Breeding Indian mustard for Australian conditions

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Summary. F_4 breeding lines of low erucic acid mustard were compared with canola and rapeseed cultivars at two sites in 1990. Some mustard selections yielded more seed and oil than any line in the two rapeseed species in a short growing season at Wagga Wagga. Canola yielded less than mustard at Canberra because of greater waterlogging damage in winter. Blackleg stem cankers affected 0-17% of plants in mustard families at Wagga; of the six canola cultivars, only Barossa had no cankered plants. Selected mustard families have been crossed with low glucosinolate and reduced linolenate genotypes as the next step towards the creation of a new Australian oilseed crop.

Introduction

During the wheat/wool crisis of the early 1970s, the second author began a search for alternative crops in the genus *Brassica.* The discovery of the low erucic acid oil trait in Indian mustard, *B. juncea (L.)* Czern. & Coss. (4), the elucidation of its inheritance (2) and a consideration of the advantages of mustard over the rapeseed species, *B. napus* L. and *B. campestris* L. (3), led to the initiation of a mustard breeding program. Mustard shatters less than *B. napus,* and is more tolerant of the blackleg fungus, *Leptosphaeria maculans,* has higher linoleic acid in the oil, and has higher protein content in the meal because of the less fibrous, yellow seed coat, than either rapeseed species. *B. juncea has* proven to be high-yielding and more tolerant of heat and drought than either rapeseed species when grown over summer in Canada (1) and USSR (3). However, the low glucosinolate trait has only recently been discovered in *B. juncea (5),* whereas low erucic acid, low glucosinolate forms of *B. napus* and *B. campestris* (canola) now predominate. A diverse population of low erucic acid, high yielding mustard breeding lines has been produced by two successive rounds of crossing and pedigree selection. This paper reports the performance of the most advanced F', families at two sites in 1990 in comparisons with the rapeseed species. The remaining steps required to develop a new oilseed crop are discussed.

Methods

Forty-one mustard lines, comprising 24 F_4 families, three accessions and 14 first-round selections were grown with six canolagrade *B. napus* and one low erucic, medium glucosinolate *B. campestris* cultivars and one high erucic, high glucosinolate *B. carinata* accession in lattice experiments with three replicates at Wagga Wagga and Canberra in 1990. The plots were sown at Wagga Wagga on 23 May, and at Canberra on 14 June. The rapeseed entries were the highest yielding cultivars grown commercially in 1990. Each plot had eight rows 17 cm apart and 7.35 m long. Starter 12 (12.4% N, 22.3% P) at 100 kg/ha and trifluralin herbicide at 0.5 L a. i./ha were incorporated before sowing. An additional 40 kg N/ha was supplied as topdressed urea at the early stem elongation stage. Days to 50% flowering were recorded at Canberra, and percentage stems cankered by the blackleg fungus were estimated at Wagga Wagga in mid-November as the plants neared maturity. Seeds were harvested on two occasions at each site. Oil content of air-dried seed from Wagga Wagga was measured with an Oxford 4000 NMR analyser, and adjusted to an oven-dried basis using the readings for oven-dried seed of one mustard and one canola selection to calculate a conversion factor.

Results and discussion

Seed yields at both sites are given in Table 1 for the three highest and the three lowest yielding mustard lines and canola cultivars at Wagga Wagga, and for Bunyip B. *campestris.* On average, Indian mustard yielded more seed at both sites than either rapeseed species, but had a slightly lower oil content at the wheat-belt site, Wagga Wagga. Mustard began flowering a few days earlier than *B napus* at Canberra, but matured about a week later on average at Wagga Wagga. This prolonged ripening phase may account for the slightly lower oil content observed in mustard seed than in rapeseed at Wagga Wagga. Oil is laid down later in seed development than the other constituents of the dry matter and therefore a higher proportion of the oil deposition phase occurred under drought conditions in mustard than in *B. napus.* Nevertheless, mustard yielded 40% more oil per hectare than *B. napus* on average (Table 1), yield being the main determinant of oil production per unit area. On average, *B. napus* yielded much less than *B. juncea* at Canberra because it was damaged more by winter waterlogging. The *B. carinata* accession yielded poorly and is not considered further here.

Table 1. Yield, oil content, oil yield, flowering time and blackleg damage in mustard and rapeseed at two sites in 1990.

	Wagga Wagga				Canberra	
Species and group	Yield (g/m^2)	Oil content (% dry seed)	Oil yield (g/m^2)	Cankered stems (%)	Yield (g/m^2)	50% flowering (days after 31.8.90)
B. juncea						
Three highest yielding lines at Wagga Wagga						
449-26	145	46.2	67.0	6.7	184	27.7
345-7	152	40.1	61.2	2.7	155	31.3
292 Plt 11	148	41.9	62.4	6.3	137	28.0
Three lowest yielding lines at Wagga Wagga						
87-6	78	43.8	34.2	8.3	140	28.0
ZE Skoro	73	43.8	31.9	0.7	104	36.0
ZE, PR 30	60	43.1	25.7	5.7	133	29.0
Means	110	43.2	47.1	5.1	142	30.0
B. napus						
Three highest yielding lines at Wagga Wagga						
Barossa	123	43.5	53.4	0.0	87	36.3
Nindoo	80	44.7	36.0	2.3	50	32.3
Maluka	74	43.2	31.7	3.7	108	30.7
Three lowest yielding lines at Wagga Wagga						
Yickadee	65	45.2	29.1	2.7	65	35.3
Taparoo	58	43.6	25.3	2.0	63	31.3
Eureka	46	43.5	19.9	1.0	104	32.7
Means	74	44.0	32.6	1.9	79	33.1
B. campestris						
Bunyip	35	42.6	15.2	11.7	105	26.0
l.s.d. line means ($P=0.05$)	34.1	1.3	15.7	10.4	35	2.2
c.v. (%)	21	2	23	164	15	4

The incidence of stem cankers in *B. juncea* rose above the levels of 0.0-0.1% observed annually at Wagga since 1979. Although seed yield was not correlated with the frequency of cankered stems (r=-0.10, P>0.10), it seems probable that selection for blackleg resistance will be necessary in future mustard breeding programs in Australia. Two mustard families were completely unaffected and seven had less than one percent cankered stems. Bunyip *B. campestris* was severely affected; all *B. napus* cultivars except Barossa had some cankered stems (Table 1). Nor was seed yield at Wagga correlated with flowering time, as measured at Canberra (r=-0.05, P>0.10). Flowering time was not measured at Wagga Wagga in 1990, but observations in earlier years indicated little genotype x environment interaction. However, all late-flowering accessions, such as Domo, which yielded well at Wagga Wagga in earlier years with effective November rainfall (6), were low yielding at Wagga Wagga in 1990.

In Table 2, the mean seed yield, oil content and oil yield for the most advanced (second round) selections are compared with those for the firstround selections and selected original accessions and their backcross derivatives. The average seed yields over both the Canberra and Wagga Wagga sites indicate that recombination and pedigree selection have been effective for this trait. Oil content at Wagga Wagga decreased by a small but significant margin from the parental generation to the first round selections. However, selection for higher oil content among P and F_3 plants in the second round appears to have almost halved the difference. The oil yield per unit area of the second round selections was greater than that for either the first round selections or the parental accessions.

Table 2. Mean yields and oil contents of parental accessions and first and second round selections.

	Canberra and Wagga Wagga		Wagga Wagga		
Population	No. of entries	Mean seed yield (g/m^2)[b]	No. of entries	Mean oil content(%)[b]	Mean oi yield (g/m
Parents and backcrosses	5[a]	107[c]	5	43.42[a]	39.20[b]
First round selections	12	122[b]	11	42.22[c]	41.50[b]
Second round selections	24	133[a]	11	42.71[b]	51.90[a]

[a]Three accessions plus two accessions into which the alleles for low erucic acid oil we backcrossed.

[b]Means followed by the same letter are not significantly different (P<0.05).

The low glucosinolate form of *B. juncea* has been developed recently by interspecific hybridisation (5) and by induced mutations (7; Oram, unpublished data). A mutation reducing the concentration of linolenic acid in the oil from 13-15% to 9-10% has been induced and identified (Oram, unpublished data). Recombination of the low glucosinolate and low linolenic acid genes with those for high yield, high oil content, low erucic acid oil, yellow seeds and disease resistance will provide the germplasm from which cultivars of a new crop can be selected. The oil and meal products will be similar to those from canola, but with a higher concentration of the stable polyunsaturated fatty acid, linoleic acid, in the oil, and a lower concentration of fibre in the meal. The areas of adaptation of the new crop are still to be defined, but overseas and local results suggest that mustard will complement canola by performing better in the hotter, drier regions of southern and eastern Australia, especially where moisture is available from rainfall or soil reserves through the seed development phase.

Indian mustard germinates better than *B. napus* in drying soils in Pakistan, where the mustard crop is grown during the cool season on stored soil water (H-H. Muendel, pers. comm., 1990). This difference in germination capacity in a drying surface layer can result in the failure of *B. napus* and the success of *B. juncea* crops under the same conditions. The difference may be due to the higher concentration of mucilage in the testa of *B. juncea* seeds (Own, unpublished data). The greater ability of mustard seeds to germinate in soils with sub-optimal moisture content should enable mustard to be sown earlier in many years and locations in Australia, with a consequent increase in yield over canola varieties. Mustard also may be more reliable for aerial sowing on soils which are too soft for ground seeding, as has been attempted with canola with minimal success in the Riverina region of New South Wales in recent years, following a late break of season and heavy winter rainfall. The greater waterlogging tolerance of mustard, as demonstrated in the Canberra trials in 1990, may give mustard an added advantage over canola in such years.

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