Understanding Autotoxicity in Alfalfa

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Alfalfa can remain productive in stands from four to ten years or more, but as plant population declines renovation eventually becomes necessary. Alfalfa is commonly grown in rotation with grain crops, however continuous production is desirable in many areas, particularly on soils that are marginal for economic grain production. Reseeding alfalfa immediately following alfalfa is not recommended in most states due to the negative effects of autotoxicity, seedling disease and insect pests which can build up in old stands. A rotation interval is commonly recommended between killing an old stand of alfalfa and reseeding new alfalfa to help insure successful establishment.

There is general agreement that autotoxicity does exist in old alfalfa fields and can cause poor establishment of new alfalfa seedlings, however the rotation interval recommended for successful establishment varies widely among states. In a 1996 survey of agronomists and forage specialists in 40 states, autotoxicity was ranked as the second most important problem for seeding alfalfa after alfalfa, when compared to soil-borne disease, soil-borne insects, soil-moisture depletion by the old stand, and other factors. Soil-borne disease was ranked as the most important problem.

The same survey respondents also reported the minimum rotation interval recommended for their area. Recommended intervals of six or twelve months were most frequently reported, but the range was two weeks to 24 months. Many respondents commented that their most common recommendation was to reseed alfalfa after rotation with a non-legume crop grown for one or more seasons.

The reasons why rotation intervals should be so different from one area to another are not completely known. An assessment of research may help explain the variation in reseeding recommendations from state to state.

Characteristics of Autotoxicity

Autotoxicity in alfalfa is described as a process in which established alfalfa plants produce a chemical or chemicals that escape into the soil and reduce establishment and growth of new alfalfa if seeded too soon following the old stand. The autotoxic nature of alfalfa has been hypothesized to be a result of environmental selection. Perennial alfalfa originated around the northern coast of the Mediterranean. During part of the time when perennial alfalfas were evolving, the Mediterranean basin was a hot, dry desert before the final opening of Gibraltar (Quiros and Bauchan, 1988). Development of the autotoxic trait may have reduced competition from nearby new seedlings for scarce soil moisture.

The chemical or chemicals responsible for autotoxic effects has not been conclusively identified although several have been implicated. The most conclusive evidence to date suggests that the chemical medicarpin may be a primary cause, but some of the characteristics observed for autotoxicity have not been reported for medicarpin (Dornbos et al., 1990).

The characteristics of alfalfa autotoxicity have been generally consistent among research studies. A summary of the characteristics of the autotoxic chemical and it=s effects are: 1) it is extractable from fresh alfalfa herbage and is not a product of microbial action (Hall and Henderlong, 1989), 2) it is water-soluble (Read and Jensen, 1989), 3) it is more concentrated in alfalfa herbage than in roots (Miller, 1996), 4) it delays germination (Dornbos et al., 1990), 5) it causes inhibition of alfalfa root growth, swelling, curling, and discoloration of the root, and lack of root hairs (Read and Jensen, 1989; Hegde and Miller, 1992), and 6) it reduces alfalfa root growth more than it reduces seed germination (Read and Jensen, 1989).

Considering the first three characteristics together, management strategies that eliminate existing alfalfa plants and residue can improve establishment of new alfalfa. The time required for breakdown of alfalfa residue in soil and subsequent removal of the autotoxic chemical from the root zone may vary with environmental conditions. The length of time needed for this to occur could partially explain the variation in recommended intervals for reseeding alfalfa.

An underlying belief about autotoxicity is that it primarily causes stand failure when alfalfa is planted too soon after old alfalfa. Often, autotoxicity is not considered to be a problem if the new alfalfa stand becomes well established. Yield reductions or poor persistence are attributed to other factors. Considering the last three characteristics together with observations from recent research suggests that the negative effects of autotoxicity may linger, causing unnoticed long-term reductions in plant stands and yield.

A Look at Research Results

Soil Effects

The role that soil texture plays in the dissipation of the autotoxic chemical has only recently been studied. In our research, extracts made from alfalfa top growth containing the autotoxic chemical passed more rapidly through leaching columns of sandy soil than through columns containing silty clay loam (Jennings and Nelson, 1998). Fractions of the leachate that passed through the columns were collected and added to petri dishes containing alfalfa seeds. Percent germination and root growth were measured after three days. Approximately fifty percent more water was required to move the extracts through the silty clay loam compared to the sandy soil. The autotoxic effect on root growth was stronger (reduced root growth more) in the sandy soil, but persisted longer for the silty clay loam.

This suggests that in the short term autotoxicity may be more severe in sandy soils, however, with irrigation the autotoxic factor may be leached out of the root zone more easily in sandy soils than in soils of heavier texture. This practice has been used successfully in Kansas and Nebraska where sandy fields are irrigated heavily after killing the old alfalfa, but before planting the new stand (J. Schafer, 1991, personal communication; B.A. Anderson, 1995, personal communication). Further research is needed to determine the amount of rainfall or irrigation needed for different soil textures to allow shortened rotation intervals.

Field Research

Work in Michigan showed that alfalfa could be successfully established after alfalfa by killing the old stand with herbicide and planting after a two or three-week interval (Mueller-Warrant and Koch, 1981; Tesar, 1993). Autotoxic effects were observed in both studies if alfalfa was seeded less than two weeks after killing the old stand.

By contrast research in Illinois and Wisconsin showed that a one year rotation with corn gave the best stands and yields of alfalfa following alfalfa compared to reseeding after shorter intervals (Klein and Miller, 1980; Cosgrove, unpublished, 1995).

In the Wisconsin study, it was observed that when the old alfalfa stand was plowed in the fall and reseeded the following spring, plant density of the new stand was acceptable, but dry matter yield was poor compared to alfalfa planted after a rotation with corn.

In Missouri, we reseeded alfalfa after old alfalfa using rotation intervals of 2 weeks, 3 weeks, 6 months, 12 months, and 18 months (Jennings and Nelson, 1995). The old alfalfa was killed with herbicides in sequence so that all treatments could be planted the same day. Each treatment was maintained as fallow during the rotation interval. The new alfalfa was no-till planted in the spring. This experiment was conducted at three locations and plots at each location were monitored for plant density and yield for three years.

Plant stands and dry matter yields were greatest for the 12- and 18-month rotations. Plant density of the 2-week and 3-week rotations were 13-20% lower compared to the 18-month treatment and yields were up to 8% lower. A yield reduction of 8% over the life of an alfalfa stand can be quite significant. The 6-month treatment had stands near equal to the 12-and 18-month treatments, but had low yield, like the results of the Wisconsin study. Plants dug from the 2- and 3-week rotation plots had extensively branched roots with little taproot development. Plants from the 12- and 18-month plots had prominent taproots typical of normal alfalfa plants. Exposure to the autotoxic chemical may have inhibited taproot growth, but plants survived by producing branch roots.

An interesting observation was that the rotation intervals became ranked for plant density and yield during the seeding year, but never grew out of the effect. The longest rotations had the greatest plant stand and the shortest rotations had the lowest plant stand. Plant density declined in all the rotation treatments at the same basic rate, however the ranking remained the same for three years. The difference between treatments was subtle, but could be visually observed compared to the 18-month control. Stands affected by autotoxicity appeared to have slower regrowth after each cutting. Even the poorest stands in the study would have been considered acceptable when viewed alone. This underscores the observation that, without a control for comparison, autotoxicity can cause modest reductions in stand or yield that may not be noticeable in a production field.

Recommendations in Missouri suggest that alfalfa production becomes uneconomical when stands drop below three plants per square foot. Stands affected by autotoxicity could be expected to drop below this critical plant density level sooner, thus reducing profitability.

Thickening old alfalfa stands

The ideal management strategy for continuous alfalfa would be to thicken declining stands by drilling more seed. Thickening old stands is not recommended because attempts usually result in failure. In two Missouri studies, severe alfalfa seedling losses were observed when alfalfa was interseeded into declining alfalfa stands, however good stands were established when alfalfa was seeded after a 1-yr rotation with sorghum-sudan (*Sorghum bicolor* L.) (Jennings and Nelson, 1991). New seedlings came up between the old alfalfa plants, but either died soon or never reached sufficient size to contribute to yield.

Recommendations reported in the popular press from southwestern Kansas (Kessler, 1994) suggested that thin areas in old alfalfa stands can be successfully thickened with new alfalfa without autotoxicity by applying high rates of seed-treatment fungicides. Frequent irrigation of the new alfalfa on sandy soils may have contributed more to the successful interseeding than did the fungicide, since later research studies in Kansas and in Iowa failed to support this recommendation.

Kansas researchers found that Apron7 seed treatment applied at rates up to double the recommended level did not improve emergence or establishment of alfalfa seeded into old stands (Shroyer et al., 1994). In Iowa, fungicides applied to soil or seed at different rates and combinations had no effect on alfalfa seedling survival when planted after alfalfa or orchardgrass (*Dactylis glomerata* L.) (Hurd et al., 1994). Seedling mortality was higher after old alfalfa, even with fungicide treatment, than it was after orchardgrass, and this was attributed to autotoxicity These studies indicate that seedling disease may not be the primary cause of stand failure when attempting to thicken old alfalfa stands. In previous research, we observed that old alfalfa plants appear to develop a zone of influence around them in which establishment and growth of new seedlings are inhibited. If the effect and size of this autotoxic zone could be determined, then thickening old stands might be possible when old plant density declines below a critical level.

We conducted experiments to determine the size of the autotoxic zone of influence around an old alfalfa plant. Old plants were selected in production fields and all other surrounding plants were killed with herbicide one year before new alfalfa was planted. Alfalfa was planted in the spring in spoke-like rows extending from the base of the old plant crown out to one meter away. Both plant survival and dry matter yield of the new alfalfa were measured, with proximity to the old plant, for two years after planting to determine the zone of influence.

Density and yield of alfalfa was strongly inhibited within an 8-inch (20-cm) radius of the old alfalfa plant (Jennings and Nelson, 1994).

A zone of this size would mean that the old stand would have to have a plant density of less than 0.8 plants per square foot before new plants could establish between the zones successfully. New seedlings emerging within the autotoxic zone of the old plant still would not likely contribute to yield. Such a thin stand would be approximately four times thinner than the minimum level of three plants per square foot suggested for economic alfalfa production. In practical terms, these results indicate that attempts at thickening a declining stand of alfalfa that has near the minimum stand for hay production are not likely to be successful.

Summary

Variable responses to autotoxicity have been observed in alfalfa planted after alfalfa. Many times, the primary response considered is whether a stand is established. Autotoxicity primarily affects seed germination and early root growth with root growth being affected more than germination. In severe cases, autotoxicity may cause stand failure, but sub-lethal exposure can alter root growth and development, thus causing an autoconditioning effect of reduced stand and yield. This autoconditioning effect can cause modest reductions in plant stands or yield that would be difficult to see in production fields.

The autotoxic zone of influence appears to prevent the thickening of old stands, but further work in variety development may produce alfalfa varieties resistant to autotoxicity so interseeding could be possible. Currently, rotation intervals of at least 12-months have been effective in avoiding autotoxic effects. Irrigation on light-textured soils may help dilute the autotoxic chemical making it possible to shorten the rotation interval. Continued research into production management and identification of the autotoxic compound may make continuous alfalfa production possible.

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