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Using pennycress, camelina, and canola cash cover crops to provision pollinators

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ABSTRACT

As pollinator decline continues, the need to provide high value forage for insects increases. Finding agricultural crops to diversify the landscape and provide forage is one way to improve pollinator health. Three winter industrial oilseed crops (pennycress, winter camelina, and winter canola) were grown in Morris, Minnesota, and Brookings, South Dakota, during the winters of 2012–2013 and 2013–2014. Each of the three crops has pollinator-friendly flowers and value as winter cover crops and cash seed crops. The crops were evaluated for pollinator use, nectar production, green cover, and yield. Pennycress, camelina, and canola flowers had high insect activity with maximum visitation rates of 67 ± 11.5, 22 ± 3.1, and 61 ± 6.8 insects min^{-1}. Cumulative nectar produced by pennycress, camelina, and canola was 13, 100, and 82 kg of sugar ha^{-1} during the 2014 anthesis period, providing an important food resource to pollinators during early spring when there is little else on the agricultural landscape that is blooming. Green cover in early spring ranged from 0 to 60% amongst the three crops, with camelina providing >25% green cover across all four site-years. Maximum seed yields were 1.1 ± 0.04, 1.4 ± 0.05, and 1.2 ± 0.19 Mg ha^{-1} for pennycress, camelina, and canola, respectively, which are economically viable harvests. Of the three crops, winter camelina provided the highest combined agroecosystem value through pollinator resources, green cover, and seed yields.

1. Introduction

The decline of honey bees and other pollinators has become an issue of increasing alarm in the US and around the world (Potts et al., 2010; Ellis et al., 2010; Gallai et al., 2009). Pollinators have been credited with adding $15 billion to the US agricultural market, and efforts to improve their health are of immediate concern (Rucker et al., 2012; Calderone, 2012). Multiple factors including viruses, varroa mite (*Varroa destructor*), bacterial disease, inadequate nutrition, climate change, and pesticides have been implicated as contributing to declining honey bee and native pollinator populations (USDA, 2014; Vanbergen and Initiative, 2013). High-intensity and low-diversity agriculture, like that of the US Corn Belt, results in landscapes lacking in floral resources beyond the low quality resources provided by cash crops and exacerbates the pollinator crisis (Keller et al., 2005a,b; Brodschneider and Crailsheim, 2010). However, increased momentum in the US to promote the use of biobased energy (U.S. Congress, 2007) offers potential to include new and alternative bioenergy crops in US cropping systems and help diversify agriculture.

From 2008 to 2013, one-third of the honey producing colonies in the US were in Minnesota, North Dakota, and South Dakota (USDA-NASS, 2014, 2013). This area traditionally has provided rich forage resources for beekeepers to manage their hives and produce honey. However, over the last seven years these same states have seen a 39% decrease in Conservation Reserve Program land, a 25% decrease in planted canola, and a 45% decrease in planted sunflower, all important forage sources for bees (Greenleaf and Kremen, 2006; Morandin and Winston, 2005; Gallant et al., 2014; U.S. Department of Agriculture, 1983; USDA-NASS, 2014). At the same time, soybean and corn acreage has increased 26% and 17%, respectively (USDA-

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Table 1
Sowing, flowering, and harvest dates of winter oilseeds in Morris, Minnesota, and Brookings, South Dakota, over the 2012/2013 and 2013/2014 growing seasons.

Year Location	Pennycress		Camelina		Canola	
	Sown	Harvest	Sown	Harvest	Sown	Harvest
MN 2012/2013	11 September	12 July	11 September	12 July	30 August	24 July
MN 2013/2014	30 August	30 June	6 September	30 June	6 September	18 July
SD[a] 2012/2013	11 September	18 July	11 September	18 July	22 August	n/a
SD 2013/2014	6 September	n/s	6 September	26 June	27 August	n/a

[a] Plots were frost seeded on 4/1/2013 due to no germination in the fall.

NASS, 2014). Honey production per colony over this same period has dropped by one-fourth (USDA-NASS, 2014, 2013). The additional cost of feeding and reduced honey production per colony worsens the losses beekeepers have been facing due to increased colony losses. The presence of melliferous, mass flowering crops can positively impact generalist pollinators such as honey bees and native bees (Westphal et al., 2003; Holzschuh et al., 2013).

The winter oilseed crops *Thlaspi arvense* L. (pennycress), *Camelina sativa* L. (camelina), and *Brassica napus* L. (canola) all flower between late April and early June in the Northern Corn Belt (NCB), providing floral resources to native insects emerging from hibernation as well as honey bee hives returning to their summer apiaries. Previous studies have reported visitation of pennycress, camelina, and canola flowers by pollinating insects (Groeneveld and Klein, 2013; De Sousa Rosa et al., 2011; Stanley et al., 2013). In addition to providing a critical early forage resource to pollinators, these crops are also green winter cover crops, providing another valuable ecosystem service. Winter cover crops in the NCB represent a small but increasing portion of the land in agricultural use. The growing season in the NCB region begins in May and ends in October, giving farmers a short growing season of only five to six months. This short growing season also means that crop land devoid of a cover crop is left vulnerable over half of the year. Cover crops offer critical improvements to environmental quality including erosion reduction, improved water quality, improved soil quality, decreased nutrient loss, and improved nitrogen management (Kladivko et al., 2014; Kaspar and Singer, 2011).

Growing a cash-generating winter cover crop may provide the incentive needed to offset the risk and cost of cover crops in the NCB and, thereby, increase the adoption of cover crops and crop diversity. Pennycress, camelina, and canola have valuable seed oils that have a variety of end-uses. Pennycress seeds contain an average of 33% oil by weight (Evangelista et al., 2012). The oil contains erucic and linoleic acids at 33 and 22 wt/wt%, making it a good feedstock for biodiesel production (Moser et al., 2009; Cermak et al., 2013). Camelina seeds have 35–45% oil by weight with α-linolenic acid making up 32–40 wt/wt% of the oil (Moser, 2010). Camelina oil has been shown to be suitable for both diesel and jet fuel production (Moser, 2010; Krohn and Fripp, 2012) as well as for cooking oil (Pilgeram et al., 2007). Lastly, canola seed has 40% oil by weight composed of 60, 20, and 10 wt/wt% oleic, linoleic, and linolenic acids, respectively (Mag, 1983; Rife and Shroyer, 2000; Assefa et al., 2014). Canola oil is used in products such as cooking oil, margarine and shortening, and salad oil and also can be used for biodiesel production (Eskin and McDonald, 1991). Moreover, winter oilseeds can be relay-cropped with soybean, thereby providing two income streams in the same year for NCB farmers (Gesch et al., 2014). Consequently, farmers can profit from all three of these winter crops. Using winter oilseed crops for fuel production can supplement food production in the NCB, increase cover crop adoption, and diversify the cropping landscape.

Here, we evaluated the yield potential of winter pennycress, camelina, and canola in western Minnesota and eastern South Dakota over the 2012–2013 and 2013–2014 growing seasons. Additionally, we examined flowering phenology, insect visitation, and nectar production throughout the flowering periods of each crop. We demonstrate that these crops have the potential to provide benefits across three broad areas. They can: (1) provide early forage resources for pollinators, (2) function as traditional cover crops, and (3) provide a seed yield to farmers with value as bio-oil feedstock.

2. Materials and methods

2.1. Plot establishment

Experiments were performed at two sites designated as MN and SD. These sites were the USDA-ARS Swan Lake Research Farm, Stevens County, Minnesota (45.68°N, 95.80°W) on a Barnes loam soil and the USDA-ARS Eastern South Dakota Soil and Water Research Farm, Brookings County, South Dakota (44.20°N, 96.47°W) on a Lamoure silty clay loam during 2012, 2013, and 2014. Treatments were arranged in a randomized complete block design with four replications at each location. Plots were 6.1 by 18.3 m. The previous crop was spring wheat (*Triticum aestivum* L.).

Seeds of pennycress ('Beecher Farms'), winter camelina ('Joelle'), and winter canola ('Wichita') were sown from late August through early September for all four site-years (Table 1). Seeds were planted at 6.7 kg viable seed ha^{-1} (pennycress and camelina) and 11.2 kg viable seed ha^{-1} (canola) at a depth of 1.3 cm and 19 cm row spacing into no-till wheat stubble. Crops in SD failed to establish in fall of 2012 because of drought and were frost-seeded on 1 April 2013. Fertilizer was applied to canola at a rate of 134–45–45–22 kg ha^{-1} of N–P–K–S with 1/3 fertilizer application at fall planting and 2/3 application in spring after snow melt. Pennycress and camelina were fertilized with 90–34–34 kg ha^{-1} N–P–K in spring after snow melt. Fertilizer was broadcast by hand in all plots.

2.2. Flower cover and insect count measures

Flower cover and insect visitation were recorded every 3–5 d throughout anthesis following protocols described by Eberle et al. (2014). The anthesis period was defined as the time from when 30% of the plants in a plot began flowering until when fewer than 30% of the plants were flowering. Flower cover was estimated visually as percent ground cover of open flowers by viewing the crop from above and estimating the area of the plot covered by flowers. Observers counted the number of honey bees, bumble bees, small bees, flies, butterflies, and other insects visiting flowers over a 2 min period per plot. Insect counts were standardized to insects per observer per min. Cumulative pollinator visitation time (pvt) was calculated by integrating the area under the curve of insects observed per minute over the anthesis period.

2.3. Nectar production and flower density

Nectar production during anthesis was measured on crops grown at MN during spring 2014. Weather data on nectar sampling days, including mean temperature, mean relative humidity,