triticum aestivum* L. emend. Thell.). The perennial legumes were alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), and white clover (*T. repens* L.). The annual legumes were arrowleaf clover (*T. vesiculosum* Savi), ball clover (*T. nigrescens* Viv.), berseem clover (*T. alexandrinum* L.), crimson clover (*T. incarnatum* L.), persian clover (*T. resupinatum* L.), rose clover (*T. hirtum* All.), subterranean clover (*T. subterraneum* L.), austrian winter pea [*Pisum sativum* var. *arvense* (L.) Poir.], caley pea (*Lathyrus hirsutus* L.), and hairy vetch (*Vicia villosa* Roth). All species were treated as winter annuals. Seed of the grasses and legumes was broadcast-seeded at conventional rates in 2 x 4 m plots in September 1996 and 1997. The study was conducted on a pasture with a history of annual poultry litter applications at Collins, MS, on a Savannah fine sandy loam (fine-loamy, siliceous, semiactive, thermic Typic Fragludult). Poultry litter was applied prior to seeding at 9 Mg ha^{-1} containing 34 g N and 18 g P kg^{-1} litter.

The experimental design was a randomized complete block with four replicates. Plants were dug from a 0.5 x 0.5 m quadrat randomly placed with each plot. Each species was harvested once at full maturity which was defined as full bloom for legumes and soft dough stage for grasses. Samples were hand-separated into roots, stems, leaves, and flowers.

Legumes under Swine Effluent

The same 13 legumes (four perennial and nine annual) listed previously were grown under swine effluent fertilization at Crawford, MS. Seed of the legumes was broadcast-seeded at conventional rates in 2 x 4 m plots in September 1997 and 1998. The study was conducted on a Brooksville silty clay loam (fine, smectitic, thermic Aquic Hapludert). Swine effluent was applied by a center pivot irrigation system from May to October at a rate of 10 cm yr^{-1} containing 400 kg N ha^{-1} and 75 kg P ha^{-1}. Experimental design and sampling procedures were identical to those listed previously.

Bermudagrass under Swine Effluent

Common, Coastal, and Tifton85 bermudagrass were established in July 1996 under swine effluent fertilization at Crawford, MS. A total of 72 plants/plot were planted in 2 x 6 m plots in a randomized complete block design with four replicates. The study was conducted on a Brooksville silty clay loam. Swine effluent was applied by a center pivot irrigation system at rates noted previously.

Plants were dug from a 0.33 x 0.33 m quadrat randomly placed within each plot. The plots were sampled two times in 1997 and three times in 1998. Plants were hand-separated into roots, upright stems, leaves, and runners.

Phosphorus Determinations

All plant parts were dried at 65°C for 48 hr, weighed, and ground to pass through a 1-mm screen. Phosphorus concentration was measured by an inductively-coupled argon plasma emission spectrophotometer (Brink et al. 2000). Phosphorus uptake was determined by the product of P concentration and dry matter. All results presented in this paper were means for both years of each study.

RESULTS AND DISCUSSION

The majority of P (58-62%) in legumes and annual grasses was located within plant stems due to the large amount of dry matter located in forage stems. In upright species, such as annual ryegrass and red clover, most of the stem dry matter is harvested during hay production and P can be exported from the farm. In prostrate species, such as subterranean and white clover, the stems are prostrate stolons or runners and cannot be harvested for hay to aid in P removal from the farm. Under poultry litter fertilization, legume stem P concentration (3.0 g P kg^{-1}) was slightly higher than that of annual grasses (2.5 g P kg^{-1}). Subterranean clover stems (runners) had the greatest P concentration (6.5 g P kg^{-1}). However, due to their greater stem dry weight, annual grass stems contained more P (1.34 g P m^{-2}) on the average than legume stems (0.62 g P m^{-2}). Phosphorus content of annual grass stems ranged from 1.07 g P m^{-2} for wheat to 1.62 g P m^{-2} for oat. In legumes, stem P contents ranged from a low of 0.22 g P m^{-2} for persian clover under poultry litter fertilization to a high of 1.49 g P m^{-2} for subterranean clover under swine effluent fertilization.

Leaves contain 20-24% of the P in annual grasses, legumes, and bermudagrass. Greatest P amounts in leaves were observed in subterranean clover (0.64 g P m^{-2}) and oat (0.55 g P m^{-2}) fertilized with poultry litter and in white clover (0.66 g P m^{-2}) fertilized with swine effluent. Phosphorus uptake in leaves of bermudagrass cultivars averaged 0.44 g P m^{-2} per harvest. No differences were noted between cultivars for P content of leaves.

Little difference was noted for P distribution in plant parts between legumes grown under swine effluent or poultry litter fertilization. Average distribution of P in 13 legumes under swine effluent was 1.00 g P m^{-2} in stems, 0.37 g P m^{-2} in leaves, 0.25 g P m^{-2} in flowers, and 0.12 g P m^{-2} in roots. Under poultry litter, P distribution of 13 legumes averaged 0.62 g P m^{-2} in stems, 0.30 g P m^{-2} in leaves, 0.10 g P m^{-2} in flowers, and 0.10 g P m^{-2} in roots. Roots contain relatively little P with only red clover under poultry litter (0.32 g P m^{-2}) and alfalfa under swine effluent (0.41 g P m^{-2}) containing appreciable P amounts. Flowers have relatively little dry weight, so even though P concentration can be quite high (i.e., 7.6 g P kg^{-1} for hairy vetch flowers), P content of flowers was quite low.

Bermudagrass contains most P in prostrate runners (55%) and upright stems (16%). Common bermudagrass averaged more P in runners (1.49 g P m^{-2}) than Coastal (1.03 g P m^{-2}) and more P in upright stems (0.45 g P m^{-2}) than Tifton85 (0.31 g P m^{-2}). Bermudagrass runners are rarely harvested for hay since they remain prostrate along the soil surface. Desiccation of these runners during winter will release P back to the soil where surface runoff or erosion of P may occur.

CONCLUSIONS

Distribution of phosphorus in legume, annual grass, and bermudagrass plant parts influences forage management for P removal. To maximize P content in hay that can be removed from the farm, plants with upright stems (i.e., annual ryegrass, red clover) should be managed to maximize stem production. Plants with prostrate stems (i.e., bermudagrass, white clover) should be managed to minimize runner or stolon production.

REFERENCES

Albrecht, K. A., and M. H. Hall. 1995. Hay and silage management. Chap. in Forages: An introduction to grassland agriculture. 5th ed. vol. 1. Ames, IA: Iowa State University Press.

Ball, D. M., C. S. Hoveland, and G. E. Lacefield. 1991. Southern Forages. Norcross, GA: Potash and Phosphate Institute.

Brink, G. E., G. A. Pederson, T. E. Fairbrother, and R. G. Pratt. 2000. Phosphorus, copper, and zinc uptake by temperate grasses and legumes. Crop Science (in press).

Kingery, W. L., C. W. Wood, D. P. Delaney, J. C. Williams, G. L. Mullins, and E. van Santen. 1993. Implications of long-term land application of poultry litter on tall fescue pastures. Journal of Production Agriculture 6: 390-395.

Sharpley, A. W. Gburck, and L. Heathwaite. 1998. Agricultural phosphorus and water quality: Sources, transport and management. Agricultural and Food Science in Finland 7: 297-314.

Smith, K. A., A. G. Chalmers, B. J. Chambers, and P. Christie. 1998. Organic manure phosphorus accumulation, mobility and management. Soil Use and Management 14: 154-159.