SOIL ENVIRONMENT AND ALFALFA NODULATION

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Root nodules in alfalfa and other legumes arise from infection of the growing roots by bacteria of the genus Rhizobium. Healthy root nodules are pink, because they contain a hemoglobin; and the cells of their central tissues are packed with a modified form of the bacteria. The bacteria in the nodules fix nitrogen; i.e. they convert atmospheric dinitrogen (N_2), which is inert, to ammonia (NH_3), which plants can use. The properly nodulated legume is therefore independent of ammonium or nitrate which most plants have to get from soil or fertilizer.

Faulty partnership between alfalfa and its nodule bacteria is evidenced by signs of nitrogen dificiency in the plant: yellowing, low nitrogen content, and ability to show growth stimulation by nitrogen fertilizer.

Causes of faulty partnership fall into two classes

1. Nodulation failure - lack or extreme sparsity of nodules. This can be difficult to ascertain in established stands because alfalfa nodules, being small (1-2 mm) and weakly attached to the fine roots, are easy to lose when plants are dug for inspection.
2. Ineffectiveness - nitrogen deficiency despite the presence of nodules. The nodules may be abnormally small, and white or green instead of pink.

Causes of Nodulation Failure

a. Soil has too few Rhizobium bacteria of a strain that can infect the particular variety of alfalfa. This is most likely in soils that have not recently grown alfalfa, burr medic (burr clover), or melilotus (sweet clover). However, some strains that can infect some varieties of alfalfa may not be able to infect others. This kind of specificity has been important in subclover establishment in California. We don't know how much it matters with alfalfa here.

remedy: seed inoculation.

b. Soil acidity stops nodulation. It also makes for sparsity of alfalfa Rhizobium. The adverse effects increase in severity as the soil pH decreases below about 5.5 (saturated paste method). An exact cutoff point cannot be set: it depends on the soil, the Rhizobium strain, soil moisture during establishment, the number of Rhizobium present. In California alfalfa-growing areas acidity is most likely in sandy soils which have received large amounts of ammonia or urea fertilizers.

remedy: lime the soil to pH 6, inoculate seed.

c. Boron deficiency stops nodules from developing. In alfalfa, this is likely to be accompanied by "yellow-tip" and tip dieback symptoms of boron deficiency in the plant itself.

remedy: borate fertilization (e.g. 20lb borax/acre).

d. Salinity (?) stops nodulation in some legumes. With alfalfa, the only relevant experiment showed that levels of salt which severely injured the plant did not interfere with nodulation. But this may not be true under all circumstances.

Causes of Ineffectiveness of Nodules

a. Nodules containing ineffective bacterial strains fix little or no nitrogen. Some strains of Rhizobium parasitize all the legumes they infect. Some are highly effective with certain species or varieties of host plant, less effective in varying degree with others. Some strains of Rhizobium are versatile, highly effective with a wide range of legumes. Ineffective wild Rhizobium have been a critical difficulty in the establishment of subclover in California rangelands. It is likely, though we don't know for sure, that

many of the wild Rhizobium on which alfalfa growers depend are less effective than they might be.

remedy: inoculate seed with Rhizobium known to be aggressive and effective.

b. Deficiency of phosphorus, sulfur, molybdenum (rarely, cobalt). Molybdenum deficiency specifically limits nitrogen fixation. It is unlikely to occur in California alfalfa except in acid terrace soils. Phosphorus and sulfur deficiencies can reduce protein content even when they are not severe enough to have much effect on yield.

remedy: fertilization.

c. Extremes of soil temperature can specifically inhibit fixation. The critical temperatures depend somewhat on the strains and varieties involved, and have not been clearly identified for alfalfa. Work with clovers would suggest the likelihood of temporary nitrogen shortage at soil temperatures below 40° F if accompanied by favorable growth conditions; and damage to nodules from prolonged exposure to soil temperature above 95° F The latter could be significant in southern areas, especially between cutting and irrigation.

remedy: use of tolerant alfalfa and inoculant strains; management of soil cover and irrigation; judicious nitrogen fertilization.

d. Poor soil aeration, due to compaction and waterlogging, prevents optimal nodule function Probably more seriously, it impairs root growth and encourages fungal attack.

Seed Inoculation

Seed inoculation is advisable whenever the soil is suspected to have too few or poorly effective indigenous Rhizobium. It costs between $0.20 and $0.70 per acre. Proper seed inoculation supplies large numbers of effective Rhizobium with the seed at sowing. Inoculation of already established stands is difficult and rarely useful.

Preferred inoculants contain the bacteria in a slightly moist peat-dust carrier which provides a favorable environment for their survival and aids mixing with the seed. Reject inoculants that are not specifically labeled for use with alfalfa, that have passed their labeled expiration date, or that have not been stored cool (preferably refrigerated).

Some seed retailers will inoculate on request, or the grower can do it himself. Follow package instructions or the procedures described for range clovers (1). The use of stickers (e.g. milk, gum arabic) is optional for normally good alfalfa sowing conditions. Lime-pelletting will help in acid soils. Plant soon after inoculation (within 24 hours if possible) and keep seed out of the sun and wind between inoculation and planting. Do not mix inoculated seed with fertilizers.

Nitrogen Fertilization of Alfalfa

Nitrate in the soil suppresses nodulation and fixation, and encourages weeds. For these reasons, the use of nitrogen fertilizer on established stands of alfalfa has usually been found to yield either no benefit or small and transitory benefits not worth the cost of the fertilizer (2). It is true that nitrogen fertilizer can increase yield where nodulation is imperfect or slowly established, as in young uninoculated stands, and that judicious use of nitrogen may be beneficial in special circumstances. The question has not been systematically researched under California conditions.

- References -

1 A. A. Holland, J. E. Street, W A. Williams. Calif. Agr. Exp. Station Bulletin 862, 1969.

2. C. T. Lee and D. Smith. Agronomy Journal 64, 527-30, 1972.