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Improving Winter Survival of Alfalfa Without Sacrificing Yield -What We Know

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Fall Dormancy and Winter Hardiness

Fall dormant alfalfa varieties produce short, prostrate shoots in autumn and exhibit slow shoot elongation after harvest. In contrast, non-dormant alfalfa resumes rapid shoot elongation after defoliation and possess erect shoot growth in autumn. Fall dormancy is determined from fall height measurement and is rated as the following: (1 to 3) are dormant, (4 to 6) have intermediate fall dormancy, and (7 to 9) are non-dormant. Fall dormancy is closely associated with winter hardiness with fall dormant varieties being more winter hardy. Although non-dormant varieties yield more forage in autumn, their winter survival is poor. Because of the close association of fall dormancy and enhanced winter survival, producers must choose a variety with a fall dormancy rating that is adapted to the production area. In Indiana producers currently plant alfalfa varieties with fall dormancy ratings of 3 or 4. The negative consequence of growing dormant varieties is slow regrowth after harvest, which can reduce the number of cuttings per year and season-long forage yield. Our goal is to understand the biological basis for genetic differences in fall dormancy and winter hardiness of alfalfa. Ultimately we want to provide producers high yielding, less fall dormant varieties with excellent winter survival and plant persistence.

We are currently evaluating several experimental lines that have been selected for less fall dormancy but high winter hardiness. These lines have high root sugar and protein concentrations. These stored reserves are critical for winter survival and initiating spring shoot growth. In order to accumulate these reserves, the plant needs a six-week period of uninterrupted growth in autumn before a killing frost. If the interval between the last cutting and a killing frost is less than six weeks, the plant will use the energy reserves for new shoot growth. As a consequence, winter survival may be compromised. To ensure root reserve accumulation, producers must follow proper fall harvest management practices: avoid harvesting after mid-September.

Effects of Untimely Autumn Defoliation on Winter Survival

Harvesting alfalfa after mid-September in Indiana often reduces alfalfa winter survival. Untimely autumn defoliation is of great concern today with the increased interest in planting higher yielding, less fall dormant varieties. A lush fall growth produced by a less dormant variety will tempt producers to harvest between mid-Sept. and Nov.1; a practice that might compromise winter survival. We wanted to determine the effects of untimely autumn defoliation on root physiology and winter survival. Six alfalfa varieties possessing contrasting fall dormancy were established in rows in the field in May. Plant heights were measured in early October to estimate fall dormancy, then one-half of the plants in each row were defoliated in order to interrupt cold acclimation. Root tissues for laboratory analyses were sampled at defoliation in mid-October and again in December. Winter survival was determined in mid-April.

Past research indicates that increased root carbohydrate concentrations in autumn are imperative for enhanced winter survival, and untimely autumn defoliation interrupts the accumulation of root total nonstructural carbohydrate (TNC) and protein reserves necessary for successful overwintering. Our results indicate that, as expected, defoliation in mid-October significantly increased winter injury (Figure 1). Compared to intact plants, defoliation substantially decreased root protein accumulation (Figure 2). However, to our surprise we found that October defoliation significantly increases root sugar concentrations in December (Figure 3). This is the first time that accumulation of sugars in roots has been associated with enhanced winter injury. Also to our surprise, defoliation in October did not reduce expression of cold hardiness genes. Clearly, the role of sugar accumulation and expression of these genes requires re-analysis before mechanisms of alfalfa winter survival are completely understood.

Root Water Relations and Alfalfa Winter Survival

In order for plants to survive winter they must be able to cope with freezing temperatures and the presence of ice. Most alfalfa winter survival research has focused on root carbohydrate reserves, whereas the role of root water relations in cold acclimation remains a mystery. In many perennial species, the water content and form of tissue water changes dramatically in winter hardy ecotypes during cold acclimation. Bound water content (unfreezable fraction) increases and the relative water content (RWC) (freezable fraction) decreases. We monitored water relations of alfalfa roots during cold acclimation in autumn using varieties with contrasting fall dormancy and winter survival. By comparing the water status of fall dormant, winter hardy alfalfa to that of non-dormant, non-hardy varieties, we can make inferences on the importance of water content with respect to alfalfa winter survival rates.

To our surprise we did not observe differences in RWC and bound water content that could be associated with genetic variation in winter survival. However, during cold acclimation plants with high fall dormancy and good winter survival accumulated more solutes in the cell sap when compared to non-hardy alfalfa plants. Solutes such as potassium (K) serve as cellular antifreeze, thus preventing ice crystal formation. In autumn months plants accumulate solutes to lessen the chance of ice crystal formation just as we salt our sidewalks or streets during the winter months. As producers, closely monitor your soil fertility and a fall application of K may enhance winter survival of your alfalfa stand.

Future Research: Cold Acclimation Response of Alfalfa Cell Suspensions

Differences in plant morphology and anatomy confound genetic variation in alfalfa winter hardiness making interpretation of our results unclear at times. Using cell culture, inherent differences in freezing tolerance, irrespective of morphology and anatomy, can be critically evaluated. Our goals were: 1) to determine if cell cultures derived from fall dormant, winter hardy varieties cold acclimate and survive freezing temperatures better than cell cultures from non-dormant, non-hardy varieties; 2) to examine the cellular mechanisms associated with improved freezing tolerance.

Our findings indicate that cold acclimated cells from fall dormant, winter hardy alfalfa genotypes survive to -25°C whereas cold acclimated cells from non-hardy varieties die at temperatures below -5°C. Cells from non-dormant genotypes had rapid growth rates and dormant cells exhibited slower growth rates. We have initiated studies aimed at understanding the physiological and molecular mechanisms for these differences including: sugar accumulation, cell water relations and differences in expression of genes associated with freezing tolerance.

What can you do to enhance winter survival of your alfalfa stand?

- **Variety Selection:**
  Make sure the variety is adapted to your production area.
  In Indiana, plant varieties with fall dormancy ratings of 3 or 4.
- **Fall Harvest Management:**
  Don't harvest after mid-September (need 6 weeks of uninterrupted growth).
- **Soil Fertility:**
  Addition of K in the fall will enhance winter survival.
  Proper pH (6.6 to 7.0) ensures good nodulation and high N_2 fixation rate- both essential for accumulation of root protein reserves.

Figure 1. Effects of untimely autumn defoliation on winter injury of alfalfa varieties with contrasting fall dormancy.

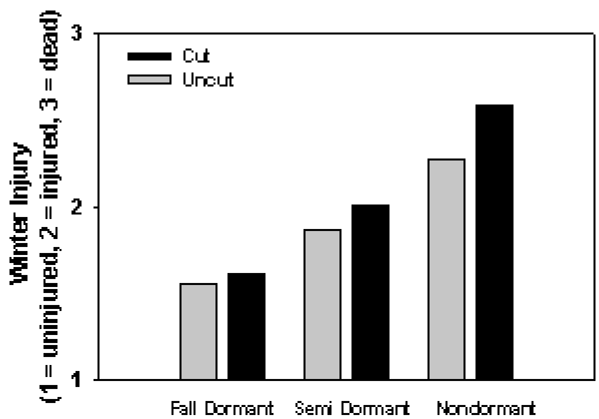


Figure 2. Compared to intact plants, untimely defoliation substantially decreased root protein accumulation in December.

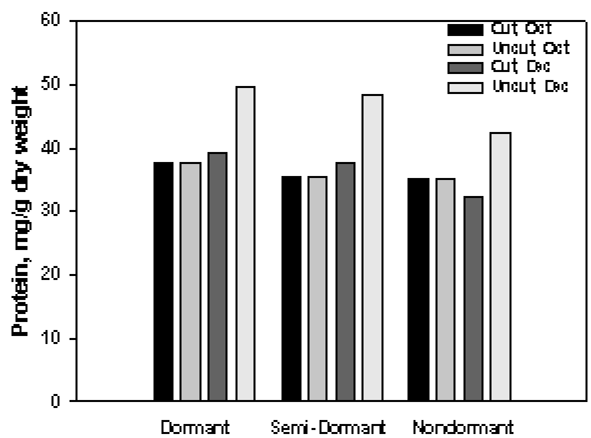
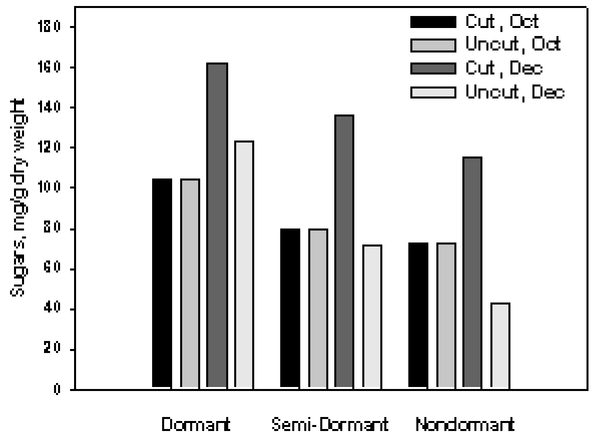


Figure 3. Root sugar concentrations increased with increased fall dormancy in cut and uncut plants, and defoliation dramatically INCREASED root sugar concentrations in December.



Cut , Oct
Uncut, Oct
Cut , Dec
Uncut, Dec
Sugars, mg/g dry weight
180
160
140
120
100
80
60
40
20
0
Dormant
Semi-Dormant
Nondormant