EVALUATION OF SEVEN SPECIES OF OILSEED CRUCIFERAE FOR AGRONOMIC POTENTIAL IN THE PACIFIC NORTHWEST

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INTRODUCTION

Production of spring rapeseed and Canola (*Brassica napus* L. or *B. campestris* L.) in most of the Pacific Northwest has been limited by poor stand establishment caused by flea beetle (*Phyllotreta* spp.) feeding on young seedlings (Auld et al. 1977: Auld et al. 1978; Auld et al. 1980; Kephart et al. 1988). Even fields with good plant establishment have often yielded less than 1,000 kilograms per hectare (kg ha) due to heat stress during flowering and seed fill. Damage caused by two species of aphids [cabbage aphid, *Brevicoryne brassicae* (L.) and turnip aphid, *Liaphis erysimis* (Kraft.)] has also reduced seed yields of spring rapeseed crops in this region. Pests and lack of adaptation have historically made production of spring rapeseed economically uncompetitive.

During 1988 and 1989, six species of *Brassica* and a single species of *Eruca* were evaluated to determine if they were adapted to the Mediterranean climate of the Pacific Northwest area of the United States (U.S.). These seven species have been grown as oilseed crops in Europe, Asia or Africa (Downey and Robbelen 1989). The agronomic potential and genetic diversity of current germplasm accessions of two of the most promising species were also evaluated during the 1989 and 1990 growing seasons.

MATERIALS AND METHODS

Species Evaluation-1988 and 1989:

Five accessions from the University of California-Davis (UCD) germplasm collection were randomly selected to represent each of the seven species. The UCD germplasm collection was made by Dr. Paul Knowles and is one of the most extensive currently available. Due to the limited quantity of seed available for each accession, individual plots consisted of two rows spaced 15 centimeters (cm) apart. In 1988, the plots were 2.4 meters (m) in length and in 1989 4.2 m in length. In both 1988 and 1989, the study was replicated three times using a split plot design with the species assigned as main plots and accessions within a species randomized as subplots. Plots were planted on 1 m centers with an experimental planter equipped with double disc openers and packing wheels to ensure firm soil contact around the small seeds.

The 1988 study was seeded on April 27 at Moscow, ID, in a field in which spring peas (*Pisum sativum* L.) had been green manured the previous year. No additional fertilizer was applied. Flea beetle control required applications of 1.7 kg ha^{-1} of carbaryl (1-Naphthyl N-methyl-carbamate) on May 14 and 1.7 kg ha^{-1} of permethrin [3-(phenoxphenyl)methyl(1RS)-cis,trans-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropane carboxylate] on May 24 and June 13. Aphids were controlled by a single application of 1.4 kg ha^{-1} malathion (diethyl mercaptosuccinate, S-ester with O,Odimethyl phosphorodithioate) on July 12.

The 1989 study was seeded on April 26 in a field at Moscow, ID, which had produced a barley (Hordeum vulgare) crop the previous year. To ensure adequate fertility, 76 kg ha^{-1} of nitrogen was applied as ammonium nitrate (34-0-0) prior to planting. In 1989, flea beetles were controlled by applications of 2.5 kg ha^{-1} of carbaryl on May 19, May 22, June 1 and June 5. Aphids were controlled by applying 1.4 kg ha^{-1} of malathion on July 5 and July 13.

Oil content was determined by the University of Idaho using a Newport MKIIIA Nuclear Magnetic Resonance (NMR) instrument on 12 g of oven-dried, open-pollinated seed obtained from each plot. The NMR was calibrated using the variety Bridger as the standard. All samples were analyzed with a 32 second integration period.

Germplasm Evaluation-1989 and 1990:

Brassica hirta. The 1989 B. hirta germplasm evaluation study contained 156 accessions and two spring rapeseed varieties. The study was maintained using the procedures described for the other 1989 studies with the following exceptions. Individual plots consisted of two rows spaced 15 cm apart and 3.5 m in length. Plots were planted on 1 m centers using a randomized complete block design with two replications.

In 1990, the B. hirta accessions were evaluated in two trials. The two row plot contained 31 accessions and the six row plots had 28 accessions of B. hirta and three commercial varieties of rapeseed. Both trials were planted on April 19, 1990. The plots were planted and maintained using the procedures described above.

Brassica juncea. The 1990 B. juncea trial contained 383 accessions and 9 commercial varieties. This study was planted on April 18, 1990 in a field which had oats (Avena sativa) grown the previous year. The plots were planted and maintained using the same procedures described above with the following exceptions. Individual plots consisted of two rows and the trial had two replications. The study was fertilized with 112 kg ha^{-1} of nitrogen and weed control was achieved with applications of 1.8 l ha^{-1} of trifluralin (a,a,a-Trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) and 2.9 l ha^{-1} of triallate (S-(2,3,3-Trichloroallyl) diisopropylthiocarbamate).

Data from all trials were subjected to analyses of variance and means were separated using a Fishers protected Least Significant Difference (LSD) test at the 0.05 level of probability.

RESULTS AND DISCUSSIONS

Species Evaluation:

The seven species produced seed yields which ranged from 1.1 to 2.8 megagram per hectare (mg ha^{-1}) averaged over both the 1988 and 1989 studies (Table 1). The B. hirta accessions produced the highest average seed yields in both years of the study. The average oil contents of the seven species ranged from 32.8% for B. campestris to only 25.2% for B. hirta. The B. hirta accessions produced the largest seed while the B. nigra (L.) Koch accessions produced the smallest seed.

The 35 individual accessions had average seed yields which ranged from 0.5 to more than 3.5 mg ha^{-1} (Gareau et al. 1990). In both years, the B. hirta accessions UCD 79 and UCD 1272 produced the highest average seed yields. These accessions also had low levels of oil and relatively large seed size. Commercial seed yields of rapeseed or Canola must exceed 2.2 mg ha^{-1} to be economically competitive with other spring planted crops currently grown in the Pacific Northwest. Both the species and individual accessions within a species showed significant variation for both oil content and seed size in these trials.

Germplasm Evaluation:

Brassica hirta. In 1989, the 156 accessions of B. hirta which had been obtained from germplasm collections around the world produced seed yields which ranged from 0.5 to 4.8 mg ha^{-1} and averaged 2.3 mg ha^{-1} (Gareau et al. 1990). The two spring rapeseed varieties used as controls in this trial, Tobin (B. campestris) and Reston (B. napus) had seed yields of only 0.9 and 0.6 mg ha^{-1}, respectively. Twenty-three of the accessions produced seed yields in excess of 3.0 mg ha^{-1} indicative of the very high seed yield potential of this species of mustard. Oil contents of the accessions ranged from 21.8 to 32.6% and averaged 28.7%. Tobin and Reston, when grown in the same conditions, had oil contents of 35.2 and 39.5%, respectively.

The two 1990 trials of B. hirta differed in relative seed yield, reflecting the inflated yield potential often observed in the smaller two row plots (Gareau et al. 1990). The two row plots had average seed yields of 3.5 mg ha^{-1} while the six row plots grown nearby had average seed yields of only 1.0 mg ha^{-1}. Seven accessions from the replicated six row plots produced in excess of 1.4 mg ha^{-1} despite the extremely dry weather observed during the summer of 1990. Oil content of all of the B. hirta accessions evaluated in 1990 were less than 33%. Fatty acid composition of 35 select lines B. hirta showed a wide range of variation. Four of the lines obtained from Agriculture Canada had less than 8% erucic acid, but Canola oils marketed in the U.S. must have less than 2% erucic acid as required by the Food and Drug Administration. This indicates that additional selection will be necessary to improve both the meal and the oil if B. hirta is to be developed as an economically competitive oilseed crop.

Brassica juncea. The 383 accessions and 9 commercial varieties of B. juncea evaluated in 1990 produced seed yields which ranged from 0.3 to 10.3 mg ha^{-1} in small plots at Moscow, ID (Gareau et al. 1990). Four accessions, 72-525, Commercial Brown (ComBrown), 77-18 and Juzanka, produced excellent seed yields and appeared to be well adapted to the Pacific Northwest. Oil contents of the B. juncea accessions and varieties ranged from 28.6 to 41.1%. Only two accessions, Jubileja and 77-978, had greater than 40% oil content indicating that commercial varieties of B. juncea would need to be selected for this important trait.

SUMMARY AND CONCLUSIONS

Experiments conducted in 1988 and 1989 at Moscow, ID, indicated that two species, B. hirta and B. juncea, have the best potential to be developed as spring planted oilseed crops in the Pacific Northwest. However, for these species to be grown as commercial crops, varieties must be developed which combine high seed yield potential with specific quality characteristics. These varieties would need to produce oil contents exceeding 40% and produce either edible (Canola) oils with less than 2% erucic acid or industrial oils with greater than 55% erucic acid. These varieties should also produce meals containing less than 30 μmoles g^{-1} of defatted meal to ensure full economic value of the seed. The ability of these species to tolerate insects, diseases, heat and drought stresses would allow the production of spring rapeseed across much of the Pacific Northwest and the Northern Plains of the U.S.

In our studies, B. hirta had excellent agronomic potential but currently available varieties and accessions have low oil contents, high levels of glucosinolates and intermediate levels of erucic acid in the oil. Selection of Canola and industrial quality varieties of B. hirta would allow expanded production of this drought and pest tolerant species. B. hirta (Sinapis alba L.) is grown as white mustard on approximately 57,000 hectares (140,000 acres) annually in Canada for use as condiment mustard (Downey and Robbelen 1989). This species has shown tolerance to both flea beetles and selected species of aphids (Lamb 1980; Putman 1977). White mustard can tolerate drought and high temperatures during flowering and seed fill (Downey et al. 1975; Downey and Robbelen 1989). Selected accessions of B. hirta have been reported to have oil contents which exceed 42% (Weiss 1983). Erucic acid levels have ranged from approximately 5% to in excess of 55% (Persson 1986). All existing accessions have had relatively high levels of glucosinolates which reduces quality of the meal residue remaining after oil extraction. Since most commercial varieties of this species were developed for production of condiment mustard, only limited selection has been practiced on characteristics needed in an oilseed crop.

Brassica juncea has been grown as brown or Oriental mustard on approximately 85,000 hectares (210,000 acres) annually in Canada (Downey and Robbelen 1989). This highly drought tolerant species originated in the Middle East but has been widely grown across Europe, Asia and Africa (Downey and Robbelen 1989). In our studies this species has produced good seed yields and oil contents which approach 40%. Researchers in Canada recently reported the development of experimental lines of B. juncea which produce Canola quality seed. Canola quality varieties should be available from Canada within three to five years (Love et al. 1990). Incorporation of these quality characteristics into adapted accessions could allow rapid development of Canola varieties adapted to the northern U.S.

The rapeseed program at the University of Idaho will continue to evaluate accessions of both B. hirta and B. juncea for both agronomic potential and oilseed quality over the next few years. Lines with promising characteristics will be hybridized and segregating lines selected for both agronomic performance and chemical composition. The development of improved varieties which combine high seed yield potential with specific fatty acid composition and low levels of glucosinolates would allow expanded production of spring planted Brassica species across the Pacific Northwest.

REFERENCES

AULD, D.L., MURRAY, G.A., MINK, E.E. and STUDER, B.W. 1977. Alternative crops for Northern Idaho. University of Idaho, Moscow. 4 p.

AULD, D.L., MURRAY, G.A., BENSON, J.A., MINK, E.E., VAN SLYKE, C.G. and STUDER, B.W. 1978. Alternate crops for Northern Idaho - 1977. University of Idaho, Moscow. 10 p.

AULD, D.L., MURRAY, G.A., CARNAHAN, G.G., BENSON, J.A. and STUDER, B.W. 1980. Flax, mustard, spring rape: alternative crops for Idaho's cooler regions. University of Idaho, Moscow. 10 p.

DOWNEY, R.K., STRINGAM, G.R., MCGREGOR, D.I. and STEPHANSSON, B.R. 1975. Breeding rapeseed and mustard crops. In: Oilseed and Pulse Crops in Western Canada. J.T. Harapiak (ed.). Western Cooperative Fertilizers Limited, Calgary. pp. 157-183.

DOWNEY, R.K. and ROBBELEN, G. 1989. Brassica Species. In: Oil Crops of the World. G. Robbelen, R.K. Downey and A. Ashri (eds.). McGraw-Hill, New York. pp. 339-362.

GAREAU, R.M., AULD, D.L. and HEIKKINEN, M.K. 1990. Evaluation of Seven Species of Oilseeds as Spring Planted Crops for the Pacific Northwest. University of Idaho, Moscow. 43 p.

KEPHART, K.D., RICE, M.E., MCCAFFREY, J.P., and MURRAY, G.A. 1988. Spring rapeseed culture in Idaho. University of Idaho, Moscow. 10 p.

LAMB, R.J. 1980. Hairs protect pods of mustard (Brassica hirta 'Gisilba') from flea beetle feeding damage. Can. J. Plant Sci. 60: 1439-1440.

LOVE, H.K., RAKOW, G., RANEY, J.P. and DOWNEY R.K. 1990. Genetic control of 2-propenyl and 3-butenyl glucosinolate synthesis in mustard. Can. J. Plant Sci. 70: 425-429.

PERSSON, C. 1986. High erucic oil from white mustard (Sinapis alba L.) for technical use. Cruciferae Newsletter 11: 134.

PUTMAN, L.G. 1977. Response of four Brassica seed crop species to attack by the Crucifer flea beetle, Phyllotreta Cruciferae. Can. J. Plant Sci. 57: 987-989.

WEISS, E.A. 1983. Oilseed Crops. In: Tropical Agricultural Series. G. Wrigley (ed.). Longman, London. pp. 169-172.

Table 1. Average seed yield, oil content and seed weight of five accessions of six species of Brassica and a single species of Eruca during 1988 and 1989 at Moscow, ID.

Species*	Seed Yield			Seed Yield			Seed Yield		
	1988	1989	Ave	1988	1989	Ave	1988	1989	Ave
	------Mg/ha-----			--------%--------			------g/100------		
B. hirta	2.1	3.5	2.8	22.7	27.7	25.2	0.49	0.51	0.50
B. carinata	1.1	2.5	1.8	25.6	33.6	29.5	0.41	0.38	0.39
B. nigra	1.2	1.9	1.6	25.8	33.7	29.8	0.21	0.17	0.19
B. juncea	0.8	2.0	1.2	26.8	34.1	30.5	0.34	0.38	0.39
Eruca sativa	0.7	1.6	1.2	26.5	30.7	28.6	0.31	0.20	0.25
B. tournefortii	0.6	1.6	1.1	25.9	31.8	28.8	0.24	0.24	0.24
B. campestris	0.7	1.2	0.9	29.6	35.9	32.8	0.34	0.34	0.34
$LSD_{(P=0.05)}$	1.1	1.2		2.3	4.3		0.18	0.06	

* B. hirta is known as both white or yellow mustard and as Sinapsis alba L.
B. carinata is also known as Abysinnian mustard.
B. nigra is also known as black mustard.
B. juncea is also known as brown, Oriental or Indian mustard.
B. campestris is also known as B. rapa L., birdsrape mustard and Polish rape.
B. tournefortii is also known as wild mustard.
Eruca sativa is also known as rocket salad.