Winter Oilseed Grower Bulletin #4: Identifying genotype and environment interactions in pennycress breeding populations

Katherine Frels[1], Ratan Chopra[2], Maninder K. Walia[1], M. Scott Wells[1], M. David Marks[2], Donald Wyse[1], and James A. Anderson[1]

[1]Department of Agronomy and Plant Genetics, [2]Department of Plant and Microbial Biology, University of Minnesota

Pennycress (*Thlaspi arvense* L., Field pennycress) is a new winter annual oilseed-producing cover crop being developed for Minnesota and the Upper Midwest by the University of Minnesota Forever Green Initiative. Historically, pennycress has been considered a weedy species, however, due to its simple genetic structure and close relations with well-known members of the Brassicaceae family and a close relative of canola, rapid progress has been made to domesticate and reduce weedy traits in pennycress [1-3]. Pennycress has many traits required to be a cash cover crop including: extreme winter hardiness, high seed yields, and a short life cycle that allows it to be integrated into the fallow period of existing cropping systems in the Midwest [3-6]. From fall through spring, pennycress provides a protective living cover, reducing nitrogen runoff and soil erosion from farm fields that pollutes water systems [7].

Figure 1. 2017-2018 pennycress advanced yield trial in St. Paul, October 2017.

The University of Minnesota Forever Green Initiative started a pennycress breeding program in 2013 to domesticate and improve pennycress into a profitable cover crop. The main breeding objectives are to develop pennycress lines with reduced pod shatter, high quality oils, high oilseed yield, and that will not develop seed banks in the soil. The first pennycress advanced yield trials were planted in fall 2017 to evaluate the performance of pennycress lines selected for good emergence, early flowering, and high seed yields across four Minnesota locations. Thirty advanced breeding lines plus two check lines were planted in replicated trials in St. Paul, Rosemount, Waseca, and Morris in Sept. 2017 **(Figure 1)**.

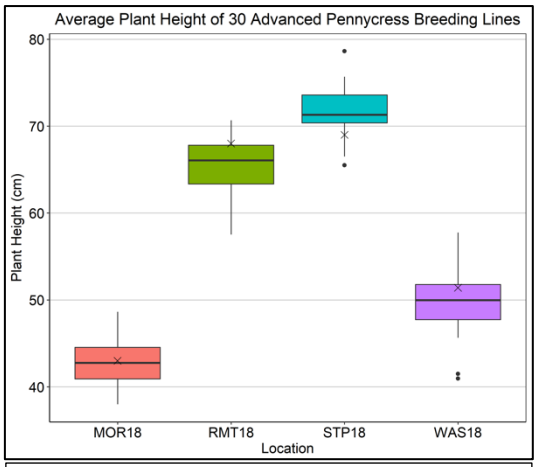

Figure 2. Boxplot showing range and mean of average plant height in the 2017-2018 pennycress advanced yield trial.

Each plot was evaluated for emergence several weeks after planting, and again in the spring to identify any additional emergence or plants killed by winter conditions. Little spring emergence was observed except for some additional emergence at Morris, and no winter killed plants were observed. The main challenge of the 2017-2018 growing season was the heavy snowfall in April and delayed spring. Flowering dates were delayed compared to previous years (average flowering date of May 17, 2018 compared to first week of May in most years). The pennycress plants were, in general, short with limited height variation among lines **(Figure 2)**. After harvest, yield data was

collected, and the seed was subjected to NIR analysis to estimate oil and protein content and levels of the anti-nutritive components erucic acid and glucosinolates [8]. Data was analyzed using a mixed model ANOVA in the statistical software SAS Proc Mixed to evaluate the effect of the four trial locations on the pennycress breeding lines. These results showed that genotype by environment interactions were not significant for any trait except protein content in this trial, however, both genotypes and locations significantly affected all traits **(Table 1)**.

Source	DF	Yield (kg/ha)	Oil Yield (kg/ha)	Emergence	Plant Height (cm)	Protein (% DWB)	Oil (% DWB)	Erucic (% DWB Rapeseed)	Glucosinolates (umol/g)
Emergence Covar.	1	***	**	-	-	-	-	-	-
Location	3	***	***	***	***	*	***	***	***
Entry	31	***	***	***	***	***	***	***	***
Entry*Location	93	NS	NS	NS	NS	***	NS	NS	NS
Error	211								
H^2		**0.40**	**0.44**	**0.55**	**0.62**	**0.82**	**0.72**	**0.72**	**0.57**
Mean		**845.8**	**221.3**	**6.5**	**57.5**	**26.1**	**31.9**	**33.1**	**104.4**

Table 1. ANOVA indicating significance levels of each factor in the analysis model. *, **, *** show significance at p= 0.05, 0.01, 0.001 respectively. Heritability and mean performance across all locations are included.

These results, while unexpected, indicated that pennycress is still a very plastic and adaptable crop. Environmental variation will have a significant effects on pennycress seed yield and oil and protein content. Compared to long domesticated crops like wheat and soybeans, the relationships between seed yield and oil and protein content are not as strong (Figure 3.) In most crops, yield and protein have a strong negative relationship, however, in pennycress, protein content appears to change more due to environmental effects than seed yield (Figure 3B). This could be due to the presence of secondary metabolites such as glucosinolates and fiber that are involved in stress response and can affect total protein content. The UMN pennycress breeding program is working to eliminate glucosinolates from pennycress seeds, and we expect that future pennycress breeding lines will be less plastic and more predictable.

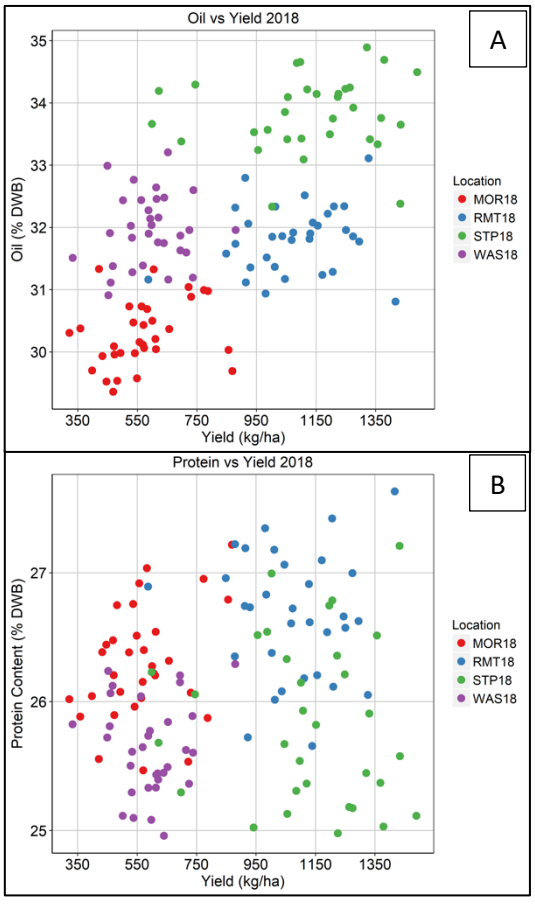

Figure 3. Scatterplots of A) Oil and yield relationship in pennycress; B) Protein and yield relationship in pennycress.

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