EVALUATION OF BRASSICA SPECIES IN CALIFORNIA

D. B. Cohen and P. F. Knowles
University of California, Davis

Since 1977-78 the University of California has evaluated over 2000 entries of several Brassica species for their potential as winter oilseed crops. Our interest was stimulated by: the improvement of edible oil and meal quality in rapeseed and turnip rapeseed; the successful use of *Brassica* oilseed species in other areas with a Mediterranean-type climate; the need for a winter crop alternative to cereals, particularly for dryland areas of California; the possibility of *Brassica* species providing seed for crushing in the spring when oilseed supplies are sometime scarce, and the successful performance of many weedy relatives including *B. kaber* (D.C.) Wheeler, *B. nigra* (L.) Koch and *B. campestris* L. Rapeseed and mustard species are not now grown for oil in California.

Materials and Methods

Sources of introductions are given in Table 1. Many of the South Asian entries were obtained by Knowles in a collection trip covering almost the entire country of Pakistan in 1976. Most of the other introductions were obtained from either the USDA Plant Introduction Station at Ames, Iowa, or the USDA Northern Regional Research Center at Peoria, Illinois. Dr. J. I. Lee, Crop Experiment Station, Suweon, Korea, supplied 377 entries of *B. napus*. Dr. T. J. Orton, formerly of the Vegetable Crops Department, UC Davis, supplied 19 entries which he had collected in the People's Republic of China. Canadian, European, Pakistani, Indian and Australian *Brassica* breeders also supplied entries.

Brassica species were grown at UC Davis as rainfed winter crops with no irrigation after planting. Nitrogen was applied at 55-110 kg/ha and Treflan was incorporated prior to planting for weed control. In 1977-78 1400 introductions selected by Knowles were grown in single-row plots 3-4 m long and spaced 75 cm apart with every 10th row a commercial cultivar of the same species. In subsequent years, in addition to genetic nurseries, the most promising introductions or selections from introductions were advanced to 4-replicate yield tests. For yield tests there were 4-row plots with rows 30 cm apart and 7.5 m long. The center two rows were hand-harvested and threshed in a Vogel thresher to determine seed yield. Special increase blocks of *B. juncea* and *B. carinata* were direct combined using a Hegge small plot harvester. Oil percent determinations were made by NMR. *Brassica* species were planted from the end of November to the end of December in all tests except 1981-82 when seeds were sown on Feb. 20, 1982. By the 1981-82 tests, some entries from a limited *B. juncea* breeding program were included in yield tests.

In addition to the described trials there also were Cooperative Extension trials in 5 counties. These were usually strip tests sown in farmers' fields with commercial grain drills, windrowed towards maturity and combine harvested when seeds were ripe. Mr. T. E. Kearney, Yolo County farm advisor, was a close associate in evaluating *Brassica* species (Knowles et al., 1981). Mr. M. A. Rana assisted in the collection of Brassica species in Pakistan and re-evaluated most of the B. juncea entries in a two-replicate nursery at Davis in 1980-81 (Rana, 1982). The potential uses of Brassica species as leaf protein or leaf forage crops were evaluated in cooperation with Dr. C. K. Lyon of the USDA-Western Regional Research Center, Berkeley, California (Lyon et al., 1983). Data from these and other, more minor, tests supports the information presented here.

Results and Discussion

No yield tests were grown at Davis in 1977-78 and those in 1978-79 were damaged by rain or high winds at harvest. Yield results from the remaining three years are given in Table 2. Entries of B. nigra, B. hirta, B. tournefortii, Eruca sativa and Raphanus sativa were never promising enough to be included in replicated yield trials. In all years, B. carinata and B. juncea were the highest yielding species, followed by spring type B. napus. B. campestris entries consistently had the lowest yields. Data from 1980-81 for some seed traits and plant development characteristics are given in Tables 3 and 4. Trends illustrated here were representative of all trial years and are discussed below for each species.

B. juncea

Indian mustard was extremely variable in most characteristics. Early, short summer types from Canada or Europe were late, tall and low yielding in California. Lines from South Asia, mostly from India and Pakistan, were relatively early and were selected for medium height. Selected B. juncea entries were well adapted to California conditions. They had vigorous early growth with rapid canopy development and were highly competitive with winter weeds in tests without herbicide treatment. In general, selected lines had strong stems, were erect or only partially lodged at maturity and were resistant to shattering. Their period of flowering ended before significant aphid infestation occurred.

B. juncea entries were easily direct combined when ripe, when proper harvester adjustments were made. Seed size varied from small (less than 3 g/1000 seeds) to large 6 g/1000 seeds) and very large lines were selected (9 g/1000 seeds). Increased shatter resistance was associated with increasing seed size. Cohen developed large, yellow seeded, early maturing lines from crosses of South Asian and European types.

Oil content at Davis ranged from 34-40% and seed yields were high. Some variation was found in fatty acid composition but none were found to be erucic acid-free. Fortunately erucic acid-free lines became available from Australia (Kirk and Oram, 1981). A glucosinolate-free selection was recently found at Davis in an introduction from the People's Republic of China (Cohen et al., 1983). It is apparent that well adapted double-zero types of Indian mustard can now be produced which will be equal in seed meal and oil quality to the double-zero cultivars of common and turnip rapeseed now available from Canada and Europe.

B. carinata

Only a relatively small number of Ethiopian mustard entries were evaluated. On average, B. carinata lines had higher seed yield than other species. However, they were late in maturing, tall, and had an extended period of flowering and ripening that could interfere with a timely harvest. Resistance to shattering was judged to be less than that of B. juncea entries but adequate for direct combine harvesting. Most entries were erect and non-lodging. Despite slower early growth, B. carinata lines were also effective competitors with winter weeds. Aphids were present at the end of flowering but did not appear to affect yields significantly. Ethiopian mustard entries were the most disease-free of all the Brassica species. Most lines had relatively low oil contents of from 33-36%. Selection for partial yellow-seed coat lines resulted in a consistent increase of 2% above the oil content of sister dark-seeded lines (from 35% to 37%) without loss of seed yield in replicated yield tests. Lines with full expression of yellow seed coat had oil contents as high as 41% in the 1982 genetic nursery. All lines tested so far are high in erucic acid and glucosinolates.

B. napus

Common rapeseed was highly variable in time to flower and maturity. Spring or summer types from Canada and Europe tended to be later than B. juncea and earlier than B. carinata for these characteristics. However, a few lines from Korea were as early as any B. campestris lines in both flowering and seed maturity and some winter types either never flowered or only flowered simultaneously with devastating aphid infestations and never set seed. All introductions and selections shattered their seed readily at harvest, without exception. B. napus entries had to be windrowed before seed ripening was complete. Most lines had extensive lodging, including all double-zero lines, although this was less severe than for B. campestris. Oil contents were high, ranging from 36-40%. Although no lines were found that were well adapted with high seed yield, some winter cultivars of the Dwarf Essex type were excellent sources of leaf yield for protein extraction or forage use. Bulks were made of introduced Korean forage types which had some seed yield under Davis conditions.

B. campestris

Turnip rapeseed, on average, was earlier in flowering and maturity than any other species. Early growth was more rapid than B. juncea entries. There was extensive variability for plant habit, pod and seed characteristics. Although selected entries were of short to medium height, almost all had poor stem strength and extreme lodging. Oil content in replicated tests ranged from 38-41% but seed yields were poor. No double-zero or zero-erucic lines were well adapted to California. The varieties Tobin and Torch performed better than other improved quality lines. Because of the potential importance of earliness in double cropping systems, a small crossing program was initiated by Cohen in 1982 using high oil, non-shattering B. trilocularis selections, later maturing South Asian lines, Tobin, and higher yielding Chinese lines as parents.

Conclusion

In the five years of initial evaluation Indian mustard, _B. juncea_ had relatively high seed and oil yields combined with well adapted plant types that were suitable for California agriculture. We remain optimistic that Indian mustard and, perhaps, Ethiopian mustard will become accepted commercial crops in California when adapted cultivars with low levels of glucosinolates and erucic acid become available. Recently commercial companies have expressed an interest in high erucic _Brassica_ oilseeds. An orderly market might require some strategem such as having separate quality objectives for different species.

Significant gains in yield can be expected from conventional breeding programs in the mustards; further improvement will be possible when hybrid seed production is introduced; and new genetic techniques that are already employed or are being developed should be particularly useful for combining of stress and disease tolerance with improved quality, high yielding lines. We were impressed, however, by the tremendous variability that is already available in _Brassica_ oilseeds species.

References

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Table 1. Sources of introductions of *Brassica* that were evaluated by the University of California at Davis, 1977-78 to 1981-82.

Country or region	campestris[a]	napus	juncea	carinata	nigra	other[b]
	Species					
Canada	24	35	5	-	-	-
USA	5	3	3	1	16	12
Europe	16	61	13	1	4	11
Middle East	11	-	1	-	8	1
South Asia[c]	453	18	535	19	23	246
China	4	2	13	-	-	-
Japan/Korea	2	384	-	-	-	2
Ethiopia	-	-	-	39	13	-
Oceania[d]	-	5	6	-	-	-
Other	2	2	2	-	-	1
Total	517	510	578	60	64	273

[a]Includes *B. trilocularis*; [b]Mainly *B. tournefortii*, *Eruca sativa*, [c]Mainly Pakistan, India; [d]New Zealand and Australia.

Table 2. Range in seed yields (kg/ha) obtained from *Brassica* species grown at the University of California at Davis.

Species	Range in seed yield (kg/ha) Date sown Dec 1, 1979	Date sown Dec 20, 1980	Date sown Feb. 24, 1982
B. carinata	2269-3137	1353-2940	1768-2441[a]
(entries harvested)	(13)	(10)	(11)
B. juncea	1911-2649	1401-3129	1762-2146
(entries harvested)	(19)	(36)	(12)
B. napus[b]	1172-2291	977-2439	1351-1445
(entries harvested)	(27)	(11)	(3)
B. campestris	1078-2203	1057-1665	898-1215
(entries harvested)	(20)	(7)	(6)

[a]2018-2840 kg/ha in a trial of the same entries with a single irrigation at the end of flowering.

[b]Spring types only.

Table 3. Range in data on plant development obtained for entries of Brassica species grown in yield tests at Davis, CA, 1980-81.

Species	Date first flower	Date last flower	Date seeds ripe	Height cm	Lodging %
B. juncea	3/7-3/28	4/235/2	5/30-6/8	150-195	19-81
B. carinata	4/2-4/18	5/4-5/10	6/5-6/10	150-195	0-21
B. napus					
Spring	3/15-4/4	4/25-5/5	5/20-6/5	130-180	43-83
Winter	4/8-4/28	5/10-5/22	6/12-6/16	170-190	-
B. campestris	3/10-3/14	4/21-4/24	5/27-5/28	140-160	69-91

[1]All data from harvested entries only, except lodging which included all entries.
[2]100% - flat on the ground; 0% - all plants erect.

Table 4. Range of data on seed and oil characteristics for entries of Brassica species grown in yield tests at Davis, CA, 1980-81.

Species	Seed weight g/1000[2]	Seed yield kg/ha[3]	Oil content %[3]	Oil yield kg/ha
B. juncea	2.5-9.5	1401-3129	34.5-39.1	511-1217
B. carinata	2.7-4.6	1353-2940	33.2-36.4	449-1055
B. napus				
Spring	3.2-4.2	977.2439	36.2-40.4	354-978
Winter	-	129-1469	-	-
B. campestris	1.9-2.7	1057-1665	37.5-40.9	403-644

[1]All data from harvested entries only.
[2]Air dry, at planting.
[3]Air dry at harvest.