Winter Oilseed Quarterly Update #13: Integration of modern genetic tools to improve winter oilseeds at the University of Minnesota

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Pennycress and winter camelina, members of the Brassica family, are being domesticated for use in the Upper Midwest as cash cover crops. In addition to their use as cover crops, both species have great potential to become economic drivers due to their oil and protein content. At the University of Minnesota, we are using interdisciplinary approaches to solve challenges such as seed loss due to shattering, late maturity, and high levels of anti-nutritional compounds like glucosinolates and erucic acid in pennycress and camelina (Figure 1). These challenges would limit the economic viability of these crops if not solved.

We initiated our pennycress work by utilizing genomics and computational biology to successfully assemble the pennycress draft genome (Dorn et al., 2015). This draft genome has allowed us to use comparative genomics to identify beneficial genes in pennycress based the well-studied model plant Arabidopsis (Chopra et al., 2018). Going further, we evaluated the genetic diversity present among a collection of wild pennycress accessions Frels et al. (2019). Without genetic diversity, our pennycress breeding program would be severely limited and unable to identify improved varieties. We have integrated high-throughput techniques such as next-generation sequencing and genotyping with EMS mutagenesis to successfully stack desirable traits such as early maturity, reduced pod shatter, and reduced seed glucosinolates with improved fatty acid composition (Chopra et al., 2020).

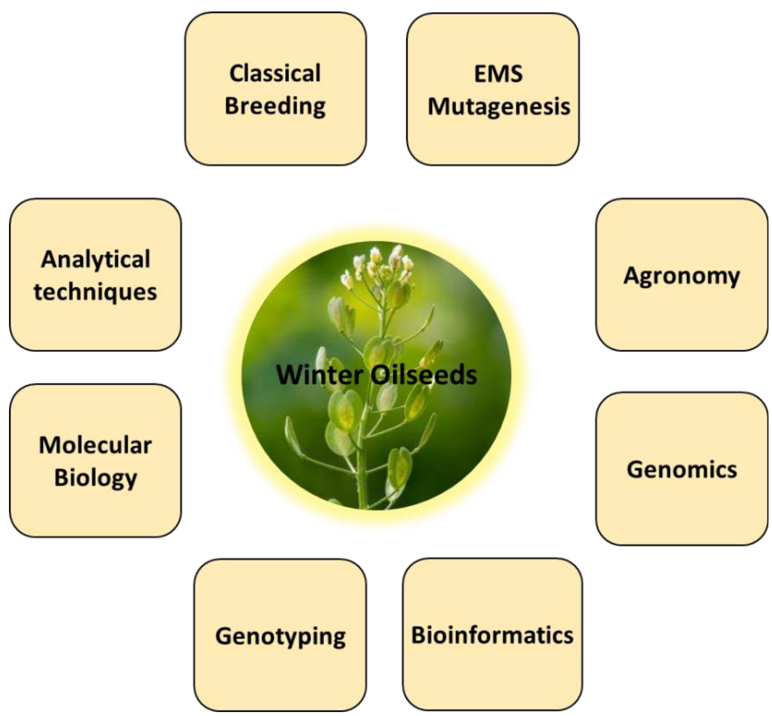

Figure 1. Interdisciplinary approaches involved in pennycress improvement program.

In collaboration with other researchers in the Upper Midwest, we have developed methods to successfully genetically transform pennycress (McGinn et al., 2019). This has enabled us to use cutting-edge CRISPR-Cas9 gene editing techniques in pennycress. A low erucic acid pennycress line was developed by successfully targeting the *fae1* gene using the CRISPR-Cas9 constructs (McGinn et al., 2019). We are also employing various modified versions of CRISPR-Cas9 to regulate the expression of the *rod1* gene, which further improves pennycress oil by making it similar to canola oil. Gene editing can also assist our breeding program by quickly introgressing gene variants needed for pennycress improvement. This can reduce the need for time and labor-intensive back-crossing work.

Our crop improvements efforts are not limited to pennycress. Camelina has a more complex hexaploid genome, which makes it more challenging to breed. However, we are using similar interdisciplinary strategies to improve camelina winter hardiness, glucosinolate content and maturity. This work is now in progress, and we started by phenotypically and genetically characterizing a collection of wild camelina accessions for winter hardiness and early maturity. In addition to testing wild camelina, we have also initiated an EMS mutagenesis approach to induce variation for maturity and other oil and protein quality traits in the winter camelina line "Joelle". Starting in 2019, we screened ~800 M_3/M_4 lines (3-4 generations after the mutagenesis treatment). We identified plants displaying variation for plant architecture, development, oil, and protein content. In addition to classical breeding and EMS mutagenesis-based methods, we also are using CRISPR-Cas9 based genome editing methods to target the genes responsible for biosynthesis of undesired compounds like glucosinolates.

As we identify improved pennycress and camelina lines, we are working with agronomic, supply chains, and food science researchers to determine how these new crops can fit into U.S. cropping systems and food supply chains. Our improved lines are more agronomically desirable and better able to fit into corn-soybean and wheat-soybean rotations. These lines could also be paired with short season summer annuals like dry beans, millet, or sunflowers. Our improved oil and protein lines could be used in new food and feed products. These interdisciplinary collaborations are key to the successful domestication and commercialization of pennycress and winter camelina, and provide new crops to U.S. farmers thatss solve ecosystem and food security challenges.

References

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