GREEN MANURE FOR SOIL NUTRIENT MANAGEMENT IN A HIGH-DESERT (3700-5100' ELEVATION) FARMING SYSTEM

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ABSTRACT

Although cover crop (CC) research in the west exists, green manure (GM) plowdown into the soil is not widely adopted among producers. Green manures can be used to enhance nutrient cycling in farming systems through two primary mechanisms: 1) by taking up and recycling excess nutrients and 2) helping to prevent nutrient leaching. By using CCs as a GM, nutrients are recycled back into the soil when the CC dies and decomposes. For example, legume CCs can fix atmospheric N, release some of this N to the soil for use by succeeding crops, and reduce the need for N fertilizer. In addition to N, other benefits include build-up of organic matter (OM), reduced use of herbicides, and more efficient long-term storage of nutrients. These benefits result in GM providing multiple services related to soil and nutrient management. While CC species have been proven to work in other areas of the US, few species have been extensively researched in high-desert (3700-5100' elevation) farming systems, such as southern Idaho, where there is an increasing interest in sustainable agricultural practices. Research conducted by the University of Idaho (UI) Extension is evaluating CC choices for GM applications in a high-desert environment. Some cold-hardy GMs promising the greatest winter survival include hairy vetch, winter cereal crops, Austrian winter peas, and clovers, with good initial establishment. A variety of GMs can be used for spring, summer, or fall plantings and include: buckwheat, canola, oilseed radish, mustards, turnips, clovers, warm season annuals, and chickling vetch. This research will develop initial Best Management Practices (BMPs) for CCs best suited for GM in both conventional and organic high-desert, higher elevation farming systems.

INTRODUCTION

Any crop grown to provide living ground cover that is planted with or in between the main or cash crop is considered a CC. Cover crops are used as a BMP to help minimize soil erosion, prevent nutrient leaching, suppress weeds, sequester carbon (C), and provide beneficial insect habitats (Dabney et al., 2001). Green manuring is the incorporation of a CC into the soil for the purpose of benefiting succeeding crops by improving soil fertility as well as improving soil physical properties (Sullivan, 2003; Janzen and Schaalje, 1992). The non-nutritional soil benefits coupled with no-till or conservation till provide OM to the soil (Sullivan, 2003; Smith et al., 1987), creating well-aggregated and well aerated soil that has a high water infiltration rate (Dabney et al., 2001). The overall benefits from GM include N fertilizer savings, reduced use of herbicides, build-up of OM, and more efficient long-term storage of nutrients (Clark, 2007).

Cover crop and GM research have primarily been conducted in the following cropping systems: vineyards, orchards, corn, small grains, and forages (Hartwig and Ammon, 2002). While GM has proven to work in these and other cropping systems, researchers with UI Extension are expanding GM research and outreach efforts for a high-desert, higher elevation climactic zone (Winger et al., 2011). These GM species will be tested for their cold-hardiness, their ability to scavenge N and phosphorus (P), contribute OM, maintain subsequent yields, and for weed control.

In most agricultural systems, GM can be used in addition to other nutrients sources, or as the primary long-term soil management strategy. Synthetic fertilizers offer a quick, short-term management plan for soil fertility but do not directly contribute OM to soil systems. Larger biomass and root production from synthetic fertilizer could indirectly increase OM if it was not harvested, but incorporated into the soil as a GM. On the other hand, short comings with the use of animal manures and compost include the expense to transport resources if off-site; as in the case of southern Idaho with the large-scale use of dairy compost. Therefore, GM can offer a sustainable management plan for soil fertility in addition to contributing soil OM.

This paper will focus on the use of GM for soil nutrient management (improved nutrient cycling and soil N and P contributions), as it pertains to high-desert, higher elevation farming systems. The literature is reviewed here along with research goals and possible GM species for southern Idaho's climactic zone.

COVER CROPS AND NUTRIENT CYCLING

Cover crops can be used to enhance nutrient cycling in farming systems through two primary mechanisms: 1) by taking up and recycling excess nutrients and 2) helping to prevent nutrient leaching. Some CC root systems are good scavengers of soil nutrients. Scavenging from deeper depths than the previous crop root system could reduce N leaching losses. By using the CC as a GM, nutrients are recycled back into the soil when the CC dies and decomposes (Clark, 2007). By helping to take up excess nutrients and lowering soil moisture content (Clark, 2007), CCs can prevent nutrient leaching, an agricultural BMP.

Some CCs can promote soil P cycling. For example, buckwheat and lupins can be used to alter soil P into a more soluble, plant available form. Research has shown that these CCs can mobilize soil P and help P uptake of succeeding crops when used in a rotation; These CCs promote the movement of P in the soil and root interface (Kamh et al., 1999). Other CCs, particularly legumes, help efficiently absorb soil P through root mycorrhizae fungi and hyphae filament. This uptake of nutrients by the CC keeps P in an organic form and efficiently cycles the nutrient back into the soil for succeeding crops (Clark, 2007). In northern Idaho, canola, oriental mustard, and yellow mustard have been studied in wheat cropping systems (Brown and Davis, 2008). These Brassicaceae crops have taproots that improve the soil structure and water holding capacity, and reduce nitrate leaching. Brown et al. (2008) suggest there are inherent differences in oilseed radish and yellow mustard ability to access and accumulate P. They found the oilseed radish had lower P uptake than the yellow mustard.

With reduced P leaching, GM can be beneficial when used with animal manure or compost, in addition to minimizing soil salinization (Cherr et al., 2006); environmental related concerns common with the use of animal manures and compost. In addition, research shows the ability for CCs to take up excess nutrients from manure or compost applications; grass, brassicas, or a mixture is ideal for this soil management strategy (Clark, 2007). Some producers in southern Idaho may consider the use of GM to compliment the application of dairy compost for better soil fertility management.

Green manures also help cycle soil nutrients by providing food for soil microbes. Diverse and active populations of microorganisms cycle nutrients more efficiently (Clark, 2007). In addition, increasing soil OM with GM can enhance the capacity of soil to store nutrients. The majority of soil N and much of soil P and sulfur (S) reside in soil OM. Soil OM contributes to the cation exchange capacity (CEC); higher CEC enhances retention of positively charged primary, secondary and micronutrients through soil chemistry complexes (Newman et al., 2007).

SOIL NITROGEN MANAGEMENT WITH GREEN MANURE

It is well documented that legume GMs help replenish soil N reserves (Janzen and Schaalje, 1992; Smith et al., 1987). Legume GMs can fix atmospheric N, release some of this N to the soil for use by succeeding crops, and reduce the need for N fertilizer (Hartwig and Ammon, 2002). Legume GMs have a lower C:N ratio. This allows for faster decomposition and re-cycling of residue nutrients (Clark, 2007).

Many studies provide evidence that N contribution to the soil from legume GMs can range from 67 to 178 lbs/acre of N. Therefore, the economic benefits of GM can be estimated by the yield of succeeding crops and the value of N derived from a GM, in relation to cost of synthetic or other non-synthetic fertilizers (Hartwig and Ammon, 2002; Smith et al., 1987). The best estimate of the economic viability for GM use is its value in providing multiple services; including soil nutrient supply, weed, insect, disease control, and improved soil physical properties (i.e. increased OM and improved soil tilth; Cherr et al., 2006). Some GM research has found hairy vetch and chickling vetch to be one of the most successful legumes for providing soil N. These vigorous GMs are able to provide lots of soil N due to their higher fixed N content and high yielding above ground dry matter (DM) (Hartwig and Ammon, 2002). Research shows that legumes do not provide as much OM compared to a grass or cereal GM. As a result, GM mixtures can often create the ideal nutrient management system that incorporates a variety of soil quality and nutrient needs (Clark, 2007).

Finding the correct C:N ratio of the GM is dependent on crop rotation and subsequent crop nutrient requirements, along with climatic and soil textural effects on GM growth. Brennan et al. (2011) found that 60-85% of the plants in a rye-legume mix should be legumes, in order to achieve adequate legume DM to justify the high cost of legume seed. They also suggested a 90% legume mix to reduce the C:N ratio, promote rapid decomposition, and release more nutrients for the subsequent crop. When the cost of the legume seed is high, it may be beneficial to consider a cereal rye, winter wheat, oilseed radish, or other brassicas, that can scavenge N and add OM. If manure or compost is readily available it could also be used with these non-legume GMs. University of Idaho Extension research revealed that sorghum, sorghum sudangrass, and pearl millet provided the largest biomass, but vetch, turnips, and rapeseed offer higher quality forages or CCs with more N (Winger et al., 2011). Striking a balance within the specific cropping system appears to be critical for optimum N management and GM efficiency.

COVER CROPS/GREEN MANURES WITH POTENTIAL FOR HIGH-DESERT, HIGHER ELEVATIONS IN SOUTHERN IDAHO

Cover crop and GM selection is not only dependent on field and farmer objectives, such as N and/or OM contribution, nutrient cycling needs, and/or weed control, but spatial and temporal niches. Selecting CCs for the local environment need to be considered as well as GM rotations that can be easily integrated into the current cropping system (Snapp et al., 2005). In southern Idaho, researchers will evaluate and review species that are promising for both winter and summer CC rotations. For winter survival, research shows hairy vetch and winter rye to be the most cold-hardy CCs (Clark, 2007; Snapp et al., 2005; Smith et al., 1987).

Hairy vetch is a N fixing legume CC that is commonly used as a spring or winter annual. Hairy vetch is a popular CC due to its high N accumulation. In legume CC comparison studies, hairy vetch consistently is as good as or better than other species on pounds N accumulated per acre (Smith et al, 1987). A favorable combination among growers is mixing hairy vetch and rye. This is due to the optimal CC growth and better mechanical control when seeding succeeding crops and/or tilling the CC into a GM. Although hairy vetch is promising as a spring and summer annual for high-desert environments and considered one of the most winter-hardy CC species, its survival as a winter annual in southern Idaho needs to be determined. Unusually cold fall weather and no protective covering (snow) may result in winter injury (Undersander et al., 1990).

Winter rye is a cool season annual cereal that is widely adapted to temperate and high altitude growing zones. Rye is commonly used in cropping systems to help take-up excess N, add OM, planted as a companion crop, suppress weeds, (Clark, 2007) and build soil organic carbon (SOC) (Kuo et al., 1997). As a fall seeded CC, rye provides considerable DM with an extensive root system. It can outperform other CCs on less fertile or poorly prepared land. Rye has commonly been used as an overwintering CC with corn, soybeans, fruits, and vegetable cropping systems. Rye however is not ideal for small grain systems such as wheat or barley. Kuo et al. (1997) found annual ryegrass (*Lolium multiflorum* Lam.) and cereal rye (*Secale cereal* L.) better suited winter CCs for building SOC and carbohydrate concentrations compared to Austrian winter pea, hairy vetch, and canola. Increasing SOC and soil carbohydrates will benefit soil structural stability and soil biological activity. These benefits help improve overall soil quality and productivity.

Growers in southern Idaho have experimented with chickling vetch and have found favorable results as a spring-seeded GM crop. Research conducted in the drier regions of the Canadian Prairies have also found chickling vetch a successful GM for producing high amounts of DM and good N fixation (Martens et al., 2001; Biederbeck et al., 1995). Biederbeck et al. (1995) found chickling vetch produced the largest biomass with a high capacity for symbiotic N fixation. Chickling vetch root systems developed more nodules per plant compared to black lentil, feedpea, and tangier flat pea. Both chickling vetch and feedpea proved best suited to conserve the long-term total soil N pool of a GM in rotation with a wheat cropping system. Martens et al. (2001) concluded the use of legume CCs such as chickling vetch for relay and double cropping systems resulted in no grain yield penalties of the main crop and were therefore agronomically feasible for southern Canada cropping systems. Biederbeck and Bouman (1994) found chickling vetch to use water more efficiently than black lentil and tangier flatpea in a dryland cropping system. Chickling vetch has potential to be a good GM for contributing N and high DM residue for both irrigated and dryland cropping systems of southern Idaho.

Additional research at Aberdeen, ID with UI Extension and Natural Resource Conservation Service (NRCS) found several CC species that survived the winter and were evaluated for DM on May 1, 2011. The crimson clover had 2,000 lbs/acre DM, sweet clover 1,500 lbs/acre, Austrian peas 2,700 lbs/acre, and hairy vetch 2,375 lbs/acre (Table 1; lbs/acre values not shown). The continuation of this research will measure the value of GM for soil nutrient management and provide relevant information to help increase adoption rates among southern Idaho producers. The results will also help develop an Idaho Cover Crop Calculator that will help growers estimate N contributions to their soils from different GM species and management practices.

Table 1. Cover crops/green manures with potential in southern Idaho at various planting times. Species selection and temporal niches based on preliminary UI Extension on-farm and R&E Center trials throughout 2010 and 2011.

Early Spring	Early Summer	Early Fall
Buckwheat	Buckwheat	Buckwheat
Canola (Rapeseed)	Canola (Rapeseed)	Canola (Rapeseed)
Red, white or crimson clover	Red, white or crimson clover	Red, white or crimson clover
Oilseed Radish	Oilseed Radish	Oilseed Radish
Mustards	Mustards	Mustards
Daikon Radish	Daikon Radish	Daikon Radish
Spring cereal crops	Hairy Vetch	Hairy Vetch
Austrian winter pea	Chickling Vetch	Winter cereal crops
Austrian Winter Pea/cereal	Sorghum	Austrian Winter Pea
Purple Top Turnips	Sorghum Sudangrass	Austrian Winter Pea/cereal
	Teff	Purple Top Turnips
	Pearl Millet	
	Spring Peas	
	Oats	

CONCLUSION

Incorporating GMs into cropping systems can have multiple positive sustainable benefits, including improved soil quality, an organic N source, and pest control (Hartwig and Ammon, 2002). Future research needs to evaluate the complexity of using GM in cropping systems and the obstacles that prevent higher adoption rates. Integration of GMs into farming systems brings both costs and benefits; therefore consideration should address the following: 1) individual farmer goals, 2) soil quality and nutrient needs, 3) current cropping systems, 4) integration with animal manure and compost applications, 5) climatic limitations, and 6) the ability to scavenge nutrients.

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