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Integrating winter camelina into maize and soybean cropping systems

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ABSTRACT

Camelina [*Camelina sativa* (L.) Crantz.] is an industrial oilseed crop in the Brassicaceae family with multiple uses. Currently, camelina is not used as a cover crop, but it has the potential to be used as such in maize (*Zea mays* L.)-soybean [*Glycine max* (L.) Merr.] cropping systems. The objective of this study was to determine the agronomic performance of winter camelina intersown as a cover crop into standing soybean or maize prior to their harvest. Experiments were conducted in Fargo, ND in 2014, Prosper, ND, in 2015, and in Morris, MN in 2014 and 2015. The experimental design was a randomized complete block design with a split-plot arrangement with three replicates. The main plot was row spacing (61 and 76 cm in maize, 31 and 61 cm in soybean) while the sub-plot was maize or soybean growth stage at relay-sowing of camelina. Winter camelina was sown on four different dates: Date 1 (SD1), at the same sowing date as maize and soybean, Date 2 (SD2) at V4-V5 of maize and V3-V4 of soybean growth stages, Date 3 (SD3) at 'silking' of maize and R1-R2 stage of soybean, and Date 4 (SD4) after maize and soybean harvest. Camelina establishment into standing maize and soybean largely depended on rainfall after sowing. Camelina intersown on SD1 resulted in lower maize and soybean grain and biomass yield of 14 and 10%, respectively, whereas intersowing after SD2 had no significant effect on yield.. Camelina N accumulation varied between 24 and 59 kg N ha^{-1} and P accumulation ranged between 4.3 and 9.2 kg P ha^{-1} in the spring when sown after maize and between 14 and 57 kg N ha^{-1} and 1.5 and 6.9 kg P ha^{-1} after soybean. Results indicate that camelina intersown after V4-V5 of maize or V3-V4 of soybean stages will likely avoid competition with the primary cash crop. Camelina establishment and winter survival was best when sown after maize and soybean harvest, and tended to be greater in soybean. However, there are many unanswered questions on camelina intersowing management. New research will allow optimization of intersowing management to increase yields of both crops while enhancing ecosystem services.

1. Introduction

Camelina [*Camelina sativa* (L.) Crantz.] seed meal and oil have multiple uses and applications as feedstock for biofuel, animal feed, human food, and many more (Berti et al., 2016). Camelina has been grown since 4000 BCE, although it is not a well-known or widely produced crop. In the last 10 years, abundant new research in camelina uses, genetics, and agronomic management have been published indicating great interest and potential of this crop due to product end-use diversity (Berti et al., 2016).

One new potential use of camelina is as a cover crop in maize-soybean rotations in the Midwest USA. Winter camelina can be direct-sown following the harvest of short-season cereals such as wheat (*Triticum aestivum* L.) (Gesch and Archer, 2013; Berti et al., 2015) and it has the potential to be established by broadcasting into longer season standing crops such as maize and soybean.

Integrating winter camelina into maize-soybean cropping system will likely increase biodiversity, and reduce: i) soil erosion, ii) nitrate leaching, iii) phosphorus run-off, and iv) production input costs, while maintaining or improving the yield of the primary cash crop.

Generally, broadleaf cover crops do not survive most winters in the northern Great Plains (NGP) region of the USA, even when drilled in later summer to early autumn. Therefore, identifying new winter-hardy broadleaf cover crops is necessary for incorporation into the NGP cropping systems.

Winter camelina is very winter hardy and has been demonstrated to be successfully double- and relay-cropped with soybean and forage sorghum [*Sorghum bicolor* (L.) Moench] (Gesch et al., 2014; Berti et al., 2015). In the NGP, winter camelina can be sown during fall (between early-September to mid-October) after a cereal crop harvest. It germinates even when soil temperatures are as low as 1°C (Gesch and Cermak, 2011). Plants established in the autumn remain in the rosette stage over winter and resume growth the following spring after which they bolt, flower, set seed, and mature in early summer (Grady and

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Nleya, 2010).

Planting a cover crop in conventional maize-soybean production systems in the northern regions of the USA is challenging due to the narrow establishment window, short growth period, and limited soil water availability (Bich et al., 2014). In areas with longer season, cover crops can be sown by drilling or aerial broadcasting after harvesting the primary cash crop (Wilson et al., 2014). Unfortunately, when cover crops are broadcast, establishment depends largely on rainfall shortly after sowing and if not received, the probability of failed stand establishment increases (Fisher et al., 2011).

In order to improve establishment of cover crops, many researchers have started investigating the establishment of cover crops by intersowing at early growth stages of maize (V4-V8). Intersowing of cover crops or legumes in winter wheat has been evaluated in Europe (Bergkvist et al., 2011). Most studies report no penalties on grain yield of wheat or oat (*Avena sativa* L.) when cover crops are intercropped into the cereal crop (Bergkvist et al., 2011; Amossé et al., 2013; Neugschwandtner and Kaul, 2014). In maize-soybean systems, most research on intersowing has been done in organic production systems in an effort to reduce weed pressure without decreasing grain yield (Baributsa et al., 2008; Belfry and Van Eerd, 2016).

Intersowing camelina into standing cash crops is not common. However, mixed cropping of camelina, with pea (*Pisum sativum* L.), lupin (*Lupinus angustifolius* L.), or wheat was evaluated in an organic cropping system by Paulsen (2007) in Germany. Both crops were grown and harvested together and sorted by seed size screening post-harvest. Overall, yields of mixed cropping with camelina were similar or lower than the sole crop with good legume plant stand. In years with poor legume stand, camelina was able to fill gaps on grain legume establishment for a higher total yield of both crops as compared with the total yield of sole legumes (Paulsen, 2007). Winter camelina was intercropped with barley (*Hordeum vulgare* L.) in Lithuania in an organic system to reduce weed pressure. After drilling camelina in strips between the rows of barley, weed density decreased by 1.79 times (Raslavicius and Povilaitis, 2013). Additionally, camelina can be grown in mixtures with flax (*Linum usitatissimum* L.), or rape (*Brassica napus* L.), to produce on-farm-biodiesel (Paulsen, 2008, 2011; Paulsen et al., 2011).

Intersowing of winter camelina into standing maize and soybean as a cover crop in the establishment season has not been previously studied. The objective of this study was to determine the overall agronomic performance of intersowing winter camelina as cover crop into a standing soybean and maize to provide soil cover in late fall and early spring, recycle nutrients, and provide secondary grain production in the season after establishment.

2. Materials and methods

2.1. Field description and management

Experiments were conducted at two North Dakota State University research (NDSU) sites at Fargo, ND (46° 89′ N, −96° 82′ W, 274 m elevation) in 2014, and Prosper, ND (46°58′ N, −97° 3′W, elevation 284 m) in 2015, and at the Swan Lake Research Farm, Morris, MN (45° 35′N, −95° 54′W, elevation 344 m) in 2014 and 2015. The soil type in Fargo was a Fargo silty clay soil (fine, montmorillonitic, frigid, Vertic Haplaquoll, with a leached and degraded nitric horizon), while the soil in Prosper was a Kindred-Bearden silty-clay loam (Perella: fine-silty, mixed, superactive Typic Endoaquoll; Bearden: fine-silty, mixed, superactive, frigid Aeric Calciaquoll). The soil type at Morris was a Barnes loam soil (fine-loamy, mixed, superactive, frigid Calcic Hapludoll). The previous crop at all three locations was either oat (*Avena sativa* L.) or soybean and the experimental plots were not tilled.

Daily temperature and rainfall were recorded by the North Dakota Agriculture Weather Network (NDAWN) system at Fargo and Prosper and by an automated weather station at the Swan Lake Research Farm. Soil samples were taken at all locations for analysis at the beginning of each experiment in 2014 and 2015, at both locations before the crops were sown. Soil samples were taken at a 0- to 15-cm depth and tested for pH, organic matter, Olsen P (Olsen et al., 1954), and K, while the NO_3—N analysis was done from the soil samples taken at 0- to 15-cm and 15- to 60-cm depth with Vendrell and Zupancic (1990) method.

2.2. Experiment description

The experimental design was a randomized complete block design with a split-plot arrangement and three replicates. The main plot was the row spacing (61-cm and 76-cm in maize and 31- and 61-cm in soybean) and the sub-plot was the maize or soybean growth stage at the time camelina was intersown into the standing crop. Check plots of maize and soybean were not intersown with camelina. Maize and soybean were analyzed as separate experiments. Experimental units were 7.6 m long and all had four rows of either maize or soybean regardless the row spacing.

The maize hybrid used was 75K85 GEN VT2PRO (85 d maturity, Roundup Ready™). The soybean variety was 13R08N GEN RR2Y (maturity group 0.8 Roundup Ready™). Sowing rates were calculated based on the percentage of pure live seed (PLS), taking purity and germination percentage into account. Soybean seeds were not inoculated before sowing. Targeted plant density was 86,450 and 432,250 plants ha^{-1} for maize and soybean, respectively.

Maize was sown on 22 April, and 29 April 2014 at Morris and Fargo, respectively, and on 22 May and 27 May 2015 at Morris and Prosper, respectively. Maize was sown at a depth of 50 mm (on minimum-till soil) with a 4-cone plot seeder (Wintersteiger Plotseed XL, Salt Lake City, UT) for the 61-cm row spacing and with a 4-row seeder (John Deere MaxEmerge 1730, Ankeny, IA) for the 76-cm row spacing.

Winter camelina was intersown between maize rows on four different dates: Date 1 (SD1), at the same sowing date as maize, Date 2 (SD2) at V4-V5 maize growth stage, Date 3 (SD3) at 'silking' maize growth stage, and Date 4 (SD4) after maize harvest. In Morris, SD2 was sown on 23 June 2014 and 22 June 2015; SD3 on 29 July 2014 and 28 July 2015, and SD4, on 1 October 2014 and 21 October 2015. In Fargo, SD2, SD3, and SD 4 were sown on 2 July, 8 August, and 8 October 2014, respectively. In Prosper, SD2, SD3, and SD4 were sown on 30 June, 9 August, and 21 October 2015, respectively.

For SD1 treatment, camelina was sown with an 8-row cone drill (Wintersteiger Plotseed XL, Salt Lake city, UT), at 15-cm row spacing right after the maize and soybean seeding and off-set by 7.5 cm from the primary crop rows. For the SD2, SD3, and SD4 in maize and soybean, camelina seed was hand-broadcasted without incorporation between the primary crop rows. Having the SD1 drilled and the other sowing dates broadcasted, could have confounded some of the results. This was done, since it is possible to sow at the same time as the main crop, but it is not possible to sow over the crop once is emerged. Nowadays, new sowing equipment is available to allow intersowing in V6-V8 of maize. The camelina seeding rate in both maize and soybean was 10 kg ha^{-1} PLS for all sowing dates. For SD1, seeds were sown to a depth of approximately 1.3 cm.

Soybean was sown on the same dates as maize at Morris in 2014 and 2015 and at Prosper in 2015, using the same equipment as used for sowing maize. The soybean at 31-cm spacing was sown with the same planter as for 61-cm row spacing. Winter camelina was sown on four different dates in soybean: Date 1 (SD1), at the same sowing date as soybean, Date 2 (SD2) at V3-V4 soybean growth stage, Date 3 (SD3) at R1-R2 soybean growth stage, and Date 4 (SD4) after soybean harvest. In Morris, SD2 was on 23 June 2014 and 22 June 2015; SD3 on 29 July 2014 and 28 July 2015; SD4 1 October 2014 and 21 October 2015. In Prosper, SD2, SD3, and SD 4 were sown on 30 June, 9 August, and 22 October 2015, respectively.

Approximately four weeks after sowing the primary crop all plots were fertilized. In 2014, all maize plots in both locations were fertilized