Evaluation of Three Oilseed Biofuel Species in Colorado Environments

Shusong Zheng, Jean-Nicolas Enjalbert, Patrick Byrne*, Jerry Johnson

Dept. of Soil and Crop Sciences, Colorado State University, Fort Collins, CO 80523

Introduction

Biodiesel and straight vegetable oil (SVO) are produced from oil extracted from oilseed crops, including a number of species in the family *Brassicaceae:* canola (*Brassica napus*), Indian mustard (*B. juncea*), Ethiopian mustard (*B. carinata*), and camelina (*Camelina sativa*). Due to their early maturity, *Brassica* oilseed crops are excellent candidates for rotation in the winter wheat cropping system. Including such a crop in the rotation will increase crop diversity, reduce chemical use, and increase profits (Gan et al., 2007). Importantly for Colorado, oilseeds offer an option that fully use the precipitations in the spring and early summer and reduce water use compared to corn by adopting limited irrigation system.

Stable seed production under variable conditions and compatibility with the dominant winter wheat cropping system are keys for successful biofuel production from these crops in Colorado. Although commercial canola hybrids are currently available, their lack of heat and drought tolerance makes them poorly adapted to Colorado, especially under rainfed conditions. Indian mustard, Ethiopian mustard, and camelina were found to be more drought and heat tolerant in some environments (Gan et al., 2007; Wright et al., 1995; Alemayehu and Becker, 2001). However, they have yet not been intensively evaluated in Colorado and adjacent states. Thus, germplasm introduction and evaluation under Colorado conditions is the starting point for oilseed cultivar development.

Reference

Alemayehu et al. 2001. Plant Breeding 120:331-335.

Gan Y.et al. 2007. Agronomy Journal 99:1208-1218.

Wright, et al. 1995. Field Crops Research 42:1-13.

Objectives

The goal of the proposed project was to identify the most promising oilseed species and accessions for use as biofuel crops in Colorado.

Specific objectives were :

- To evaluate a broad range of germplasm of Indian mustard (*B. juncea), Ethiopian mustard (B. carinata), and* camelina *(C. sativa)* for agronomic traits, oil properties, and adaptation to Colorado environments.
- To determine drought tolerance of the germplasm by growing the accessions under irrigated and rainfed field conditions.

Materials and Methods

We evaluated 102 accessions of *B. juncea* from the USDA GRIN system, 88 accessions of *Camelina sativa*, and 39 accessions of *B. carinata* from Germany's IPK germplasm bank.

Plants were grown in one-row plots with two replications under irrigated and rainfed conditions at CSU's Agricultural Research, Development and Education Center (ARDEC) in spring, 2008 . The plots were 1 foot wide and 4 feet long. The field was arranged in an alpha-lattice incomplete block design (Fig. 1).

Fig. 1. *Field evaluation of B. juncea, B. carinata, and C. sativa at ARDEC, 2008*

Results

Irrigation	Rainfed			Irrigated		
Species	***B. juncea***	***B. carinata***	***C. sativa***	***B. juncea***	***B. carinata***	***C. sativa***
Days To Flower (days)	50.4 (39.0-63.0)	60.7 (40.0-69.0)	49.7 (44.0-50.0)	52.2 (39.0-65.0)	60.7 (45.0-70.0)	50.7 (45.0-51.0)
Yield/Plant (g)	0.4 (0.05-2.0)	0.3 (0.1-0.7)	0.3 (0.03-1.4)	1.3 (0.03-8.3)	1.1 (0.2-2.4)	0.6 (0.01-7.8)
Biomass/Plant (g)	1.9 (0.4-10.5)	2.9 (0.8-7.2)	2.1 (0.7-5.9)	5.4 (0.1-30.2)	6.3 (2.3-15.2)	2.8 (0.4-24.6)
Plant Height (cm)	65.7 (32.0-96.8)	51.9 (32.4-77.0)	38.8 (25.0-50.8)	92.0 (30.0-146.6)	101.4 (68.0-128.0)	54.8 (27.0-73.2)
1000 seed weight (g)	2.1 (0.3-4.3)	3.7 (2.5-5.1)	1.0 (0.1-1.4)	2.9 (1.0-4.5)	3.5 (1.8-6.0)	1.0 (0.7-1.4)
Oil dw (%)	36.4 (28.1-44.7)	26.7 (20.1-34.4)		37.4 (30.7-47.2)	32.3 (22.6-37.9)	
C18_1 fatty acid (%)	69.9 (53.3-76.2)	64.6 (56.2-70.9)	18.4 (13.8-24.7)	68.5 (53.3-76.2)	68.3 (63.7-72.0)	18.1 (14.4-38.8)
C18_3 fatty acid (%)	3.6 (1.1-7.3)	7.3 (5.1-9.7)	29.5 (24.0-34.6)	5.5 (1.2-9.4)	8.3 (5.2-11.7)	30.6 (21.8-36.9)
Glucosinolate (uMol/g)	127.9 (77-167.7)	146.6 (123.5-174.8)		122.4 (64.4-157.8)	117.0 (88.8-155.2)	

Table 1. *Trait means and their ranges for B. juncea, B. carinata, and C. sativa accessions grown at ARDEC, 2008*

Results (continued)

A high degree of variation was observed for all the traits, including emergence, maturity habit, flea beetle tolerance, plant stature traits, and yield (Table 1). Drought stress reduced the value of most yield related traits. Each species has its own advantages and disadvantages as discussed below:

B. juncea

Advantages

- Good emergence except those with seed dormancy
- Appropriate maturity (Fig. 2.)
  - Life cycle: Rainfed=88 days; Irrigated =96 days
- Relatively drought tolerant
  - Yield/plant: Rainfed=0.4g; Irrigated=1.4g
- Highest oil content among the three species
  - Rainfed=36%, max=45%; Irrigated= 37%, max=47%

Fig.2. *Early flowering of B. juncea plots*

Disadvantages

- Flea beetle damage at seedling and flowering stages (Fig. 3)
- Aphid damage at flowering and seed filling stages
- Bird feeding damage
- Stem lodging for some accessions (Fig. 4)
- High glucosinolate content
  - Rainfed=128 uMol/g; Irrigated=122 uMol/g

Fig.3*. Flea beetles*

Fig.4*. Stem lodging*

B. carinata

Advantages

- Very good emergence (Fig. 5)
- Large seed size; 1000 seed wt:
  - Rainfed=3.7g, max=5.1g; Irrigated=3.5g, max=6.0g
- High biomass production (Fig. 6)
  - Rainfed=2.9g/plant; Irrigated=6.3g/plant
- Strong stems/little stem lodging

Fig.5*. Good emergence*

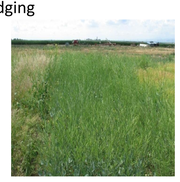

Fig.6*. High plant vigor*

Fig.7*. Flea beetle*

Disadvantages

- Flea beetle and aphid damage at flowering stage (Fig. 7)
- Some accessions flowered too late and suffered from heat stress (Fig. 8)
  - Life cycle: Rainfed=104 days; Irrigated=108 days
- High glucosinolate content
  - Rainfed=146.6 uMol/g; Irrigated=117 uMol/g
- Low seed oil content
  - Rainfed=27%, max=34%; Irrigated=32%, max=38%

Fig.8*. Late flowering*

Results (continued)

C. sativa

Advantages

- Appropriate maturity (Fig. 9)
  - Days to flowering: Rainfed=50 days; Irrigated=50 days
- No flea beetle or aphid damage
- Very high omega 3 fatty acid (C18:3) content: Rainfed=29.5%; Irrigated=30.6%
- Low glucosinolate content (<20 uMol/g)

Fig.9*. Early maturity*

Disadvantages

- Low emergence
  - 1000 seed weight: Rainfed=1.0 g, max=1.4 g; Irrigated=1.0 g, max=1.4 g
- Indeterminate maturity leading to shattering: (Fig. 10)
- Medium oil content: 30-35%

Fig.10*. Indeterminate maturity*

Summary

We evaluated a large collection of *Brassica juncea*, *B. carinata*, and *Camelina sativa* under irrigated and rainfed conditions at ARDEC in 2008. A high degree of variation was observed for all the traits, including emergence, maturity habit, flea beetle tolerance, plant stature traits, and yield. *B. juncea* accessions were adapted to the Colorado crop rotation and had the highest seed oil content among the three species, but vulnerable to flea beetle and aphid damage. *B. carinata* had the largest seed size and highest emergence among the three species, but some accessions were too late in flowering and were exposed to high temperature stress in the summer; some accessions had lower than 20% oil content. *C. sativa* was free of flea beetle and aphid damage throughout the crop season and readily fit into the Colorado crop rotation, but had very low emergence and low thousand-seed weights. All *B. juncea* and *B. carinata* accessions had above 100 umol/g glucosinolate in the seeds, whereas all *C. sativa* accessions had low glucosinolate, less than 20 umol/g in the seeds. All three species have the potential to become successful oilseed crops in Colorado, but all need additional breeding efforts.

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***Contact: Patrick Byrne, Patrick.Byrne@ColoState.EDU**