ORCHARD GROUNDCOVER MANAGEMENT: LONG-TERM IMPACTS ON FRUIT TREES, SOIL FERTILITY, AND WATER QUALITY

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Summary

Nitrogen (N) fertilizers can increase tree fruit yields, but if applied in excess they also may contaminate water resources. We are studying the availability, uptake, recycling and losses of N in a New York apple orchard, using a naturally occurring non-radioactive nitrogen isotope (^{15}N) to trace N dynamics year-round under different soil and groundcover management systems (GMSs). Our goal is to identify factors that sustain tree growth and yield, maximizing N uptake and minimizing N losses. We have amassed three years of continuous data at the test orchard, and are just beginning the comprehensive data analysis. Some preliminary conclusions are that hardwood bark mulch and mowed turfgrass reduced N losses and improved soil quality substantially. Early summer was the critical time for N uptake by trees, and N leaching was relatively low (less than 5 ppm nitrate-N) in all GMSs. Post-emergence glyphosate application in May and July annually, that permitted substantial weed regrowth and soil groundcover from August to May each year, was the best GMS from the fruit yield perspective, followed closely by the mulch treatment. Year-round weed-free tree rows maintained by residual herbicides treatment—the industry standard in much of North America—ranked second to last in terms of fruit yield and tree growth after 10 years of observations. Bark mulch increased soil organic matter, supported excellent fruit yields, and did not result in leaching losses of N despite the nitrogen and organic matter additions it provides to soil.

Research Objectives

1. Determine the effects of different groundcover management systems (mowed turfgrass, hardwood bark mulch, and pre- and post-emergence herbicides) on apple tree growth and productivity, and nitrogen release, uptake, retention and recycling in a northeastern apple orchard.

2. Integrate and synchronize groundcover vegetation management in relation to critical periods of fruit-tree N demand and leaching losses, managing the groundcovers to prevent erosion and retain excess N during periods of low crop demand, so as to minimize N losses from orchards.

Methods and Approach

Many orchards are located on well-drained upland sites near rivers and lakes where nitrate and phosphate contamination of surface and groundwater is a potential problem. Nitrogen (N) pollution of water resources can affect ecosystems and human health, but it can be reduced by increasing the efficiency of nutrient, crop and soil management. We are studying the impacts of alternative groundcover management systems (GMSs) on the nutrient status of apple trees, and the mineralization, uptake, retention and losses of N in an orchard agroecosystem. Four GMSs have been maintained continuously since 1992 in the tree-rows of a commercial orchard near Cayuga Lake in upstate New York: 1) A mowed red fescue turfgrass (MwSod); 2) a hardwood bark-chip mulch (ChpMulch); 3) a conventional pre-emergence residual herbicides treatment (PreHrb) that keeps soil weed-free all year; and 4) May and July post-emergence herbicide treatments (PostHrb) that permit weed re-growth and sparse soil cover from August to May.

We are using ^{15}N enriched stable isotopic fertilizer to trace the movement of N throughout the test orchard. A small amount (0.5 g of 99% enriched $K^{15}NO_3$) of fertilizer was applied on May 10, 1999 beneath the drip-lines of 24 trees (2 trees per GMS replicate plot). In subsequent years, we used different trees for all treatments, and added a split application treatment, applying 0.5 g of 99% enriched $K^{15}NO_3$ to 24 trees (two trees per GMS plot) on May 3, 2000, and 0.17 g in three split application to another 24 trees in mid May, July and September. We are collecting biweekly samples of root-zone soil, drainage and suction lysimeter ground water, shoots, leaves and fruit from trees, and groundcover vegetation from each plot during each growing season, and analyzing their total N content, atom-percent ^{15}N proportion, and total carbon by mass spectroscopy. The ^{15}N tracer enables us to determine the uptake efficiency and biological pathways of N under each GMS, and since the quantity of N is relatively small compared to typical N fertilizer programs in orchards, our observations reflect the intrinsic efficiency and dynamics of N cycling and uptake in fruit trees adapted to low N supply. All other orchard studies involving N isotope tracers have applied large quantities of N to trees that had regularly received such fertilizer applications. Our data will thus provide some very different information about orchard N dynamics under low-input conditions typical of many orchards on high fertility soils in the cool humid climate of the Northeast. Collectively, these data represent the most comprehensive information to date on the year-round dynamics of N in a representative commercial orchard under different soil management systems.

Results to Date

We collected more than 10,000 tree, soil, water and fruit samples during the three years of this study, and have almost completed sample processing and analysis at the time of this report. Fruit yields per tree have been affected significantly by the GMSs, ranking PostHrb = ChpMulch > PreHrb > MwSod, and ranging from 55 to 110 kg per tree from 1999-2001 (Figure 1). Nitrogen has been a significant factor in these effects, with substantial differences in soil, leaf, shoot and groundwater N each year. Soil N and carbon content were greatest in the mulch treatment, averaging twofold greater than in the other GMSs (Figure 2). Leaf N content and fertilizer ^{15}N uptake efficiency of trees have been consistently lowest in Mowed Sod plots, and usually higher in the two herbicide treatments. Tree uptake of soil N was very rapid during the early summer (May and June), and then declined steadily during the rest of the growing season. Unlike previous studies of N-saturated trees, the uptake of soil-applied N was almost instantaneous, and it accumulated within days in flowering spurs and leaflets of these low-N adapted trees. Leaf N was remobilized into shoot tissues during Oct. and Nov. each year, then moved rapidly into other storage tissues after leaf drop (late November and early December), and then increased greatly in the shoots during early March the following year. Similar trends have been observed for fruit N content.

The N content and atom-percent ^{15}N (representing the uptake efficiency of applied N) in grass and herbaceous weed groundcover vegetation has differed strikingly from that in our fruit trees. The N content of grass and weeds averaged two to three times greater than in fruit tree tissues, and the efficiency of fertilizer ^{15}N uptake has been similarly greater in groundcovers than in trees. These observations demonstrate the weak competitive ability of fruit trees relative to groundcovers for soil N supply, and the potential for taking advantage of retention and recycling of N by orchard groundcovers, to reduce off-site N losses. The challenge is to minimize groundcover competition for N during the vitally important early summer months, and then utilize their high affinity for N to keep N in the orchard during the rest of the year.

Losses of N in surface runoff and subsurface leachate from the drainage sampling system have been greater in the PostHrb and PreHrb than in the other GMSs, but relatively low in all the treatments (Figures 3 and 4). Averaged by season, concentrations of nitrate-N in drainage from this orchard typically ranged from undetectable (< 0.1 ppm) to 5 ppm throughout the year. Surprisingly, nitrate-N losses during the irrigation season (May to October) were actually somewhat greater than during the dormant season. Recent growing seasons have been variable—unusually hot and dry during 1999, wet and cool during 2000, and intermittently dry during 2001. Our data therefore cover the range of expected growing conditions in central New York, and suggest that nitrate leaching from orchards with sod drive-lanes receiving low inputs of N fertilizers may be minimal, considerably less than reported for other crops such as corn or potatoes, and comparable to undisturbed forest reservoir watersheds.

The soil at our site is a silty-clay loam averaging 4.5% organic matter content, and mineralizes about 80 kg N per year without any fertilizer additions. This amount of soil N is probably sufficient to meet the needs of mature bearing trees. The ^{15}N fertilizer applied to trees growing in turfgrass plots was almost entirely captured by grass instead of trees during early and mid-summer, while in the bare soil of residual pre-emergence herbicide plots, much of the ^{15}N tracer appeared in leaves of the fruit trees. Leaf N content of trees in all GMSs was adequate, so we considered the elevated tree N uptake in herbicide plots as superfluous and not essential for optimal fruit quality and yields. However, the best cumulative fruit yields were in the post-emergence herbicide and mulch treatments, and the lowest were in grass plots.

Soil temperature and moisture fluctuated substantially among the GMSs during 1999, which was an abnormally hot and dry year in upstate N.Y. Generally, root-zone temperatures were 2 to 4 degrees C warmer under the two herbicide systems compared with grass and mulch plots, and then cooled more rapidly beneath the herbicide treatments in late Fall. During drought conditions, we irrigated the orchard regularly with micro-sprinklers covering the entire treated tree-row area. Despite this irrigation, there were marked differences in soil water content among GMSs. Soil under the grass was usually drier, and under the mulch it was often wetter during early and mid summer, while soil in herbicide plots was usually more saturated later in the growing season and early this winter. These observations may have important implications for nutrient availability and drainage or runoff losses from the orchard.

The final phase of this project will involve integration of practices such as N fertilizer form or timing, and deferring or modifying weed suppression and other GMS treatments during critical periods when fruit tree uptake is not sufficient to retain N within this orchard. We will also develop nutrient budgets for each GMS system, quantifying the amounts and movements of N in each major component of the tree/crop/groundcover/soil/water system. This will enable growers in comparable orchards to adjust their fertilizer programs so that only the amount actually lost from the orchard each year is added in fertilizer form—a strategy that should reduce or eliminate leaching of N from the agro-ecosystem. Results of this study will be made available to growers, students, extension staff and crop consultants, and disseminated in commercial fruit production recommendations and extension bulletins. We hope this project will help sustain fruit growing and conserve our vital soil and water resources in the Northeast.

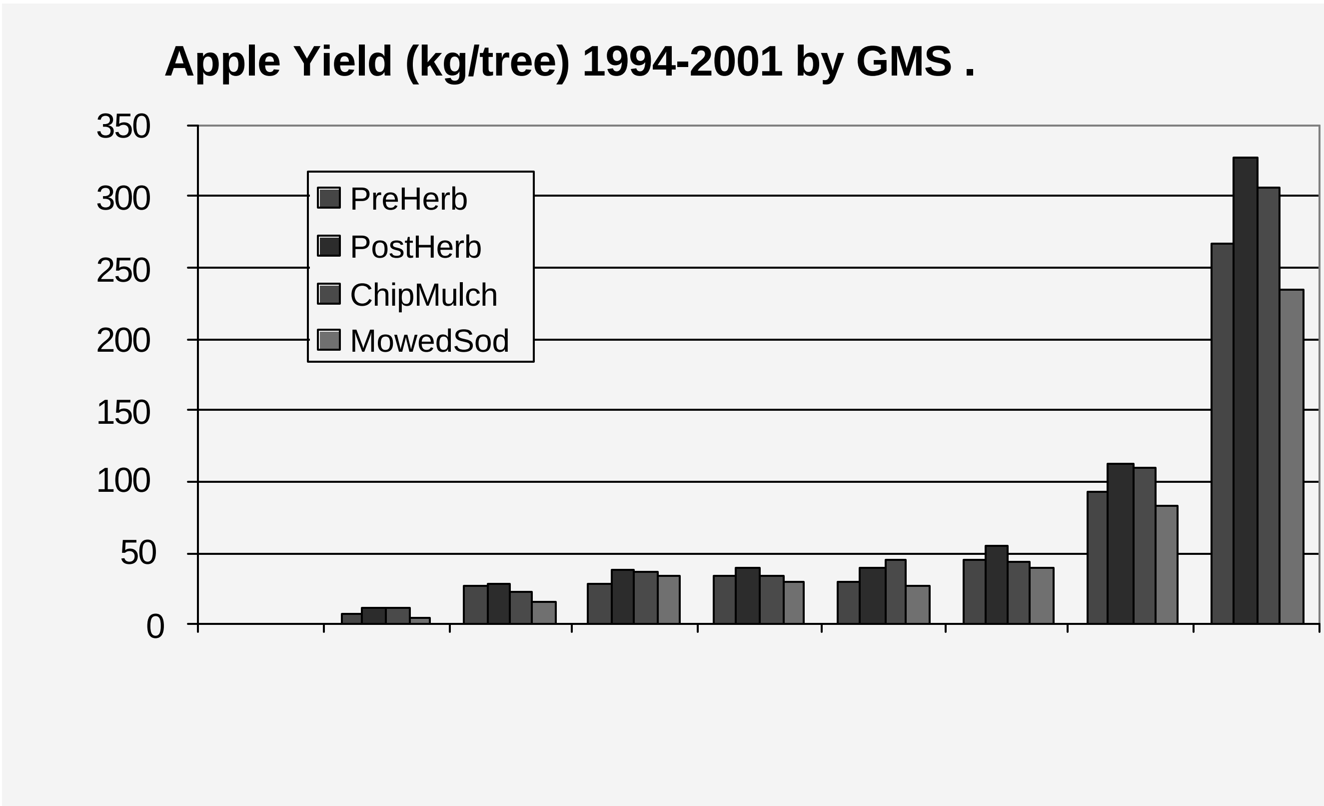

Figure 1. Yearly and cumulative fruit yields in a New York apple orchard during eight years under four different groundcover management systems.

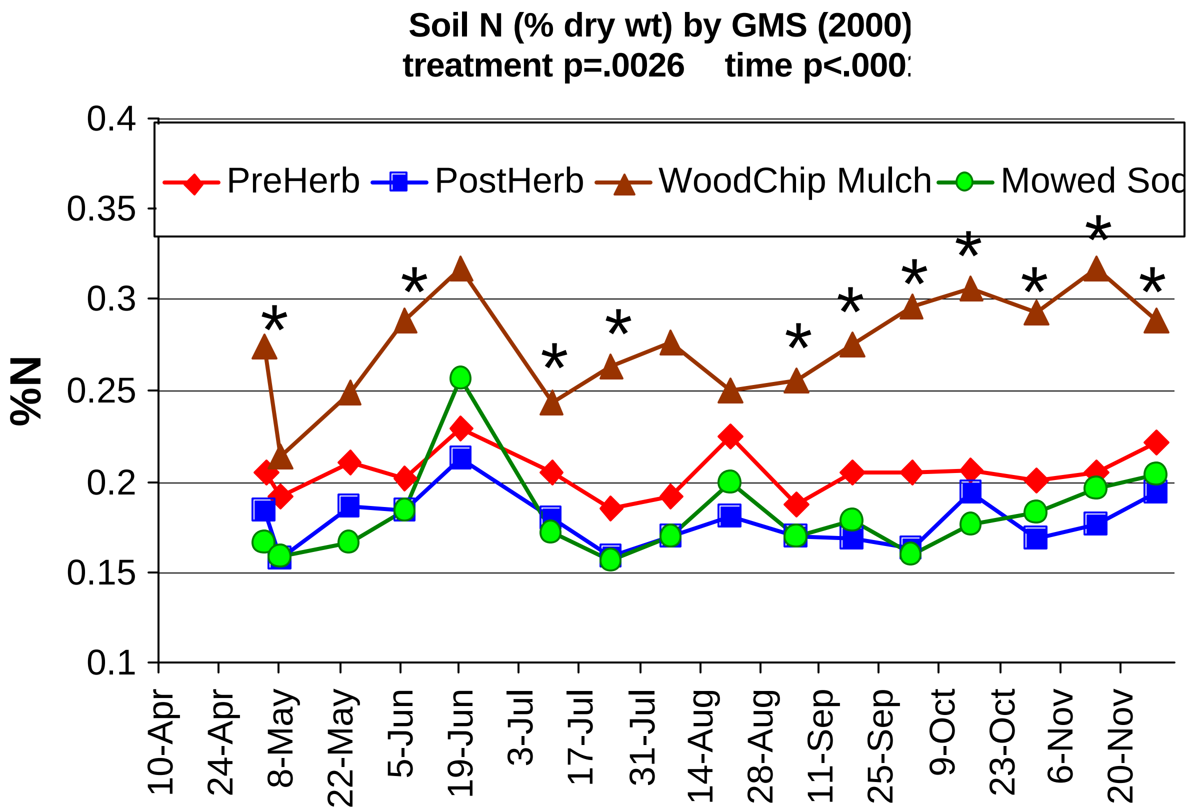

Figure 2. Soil nitrogen content (percent dry weight basis) during the growing season of 2000, after ten years of four different groundcover management systems in a New York orchard.

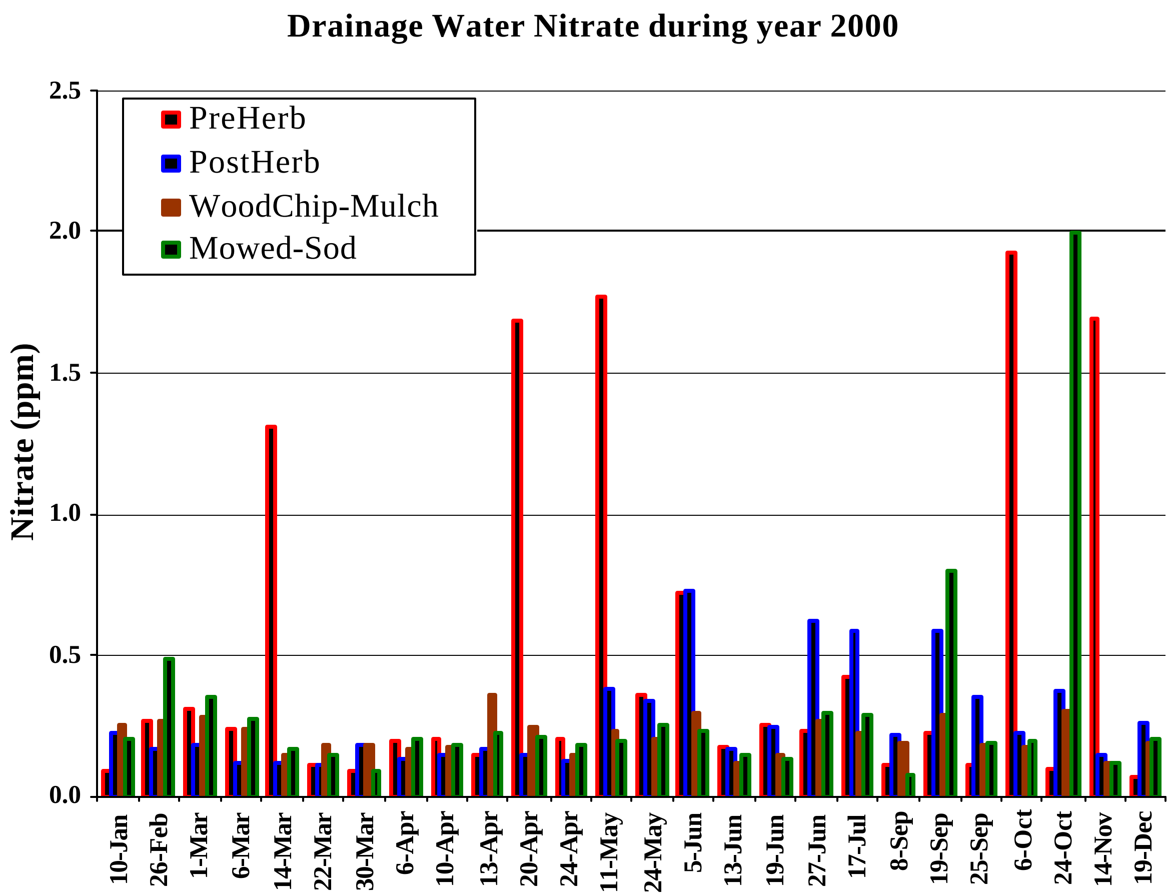

Figure 3. Nitrate-N leachate concentrations averaged by month, in drainage tiles under four different groundcover management systems in a New York orchard during the year 2000

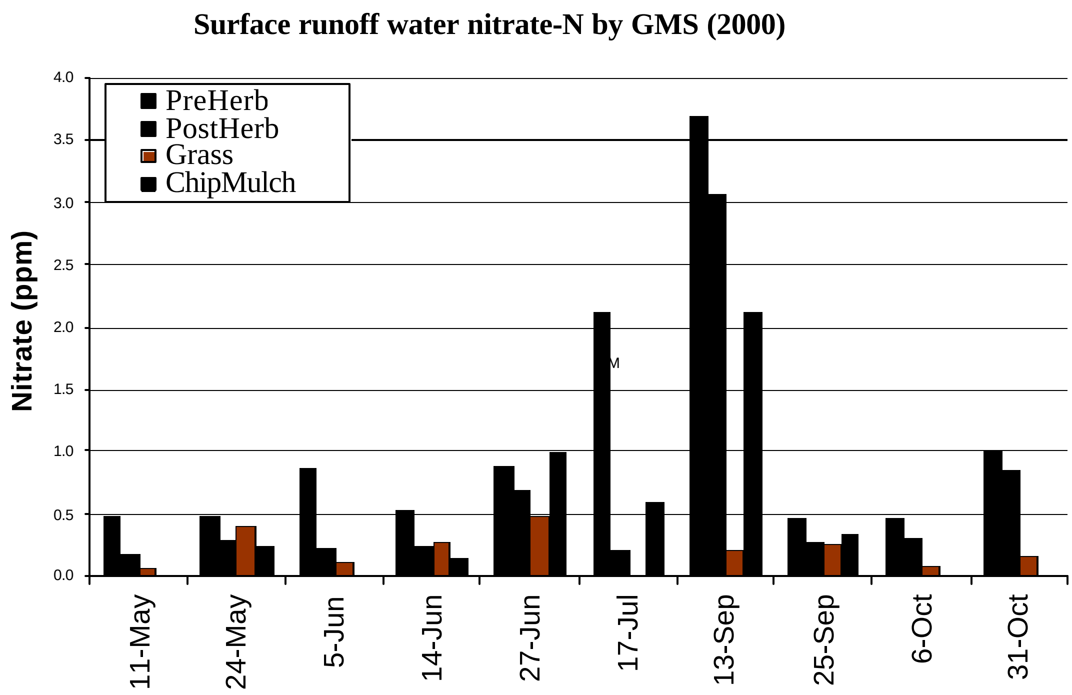

Figure 4. Nitrate-N concentrations in surface runoff water from four different groundcover management systems in a New York orchard during the growing season of 2000.