Title: Development of Camelina Varieties Resistant to Group 2 Herbicides

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Funding term and duration: 2007-2013

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Background:
Use of ALS inhibitors, or Group 2 herbicides, in the Pacific Northwest continues to be widespread and is probably expanding with the increased popularity and availability of Clearfield wheat varieties. Approximately 300,000 acres of Clearfield wheat varieties were grown in Washington last year and acreage is expected to increase as better varieties are developed. Most of this acreage is sprayed with Beyond® herbicide, an imidazolinone ALS inhibitor. Acreage sprayed with Beyond should not be planted to camelina for several years because of carryover problems. In addition, poor weed control is one of the biggest problems with camelina production. There are currently no herbicides labeled for control of broadleaf weeds and only one for control of grasses.

At least two U.S. companies started camelina breeding programs several years ago but the slow progress in market development (especially meal) of the crop has disappointed investors and we now know of no private breeders in the U.S. The Canadian company Linnaeus has a breeder that works on camelina as well as other oilseeds but is based in Saskatoon. Thus, the private breeding programs that had started working with our herbicide tolerant mutants are unlikely to develop good herbicide tolerant (HT) varieties, especially varieties adapted for PNW agriculture. Development of varieties adapted to the region therefore remains a high priority.

In previous experiments, the SM4 mutant was identified which was tolerant to both imidazolinone and sulfonylurea herbicides and showed higher levels of resistance to both classes than all the other mutants. This mutant was in the Cheyenne background and was crossed to the variety Calena to generate segregating populations to initiate a breeding program. The germplasm release and first variety we will release (objectives 1 and 2, below) will be derived from this population.
Objectives:
The main objective of the project is to release HT germplasm and HT varieties that perform well in the PNW. The specific objectives are to:

1) Release HT germplasm in 2013 that is composed of an improved bulk population derived of approximately 300 F4 derived lines that are homozygous for the SM4 gene.

2) Release an HT variety composed of the best performing line from the SM4 x Calena breeding population. We expect this variety to perform at least as well as existing varieties, like the parents, and enable camelina production with much less risk of herbicide damage. The target date for this release is Fall 2014.

3) Release one or more advanced HT varieties with better agronomic performance and oil yield than the current varieties.

Methods:
The initial HT breeding population was derived from a very large SM4 x Calena F2 population. It was advanced by selection for vigor, seed yield and herbicide tolerance through the F4 generation to establish F4-derived lines. These were amplified and planted in replicated plots at the Wilke Farm in Davenport and the Palouse Conservation Field Station in Pullman. The Wilke Farm plots suffered from cross contamination; the new no-till plot drill we purchased with the WSU wheat breeding programs had some problems that were exacerbated by the light seed weight of camelina and these plots were therefore not used to advance lines. The replicated plots in the Pullman nursery allowed us to examine traits like seedling vigor, competitiveness and seed yield. There was minimal variation for maturity date or seed size so this data was not recorded.

Germplasm was collected from different sources to broaden the genetic base of the breeding program. This included the public collection from the National Genetic Resources Program which were all grown in Pullman for observation. Variation was observed for a variety of traits including seed yield, height, flowering time and seed size. Crosses were made between favorite HT breeding lines and germplasm accessions to improve specific traits like oil content and seed size. Populations derived from these crosses will likely result in our second generation of HT varieties (objective 3).

Results and Discussion:
Fifty lines were selected for advancement from 336 lines included in the Pullman breeding nursery. Selections were based on plot yields and ratings of seedling competitiveness. Seed from these lines will be included in 2013 spring nurseries at three sites and again compared to the parents for yield potential. Oil analysis will be conducted on seed from both seasons and selections will be made from the highest yielding lines based on oil content and possibly composition. We found the oil content in the two parent lines, Cheyenne and Calena to be pretty similar, so the breeding lines may not vary extensively, but they will still need to be analyzed. Some differences were observed between the parents in oil composition (e.g. oleic acid levels) but environmental effects and/or G x E were very extensive. Our initial HT germplasm release and varieties will not be selected for unique oil composition because there is little demand for this at the present.

Of particular importance for the HT tolerant lines is that they perform well when grown on land which previously had applications of Beyond herbicide. While we did not have large amounts of seed of any of
our breeding lines until recently, we were able to make a bulk population of many of our HT lines and
had sufficient seed for testing. Replicated plots of the HT-bulk population yielded essentially the same
as plots of Calena and Cheyenne in the control plots where no Beyond had been applied to wheat the
previous seasons. However, in plots where the recommended rate of Beyond was applied, or where
two times or four times the recommended rate had been applied, the HT-bulk population out-yielded
the control parental varieties. In the plots where four times the recommended rate had been applied,
most plants of the parental varieties died without making seed, while HT-bulk yielded the same as the
untreated plots. Camellina lines carrying the SM4 mutation were therefore considered sufficiently
tolerant to Beyond to prevent damage when following a Clearfield wheat crop.

Crosses were made between our five highest yielding breeding lines and other germplasm found to have
desirable traits. While comparing diverse germplasm, the lines with larger seed size seemed to have the
best early seedling vigor which is an important consideration for competition with weeds. Oil content
will be another important trait and at least one of the accessions collected is reported to have higher oil
content than the varieties currently grown.

Impact/Potential Outcomes:
We expect HT varieties to improve acceptance of the crop to growers by reducing the risk of
encountering herbicide carryover damage. This will be particularly true of growers that are not
currently growing oilseed crops, or non-cereal rotation crops in general. These growers have not
avoided herbicides with long residual activities in the soil and are likely using a wider variety of
chemistries in their weed control programs.

Affiliated projects and funding:
We are in the process of making mapping populations for genetic analysis of important traits like seed
size, earliness and oil content. Some of these are nearly complete. These projects would be more
suitable for graduate students who could contribute to a breeding program but need a more
fundamental objective for their main emphasis. We hope to find opportunities for financial support of
these types of projects in the near future.

Presentations and Publications:
in the Dryland Pacific Northwest. WSU Extension Fact Sheet FS073E


Workshop, Colfax, WA (presentation).

Hulbert, S. Oilseed Variety Development: A Key to Successful Crop Adaptation. November 13, 2012,
Bioenergy Research Symposium, Seattle, WA (presentation).
**Proposed Future Research/Extension for 2013/2014**

We are planning to submit a variety release publication this spring which will make the HT breeding material available and make any breeding programs we do not know of aware of it. We will not be ready to release a variety in the next year, but will rather look towards fall of 2014 when we will have had two more field seasons to select the best line. We will continue to make growers aware of the project as we have this year through the oilseed meeting, direct seed breakfasts and winter grower meetings.

Research will focus on selecting the best line in multiple locations for the first HT camelina variety. We will simultaneously be selecting and advancing material for subsequent HT varieties with additional benefits.

![Image of camelina seeds](image.jpg)

**Figure 1.** Variation for seed size in camelina accessions.