Characteristics of Black Medic (*Medicago lupulina* L.) Seed Dormancy Loss in Western Canada

by

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A thesis submitted
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Table of Contents

List of Tables

List of Figures

List of Appendices

Abstract

Characteristics of Black Medic (*Medicago lupulina* L.) Seed Dormancy Loss in Western Canada

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Cover crops are an important innovation in sustainable cropping systems. The successful use and management of black medic (*Medicago lupulina* L.) as a self-regenerating cover crop requires a better understanding of its physical seed dormancy. In order to break this seed dormancy, it appears that a low temperature 2-stage seed softening process is required. However, whether or not this 2-stage process is required for black medic seed softening in Western Canada is unclear. Also, the influence of the presence of a companion crop, medic population type, seed burial depth and seed production environment on black medic production and seed softening is unknown. Field and controlled environment studies were established in 2003 and 2004 in an effort to address these questions.

The results from a field study conducted in different prairie environments showed that although, seed production environment, the presence of a companion crop, and medic population affected the growth and development of the black medic plants, they did not affect initial seed dormancy. A second field study tested the effect of seed production environment, seed burial depth and population on seed softening. Results indicated that there was an effect of population on summer seed softening, which suggested that there were differences in seed dormancy between a population of black medic that had been subjected to selection pressures (e.g., herbicides, competition) for 12

years versus one that had not (Foundation stock). Therefore, this suggests that some genetic drift had occurred within the population. The results also indicated that there was an effect of seed burial depth on seed softening, with more seed softening occurring for the buried seed during winter/spring and more for the surface seed during summer, and these differences appeared to be somewhat linked to differences in soil temperature.

Results of this field study suggested that black medic in Western Canada goes through a 2-stage softening process. Hence, a controlled environment study was established to test this hypothesis. Results from both studies confirmed that a 2-stage softening process is required for black medic softening in Western Canada. Stage 1 requirements appear to be met by exposing seed to temperatures between –5°C and 5°C for at least 4 weeks, while exposure of the seed to a low fluctuating temperature (e.g. 15/6°C) for a short period of time (i.e., approximately 4 days) appears to meet stage 2 requirements.

In summary, this research has provided us with valuable information about black medic seed softening under Western Canadian conditions, which will hopefully lead to a better understanding of how to best manage and utilize black medic as a self-regenerating cover crop in a Western Canadian cropping system.

Chapter 1: Literature Review

1.1 Cover Crops

Cover crops are typically low growing plants that are grown in association with a main crop. Cover crops fill either a temporal or spatial gap that has been left bare by the main crop (Lal et al. 1991). Annual cover crops are usually seeded at the beginning of the growing season or once the main crop has been established; the successful cover crops are those that continue to grow once the main crop has been harvested, thereby providing benefits throughout the fall. The dry matter produced by the cover crop can either be used as feed for livestock or as a green manure (Stopes et al. 1996).

Cover crops are an important innovation in sustainable crop production systems. In the past few decades, environmental concerns over excessive fertilizer and pesticide use and soil erosion have lead to renewed interest in cover crops (Hartwig and Ammon 2002). Cover crops can also "perennialize" the annual cropping system to more thoroughly utilize water, nutrient and light resources (Nason, University of Manitoba, pers. comm.). Since cover crops are usually grown along with a cash crop, the farmer is able to receive in one growing season both an income from a cash crop and the benefits associated with having a cover crop in the cropping system.

1.1.1 Positive Impacts of Cover Crops

Benefits of cover crops have been documented for centuries (Hartwig and Ammon 2002). For example, in ancient Greece and Rome, the use of legume cover crops, such as vetch (*Vicia* species) and lupines (*Lupinus* species), to enhance soil fertility and crop production was well documented (Hargrove and Frye 1987). Today, there are several other reasons for including cover crops in cropping systems. For example, species such as hairy vetch (*Vicia villosa*) and annual ryegrass (*Lolium multiflorum*) are able to suppress weed growth through competition and/or allelopathy (Brandsaeter and Netland 1999; Lal et al. 1991). In some instances, cover crops can provide improved disease control by, for example, preventing the splashing of fungal spores (e.g. common smut (*Ustilago maydis*)) from the soil surface to the leaves of the host crop (Hartwig and Ammon 2002). Cover crops have also been noted to provide insect control by directly interfering with the pest insect (e.g. inhibiting the movement of the insect to the host plant) or by providing habitat for predatory insects (Hartwig and Ammon 2002; Verhallen et al. 2003).

Other benefits of cover crops include: soil moisture retention, improved soil structure, increased soil organic matter, reduced soil erosion and reduced runoff (Lal et al. 1991; Worsham 1991; Hartwig and Ammon 2002). Zhu et al. (1989) found that winter cover crops (common chickweed (*Stellaria media L.*), Canada bluegrass (*Poa compressa L.*), and downy brome (*Bromus tectorum L.*)) established in soybeans reduced spring soil erosion and runoff by an average of 93% and 47%, respectively, compared to when the soybeans were grown without a cover crop. Overall, due to the many benefits that cover crops can offer, their use can indirectly improve crop yields and reduce the need for chemical inputs (Power and Koerner 1994).

Currently, cover crops are being used across Canada in several applications. In drier areas, such as southern Alberta, cereal cover crops (e.g. fall rye (*Secale cereale*)) have been successfully used for soil conservation and weed suppression during the fallow phase of a crop rotation (Moyer et al. 2000). In wetter areas of the prairies, such as southern Manitoba, legume cover crops (e.g. red clover (*Trifolium pratense*)) are being grown after the crop has been harvested in order to provide some late season production by taking advantage of available heat and moisture, and are also being used as an alternative to fallow (Thiessen Martens et al. 2001). In Ontario, a variety of different legume, broadleaved and grass cover crops are being used for their abilities to reduce soil erosion, improve soil structure and fertility, reduce pest populations, improve water management and for many other reasons (Verhallen et al. 2003).

1.1.2 Negative Impacts of Cover Crops

Although cover crops are generally considered to be beneficial to a cropping system, there are often a number of negative aspects associated with their use. For example, additional management, interference with crop establishment, cooler soil temperature and less predictable crop fertilizer requirements have been cited as some problems associated with using cover crops (Teasdale 1996). Some cover crops are quite competitive and may outcompete the main crop for resources, which in turn may result in yield losses. For example, Thiessen Martens et al. (2001) showed that the presence of an alfalfa (*Medicago sativa*) or red clover (*Trifoloum pratense*) cover crop decreased winter wheat and rye grain yields slightly (3.4 to 3.8%). Also, even though the cost of cover crop seed has been shown to be equal to the value of the benefits received (Mallory et al. 1998), the monetary cost of the seed can still often be a deterrent to farmers (Brandsaeter and Netland 1999).

1.1.3 A Cover Crop Ideotype for the Canadian Prairies

A cover crop ideotype is one that provides all the aforementioned benefits, and at the same time minimizes the associated problems. Most importantly, a cover crop for a particular system should have a low maintenance cost and should not outcompete the main crop for resources (Brandsaeter and Netland 1999). It is also essential that the cover crop species chosen is well adapted to the local climate (Brandsaeter and Netland 1999). Zhu et al. (1991) suggest that an ideal cover crop species should have a relatively short height to minimize interference with the main crop and, in the case of self-regenerating species, should be a prolific seed producer.

1.2 Self-Regenerating Cover Crops

The idea behind self-regenerating cover crops is that the farmer only has to seed this crop once and it will regenerate on its own from seed in the seed bank each subsequent year. This allows the farmers to get the yearly benefits of having a cover crop without having the yearly cost of reseeding it.

Self-seeding cover crops have been used for decades in many places around the world, in both Mediterranean and temperate climates. In Australia, self-regenerating *Trifolium* and *Medicago* legume species have been used in the ley-farming system since the 1950s (Puckridge and French 1983). Ley-farming is a system that integrates livestock and crop production by having a rotation of cereal crops with annual legume pasture phases that regenerate from seed at the start of each pasture phase (Walsh et al. 2001). This ley farming system has been shown to increase soil fertility, provide high-quality pasture and increase production from crops and livestock (Puckridge and French 1983).

However, a major requirement of these systems is that the pasture crop can maintain a high enough seedbank level to allow regeneration from seed at the start of each pasture phase (Walsh et al. 2001).

In Scandinavia, a number of self-regenerating legumes have been used as winter annual cover crops to help suppress weeds and provide other benefits to the cropping system (Brandsaeter and Netland 1999; Enache and Ilnicki 1990). In this temperate climate, winter survival for many annual cover crop species is very low or inconsistent, and therefore it is important that they be able to regenerate each year from seed (Moomaw 1995). On the Canadian prairies, one self-regenerating species drawing particular interest is *Medicago lupulina*, due to its proven ability to regenerate well in this region of the world (Braul 2004). The first Northern Great Plains researcher to work on *Medicago lupulina* was Jim Sims of Montana State University (Entz, University of Manitoba, pers. comm.).

1.3 *Medicago lupulina*

1.3.1 Biology

Medicago lupulina, commonly known as black medic, has been used for decades in many cropping systems around the world. Black medic is a low growing, short-lived perennial, biennial or annual species (Sims et al. 1985; Turkington and Cavers 1979). This plant is an obligate self-pollinated species, and therefore interbreeding among individuals is not likely (Sidhu 1971). In Mediterranean climates, black medic usually germinates during the first fall rains and grows rapidly under the warm and moist conditions, with flowering being completed in spring (Rumbaugh and Johnson 1986).

Since black medic has some frost resistance, it is sometimes used as a winter annual in temperate climates (Brandsaeter et al. 2000). However, in order to take advantage of its reseeding ability, *M. lupulina* is best used as a summer annual in these environments. In general, although seedlings can emerge throughout the growing season, the greatest number of seedlings appear in spring (Turkington and Cavers 1979).

Black medic has been noted to be a prolific seed producer, often out producing many other annual *Medicago* species (Rumbaugh and Johnson 1986). In pastures, the seedbank size for black medic has been found to be approximately 600 to 2000 seeds per m^2, though estimates of the seedbank size vary (Pavone and Reader 1982). This available seed reserve gives black medic its self-regenerating ability. Since seed cost often limits the value of a particular cover crop species, it is important that the natural reseeding ability of black medic is understood and exploited (Moomaw 1995).

1.3.2 Origin and Distribution

The exact origin of black medic is unknown, but it is believed to be native to Western Asia, Eastern Europe or the Mediterranean (Turkington and Cavers 1979; Sidhu 1971). Black medic was likely introduced to North America in the 1600s as either a contaminant in alfalfa seed or as a constituent of general pasture mixtures, and was subsequently naturalized throughout most of North America (Turkington and Cavers 1979; De Haan et al. 1997; Sidhu 1971).

Black medic is typically found in 'disturbed' areas such as roadsides, riverbanks, lawns, and fields in both temperate and subtropical regions, such as North America, Asia, North Africa and Europe (Sidhu 1971; Turkington and Cavers 1979). This species has even been documented in weed surveys done for fields in Manitoba (Ominski et al. 1999) and Ontario (Thomas and Dale 1991; Frick and Thomas 1992). Black medic is adapted to a wide range of environmental conditions, as noted by its widespread distribution (Turkington and Cavers 1979). Although black medic grows best in moister soils and at cooler temperatures than other annual *Medicago* species, it is also considered to be resistant to drought stress (Foulds 1978; Rumbaugh and Johnson 1986). In general, black medic is best adapted to well-aerated soils of calcareous origin (Blaser and Stokes 1946).

In the 1980s, the cultivar 'George' black medic was developed using seed collected from naturalized plants adapted to Montana conditions and was subsequently registered as the first North American *M. lupulina* cultivar (Sims et al. 1985).

1.3.3 Genetic Plasticity

Black medic's adaptability to a wide range of environmental conditions is attributed to the genetic plasticity of this species. *M. lupulina* is considered to have high morphological and phenotypic diversity both within and between populations, and therefore many varieties and accessions of this species can be found (Turkington and Cavers 1979; Sidhu 1971). A single population of black medic can consist of a number of different genotypes and phenotypes in varying proportions and these proportions can be shifted under different environmental stresses (Rumbaugh and Johnson 1986; Sidhu 1971).

Norman et al. (2002b) suggested that for different legume species, physical seed dormancy (i.e. hardseededness) might shift in response to environmental selection. More specifically, seed dormancy will tend to be highest in populations subjected to conditions that reduce the chance of successful reproduction. For example, Norman et al. (2002b) reported that for *Trifolium tomentosum* and *Trifolium campestre* the level of hardseededness decreased with decreasing grazing intensity. In general, ecological theory predicts that as conditions become more favourable for the plant (i.e. less grazing pressure), dormancy of a given species should decrease (Cohen 1967; Brown and Venable 1986).

With this in mind, other stresses associated with different cropping systems may also result in a shift in the hardseededness of a particular legume population. For example, exposure to pre-emergence herbicides may result in a shift in the population towards a phenotype that emerges later in the growing season. Later emergence would allow the seedlings to escape the pre-emergence herbicides. In order to facilitate later emergence, the proportion of seeds in a population that normally breaks dormancy (i.e. softens) during the pre-emergence period would be shifted towards the cohort of seeds that have a longer lasting dormancy, thereby enabling the population to break dormancy and successfully establish after the herbicide has been applied.

Such a response is believed to be the case for a population of black medic, which we denote as 'selected George'. In 1992, this population of black medic was established from certified 'George' black medic seed on a no-till farm near Goodrich, North Dakota. Over the years, this population has regenerated successfully every year, even though it has been subjected to continuous grain crop competition and a number of yearly herbicide applications. However, it appears that this selection pressure has resulted in a shift from more spring recruitment to more mid-summer recruitment (Entz, University of