The evaluation of linola as a new oilseed crop for Australia

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Summary. Breeding lines of Linola, a low linolenic acid yellow-seeded strain of linseed, were compared to a variety of Australian and overseas linseed cultivars at a wide range of sites throughout Australia in 1989 and 1990. Two lines were identified, GL-BC4*17-258 and CRBC1*2-15, that had seed and oil yield equivalent to the Australian linseed cultivars Glenelg and Croxton from which they were respectively derived. Oil content in both lines was 2% higher than in their linseed parents. The performance of some overseas linseed cultivars indicated the potential to further improve seed yield, wilt resistance and lodging resistance in Linola.

Introduction

Linola™ is anew oilseed crop developed in Australia by converting linseed, *Linum usaaassimum,* from a source of industrial quality drying oil in low demand into one of high quality edible oil suitable for widespread use in polyunsaturated products. Normally linseed oil contains very high levels of linolenic acid (45-65%), an oxidatively unstable fatty acid that imparts the drying quality to the oil, but makes it unsuitable for edible use. By inducing mutations in two genes, *Lnl* and Ln2, linolenic acid has been reduced to levels around 1-2% of total fatty acids (1). This reduction was associated with an equivalent increase in linoleic acid from 20% to 60-70%, resulting in a high quality polyunsaturated oil similar to sunflower oil in composition and hence suitable for widespread edible uses.

The initial low-linolenic mutants were induced in the Australian linseed cv. Glenelg, but were associated with greatly reduced seed yield due to random mutations in the background genotype. In order to rapidly develop Linola cultivars suitable for Australian environments, a backcross breeding program was conducted, aimed at introducing the low-linolenic acid genes in combination with a yellow seed marker gene into the current Australian linseed cultivars Glenelg and Croxton, and also into a range of recently-bred overseas linseed cultivars. This paper summarises the results of extensive field trials conducted throughout Australia in 1989 and 1990 aimed atevaluating the most advanced breeding lines from this program and selecting the initial cultivars of Linola.

Methods

Trials were conducted at eight sites in NSW, Victoria, Tasmania and the ACT in 1989, and were extended to cover 13 sites in 1990, including South Australia and Western Australia (Table 1). The composition of the entries was essentially the same at each site within years, but differed between years. In 1989, the Linola entries consisted of four Croxton derivatives and nine Glenelg derivatives. The 13 linseed entries consisted of cultivars from Australia (Glenelg and Croxton), Canada (Dufferin, McGregor, Norlin, Norman and Vimy) and Argentina (Alcorta, Areco, Tape Parana and Taragui), and two yellow-seeded accessions (CPI 84495 & CPI 90432). In 1990, there were 15 Linola entries, consisting of backcross derivatives of Glenelg (four lines), Croxton (four lines) and Areco (two lines), and 13 linseed entries, consisting of cultivars from Australia (Glenelg and Croxton), Canada (McGregor, Norlin, Norman and Vimy), Argentina (Alcorta, Areco, Conesa, Tape Parana and Taragui) and UK/Europe (Atalante and Antares). In addition, the Dirnaseer trial in both 1989 and 1990 included entries of canola (four cultivars), mustard (four breeding lines) and wheat (four cultivars) for comparative purposes.

All trials were sown as four replicate randomised complete block designs. Plot sizes varied between sites, but were generally in the order of 10-15 m^2. Time of sowing, seeding rate, and fertiliser, herbicide and insecticide use varied between sites and were in accordance with standard local practice for linseed cropping. Irrigation was provided at Canberra, Trangie and Cressy, with all other trials being rainfed. Following harvest, seed from all sites was cleaned to an equivalent standard, weighed and subsampled for quality analysis. Oil content was determined on oven-dried seed using an Oxford 4000 NMR analyser with reference to appropriate seed samples of known oil content, and data are reported on a moisture-free basis. Fatty acid composition was determined by gas-chromatographic analysis of fatty acid methyl esters using standard methods. Analyses of variance were conducted on an individual site basis and means compared using the least significant difference procedure.

Results and discussion

1989 seed yield data for the two highest yielding Linola backcross derivatives and their respective recurrent linseed parents are presented in Table 1. Averaged across all sites, the linseed cv. Glenelg was the highest yielding entry, however, the top Linola lines, CR-BC1*2 and GL-BC4*1, yielded only 2% and 4% less than Glenelg respectively. At four sites (Canberra, Dirnaseer, Trangie and Wamcoort) the Linola line CR-BC1*2 was the highest yielding entry, with Glenelg being the top at the other four sites. Croxton significantly outyielded Glenelg only at Warncoort where its much greater resistance to *Fusarium* wilt was an advantage. Linola lines consistently had higher oil contents than linseed cultivars (data not presented), with CR-BC1*2 averaging 43.8% compared to 41.6% for its recurrent parent Croxton and 41.3% for Glenelg. This superior oil content combined with its high seed yield, resulted in CR-BC1*2 being the top entry for oil yield, averaging 743 kg/ha compared to 717 kg/ha for Glenelg.

Table 1. Seed yield for the two highest-yielding Linola lines compared to their recurrent backcross parents in 1989 interstate field trials.

			Seed yield (kg/ha)			
			Linola		Linseed	
Site	Sowing date	c.v. (%)	GL-BC4 *1	CR-BC1 *2	Glenelg	Croxton
Canberra, ACT	15 May	12	2470^a	2493^a	2471^a	2173^a
Canberra, ACT	1 Sep	16	1256^a	1609^b	1155^a	1351^{ab}
DirnAseer, NSW	17 May	13	1851^a	2186^b	1940^{ab}	1794^a
Narrabri, NSW	27 May	25	834^{ab}	595^a	1017^b	668^a
Condobolin, NSW	16 Jun	31	1414^a	1428^a	1682^a	1332^a
Trangie, NSW	29 Jun	14	2131^a	2376^a	1993^a	2180^a
Horsham, Victoria	24 May	30	1303^a	789^b	1448^a	879^b
Warncoort, Victoria	21 Sep	22	552^a	1016^b	437^a	985^b
Cressy, Tasmania	4 Oct	18	3187^a	2753^{ab}	3405^a	2359^b
Mean			1666	1694	1728	1525

[a]Within sites, means with different letters are significantly different ($P<0.05$).

Several new Linola lines were included in the 1990 interstate trials based on their superiority over CR-BC1*2 and GL-BC4*1 in a separate preliminary yield trial conducted at Canberra in 1989 (data not presented). The 1990 performance of two of these lines, CR-BC1*2-15 and GL- BC4*17-258, relative to Croxton and Glenelg (Table 2) indicates that further progress to selection was achieved. Averaged across all 1990 sites, GL-BC4*17-258 performed 5% better relative to Glenelg than GL-BC4*1 did in 1989. Also CR-BC1*2-15 outyielded CR-BC1*2 by an average 4% in 1990, however both were lower yielding than Glenelg and GL-BC4*17-258. The highest yielding entry in the 1990 trials was the European linseed cultivar Atalante, which outyielded GL-BC4*17-258 by 5%, indicating that further opportunity exists to improve seed yields in Linola.

Table 2. Seed yield for the two highest-yielding Linola lines compared to their recurrent backcross parents in 1990 interstate field trials.

Site	Sowing date	c.v. (%)	Seed yield (kg/ha)			
			Linola		Linseed	
			GL-BC4 *17-258	CR-BC1 *2-15	Glenelg	Croxton
Canberra, ACT	4 May	10	642^{ab}	2186^{c}	2879^{ab}	2371^{bc}
Warwick, Queensland	22 June	12	641^{a}	912^{c}	674^{ab}	762^{b}
Dirnaseer, NSW	21 May	25	2268^{a}	1525^{b}	1816^{ab}	701^{c}
Condobolin, NSW	26 May	13	1081^{a}	899^{c}	1256^{b}	742^{d}
Trangie, NSW	5 June	14	3117^{a}	2170^{c}	2854a^{b}	2363b^{c}
Rutherglen, Victoria	1 May	31	1311^{a}	1532^{a}	1188^{a}	1471^{a}
Horsham, Victoria	15 Jun	9	876^{a}	1115^{b}	735^{c}	1036^{b}
Warncoort, Victoria	1 Aug	29	1039^{a}	634^{a}	1040^{a}	883^{a}
Hamilton, Victoria	18 Oct	16	474^{a}	871^{b}	611^{a}	1192^{c}
Badgingarra, WA	13 Jun	26	1203^{a}	840^{b}	1290^{a}	614^{b}
Katanning, WA	30 May	41	491^{a}	430^{a}	538^{a}	285^{b}
Mt Barker, WA	25 May	17	1147^{a}	1233^{a}	1310^{a}	1082^{a}
Struan, SA	27 Aug	52	413^{ac}	722^{b}	474^{a}	212^{c}
Mean (excluding Struan)			1358	1196	11349	1125

*Within sites, means with different letters are significantly different (P<0.05).

The reversal in ranking between years for the Glenelg and Croxton based Linola lines is probably explained by the fact that 1990 was a considerably shorter season than 1989, with an earlier onset of moisture stress and high temperatures reducing the period of flowering at a number of sites. These conditions would have been more detrimental to Croxton and CR- BC1*2-15, because of their greater ability to capitalise on longer growing seasons than the more determinate Glenelg and GL-BC4*17-258. The seasonal differences also affected oil contents which were on average 2% lower in 1990 than in 1989. However, the tendency for higher oil content in Linola lines was again evident and resulted in a greater superiority of GL-BC4*17- 258 over Glenelg for oil yield than for seed yield.

The occurrence of severe rainstorms and the proximity of large trees to the trials at Dirnaseer and Warncoort in 1991 created conditions of high turbulence that enabled lodging resistance to be *assessed* under extreme conditions. At both sites Croxton and Croxton-based Linola lines were generally more prone to lodging than Glenelg and Glenelg-based Linola lines. However, these sites clearly demonstrated that a number of overseas linseed cultivars, especially Areco and Atalante, are sources of very high levels of lodging resistance that can be utilised in breeding improved Linola cultivars. One Areco-based Linola derivative (AR-BC2*6) had equivalent lodging resistance to cv. Areco, however, its seed yield was not as high as the top Linola lines. The Hamilton site was included in 1990 to assess performance in the presence of *Fusarium* wilt disease. Croxton and Croxton-based Linola lines were clearly superior to Glenelg and Glenelg- based Linola lines, but Atalante was even more resistant, confirming results previously obtained under both a field wilt nursery in 1989 and subsequent wilt trial under glasshouse conditions (data not presented). Fe deficiency at Struan in 1990 severely affected the performance of most entries, with the noted exception of Atalante and the Linola line CR- BC1*2-15.

The analysis of fatty acid composition revealed no significant difference between the top two Linola lines and demonstrated that the low linolenic acid character is highly stable across environments (Table 3). Linolenic content varied only between 1.3% and 2.2%, and linoleic acid content was consistently high, averaging 68% and not falling below 64%. This may indicate that Linola will be a more reliable source of high-linoleic oil than sunflower, which often produces oil with linoleic acid below the 62% required for the manufacture of premium polyunsaturated products.

Table 3. Oil content and fatty acid composition of Linola lines (GL-BC4*17-258 and CR- BC1*2-15) and linseed cultivars (Glenelg and Croxton) averaged over all 1990 trial sites.

		Oil (%)	Fatty acid composition (%)				
			Palmitic	Stearic	Oleic	Linoleic	Linolenic
GL8*17-258	Mean	0.9	8.0	4.7	18.1	67.7	1.5
	Range	37.2-44.5	7.2-8.9	4.0-5.1	15.9-20.7	64.3-71.0	1.3-1.8
CR8*2-15	Mean	41.0	8.5	4.4	17.3	67.9	1.9
	Range	36.8-43.5	7.7-9.4	3.8-4.8	15.2-20.4	63.6-71.0	1.7-2.2
Glenelg	Mean	39.1	7.5	5.1	19.7	19.0	48.7
	Range	33.0-41.9	6.8-8.1	4.6-5.7	17.4-23.71	7.4-20.7	43.4-51.8
Croxton	Mean	39.6	7.6	4.6	17.7	16.7	53.4
	Range	32.9-41.9	6.8-8.7	4.0-6.1	14.9-22.9	15.3-18.6	45.7-56.9

In conclusion, comparisons of the top-yielding Linola lines with their respective recurrent parents in both 1989 and 1990, confirm that the backcross breeding strategy has been successful in recovering Linola lines with yield and performance levels equal to or better than the current Australian linseed cultivars. The GL-BC4*17-258 and CR-BC1*2-15 lines will be released for commercial cultivation in 1992, with the former line likely to be the higher yielding cultivar, but lacking the important wilt resistance of the Croxton derivative. The performance of these two cultivars should be sufficient to establish a Linola industry in Australia. The performance of the Areco-based Linola breeding lines, and more particularly that of the linseed cv. Atalante, indicate that it should be possible to develop improved Linola cultivars combining increased seed yield with high levels of resistance to lodging and wilt. Such 'second-generation' cultivars should improve the competitiveness of Linola relative to other alternative crops and lead to an expansion of the crop.

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Reference

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