Hairy Vetch: Breeding for Cover Crop Systems

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Hairy vetch (*Vicia villosa* Roth) is a diploid (2n=14), outcrossing annual legume (Yeater *et al.,* 2004) that originated in Eurasia and is distributed across most temperate regions of the world (Undersander *et al.,* 1990). Hairy vetch is primarily used for cover cropping, green manure, mulch, forage, and erosion control along roadways. Improvement of hairy vetch has been minimal in the last century and limited to phenotypic recurrent selection given its self-incompatibility and outcrossing nature (Zhang and Mosjidis, 1995). The ability of *V. villosa* to biologically fix a large quantity of nitrogen (50 to 190 kg ha^{-1}) has made it a reputable contender in many cropping systems that utilize cover crops (Teasdale *et al.,* 2004). Recent breeding efforts for the crop have been primarily for early flowering and improved winter hardiness. For producers in Minnesota, these two traits have the greatest impact on the low adoption of *V. villosa* for use as a cover crop.

Cover crops have long been utilized in crop rotations for fertility conservation, weed suppression, soil improvement, and various other ecosystem services (Snapp *et al.,* 2005). Prior to synthetic fertilizers and chemical pest management, the use of cover crops was necessary to maintain soil productivity (Crews and People, 2004). The absence of ground cover in conventional crop production systems has resulted in soil erosion from exposure to wind and rain energy and also ground and surface water contamination due to fertilizer misapplication and inability to capture residual nutrients prior to planting and following harvest (Pimentel *et al.*, 1995). As a reactive means of mitigating the environmental effects of intensive crop production, breeding efforts should be applied to cover crop species to expand their compatibility with modern cropping systems.

As a leguminous species, hairy vetch is able to produce plant usable nitrogen by means of symbiosis with nitrogen fixing soil rhizobium. This phenomenon has been exploited since the beginnings of agriculture to provide nitrogen for subsequent crops. The Haber-Bosch process, a revolutionizing method which synthesizes ammonia from atmospheric nitrogen and hydrogen, increased food production drastically worldwide starting in the early twentieth century, but consequently reduced legume utilization on the landscape (Smil, 2001). While nitrogen use by plants is relatively inefficient regardless of the source, synthetic nitrogen is fundamentally reliant on natural gas as its hydrogen source, making it the most energy demanding input for conventional farming operations (Crews and People).

Compared to Poaceae and Brassicaceae cover crop species, leguminous species have had insufficient survival when over-wintering in northern regions of the U.S. Hairy vetch is the most winter hardy of the approximately 150 vetch species within *Vicia* and can more reliably overwinter compared to other leguminous cover crops (Undersander *et al.,* 1990). Although this species has shown high potential as a winter hardy cover crop, it still lacks sufficient winter survival for utilization in northern Minnesota (Harbur *et al.,* 2009). Among limitations to integrating hairy vetch into cropping systems, which include rotation compatibility, hardseededness, and difficulties with termination (Maul *et al.,* 2011), lack of winter hardiness stands as the greatest restraint.

Winter hardiness is a quantitative trait that is influenced by many environmental and biological factors. The most significant determinant of winter hardiness is freezing tolerance: the ability of a plant to resist cell dehydration from the freezing of extracellular fluid (Levitt, 1980). Screening for winter hardiness has routinely been done by advancing surviving plants following a test winter. Test winters, however, are highly variable from year to year and can be unreliable for breeding purposes. To circumvent these issues, better methods for evaluating freezing tolerance among individuals in a population are needed to increase gains for this complex trait.

Two methods that have been successfully employed to improve winter hardiness in other crops are controlled freezing tests and measures of chlorophyll fluorescence to indirectly measure the efficiency of photosystem II during stress (Rizza *et al.,* 2001). These tests could be implemented into a recurrent selection scheme that aims to improve winter hardiness, but also to maintain relevant traits such as biomass, seed production, and nitrogen fixation.

Minimal ground cover on agricultural terrain has been associated with increased top soil erosion and nutrient escape. Hairy vetch, as a leguminous cover crop, can not only mitigate these effects, but can also provide additional nitrogen for subsequent crops. Given the lack of leguminous species that can reliably overwinter in Minnesota, breeding efforts should be applied to this specie, which has shown to have high potential to fill this gap in Minnesota cropping systems. These efforts should involve alternative methods of screening for freezing tolerance and the incorporation of those methods into a recurrent selection scheme to improve the winter hardiness and cropping system compatibility of hairy vetch.

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