Evaluation of two new linseed cultivars for oilseed production in Canterbury

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Abstract
Linseed (*Linum usitatissimum*) is grown in New Zealand for both oil extraction and baking purposes. Two new brown linseed cultivars 'Bilton' and 'Biltstar', both of Dutch origin, were trialled in the Ashburton district in 2006-07 and 2007-08, to evaluate their suitability for seed and oil production. They were compared with the current industry standard cultivar 'Hinu' and the more recently released cultivar 'Juliet'. There was a large range in yields among sites and seasons. When meaned across sites, cultivar yields ranged from 2,596 to 3,012 kg/ha. Bilton and Juliet produced significantly higher yields than Hinu, while Biltstar was intermediate. Thousand seed weight ranged from 5.76 g to 7.65 g with Biltstar producing the heaviest seed. There was a significant cultivar effect for both oil content and α-linolenic acid (ALA) content. Biltstar and Juliet produced the highest oil content (40.7% and 40.3% respectively). ALA levels were highest in Biltstar and Hinu (62.1% and 60.9% of total fatty acids respectively). There was no significant difference in oil yield (kg oil/ha) among cultivars. Four cultivars may have a place in Canterbury for oilseed production depending on end use and grower payment conditions.
Keywords: *Linum usitatissimum*, flaxseed, seed yield, oil content, α-linolenic acid, thousand seed weight

Introduction

Linum usitatissimum L. is grown worldwide as linseed for oil production (for both human consumption and industrial products) and flaxseed for fibre. Although the same species, linseed and flaxseed have been bred separately for these specific end uses (Foster *et al.* 1997). Linseed has been produced in New Zealand for over a century (Anon. 1883). Traditionally most seed produced was exported as whole seed, destined primarily for oil extraction, which was used in paints, linoleum and wood preservatives (McLintock 1966; Keating 1970; Diepenbrock *et al.* 1995). In the late 1940s a linseed oil mill was built in Dunedin to process up to 12,000 ha for the domestic paint and allied trade (Anon. undated). The facility no longer exists and no new facilities have opened to replace it, as the demand for linseed oil has decreased, primarily due to its replacement in paints by synthetics. In 1951-52 linseed acreage peaked at 9,800 ha (Claridge 1972). An estimate of the current area grown in New Zealand could not be confirmed. However, seed certification data from 2006-07 report 23,650 kg of cv. Hinu 2nd generation seed dressed in 2004, but none in 2005 or 2006. In addition, 5 ha of cv. Juliet was planted for certification in 2005 (AgriQuality 2007). Linseed currently produced in New Zealand maybe pressed to produce industrial or human consumable oil at one of several boutique pressing facilities or supplied to local or international baking companies for processing into food products (A. Davidson pers. comm. 2006).

Linseed oil is one of nature's most concentrated forms of α-linolenic acid, commonly known as ALA and is one of several omega-3-polyunsaturated fatty acids. ALA is an essential fatty acid, which is important for human health and must therefore consume as part of their diet (Bang *et al.* 1980). Oils with a high ALA content dry rapidly, which is a trait important to the paint industry (Green & Marshall 1981). However, a high ALA content also makes the oil unstable, meaning it is readily oxidised resulting in rancid oil. High ALA linseed oil is normally consumed in capsule form by people, which reduces the risk of it becoming rancid. In addition, there is a growing demand for whole linseed as a baking ingredient for breads, muesli bars and other health products. The preference for this market is small, glossy seeds with high oil content (A. Davidson pers. comm. 2006).

Prior to 2007, there was only one common cultivar of brown linseed available to New Zealand growers, which was cv. Hinu (Plant Variety Rights 2008). This cultivar is a small-seeded type, has good standability and relatively good oil content and essential fatty acid profile. More recently cv. Juliet has been commercialised by PGG Wrightson Seeds. Juliet reportedly produces higher seed yields, has a much larger seed and high oil content (unpublished data PGG Wrighton Seeds). It is later flowering and longer maturing than Hinu. Juliet was bred by Gabonatermesztesi Kutatointezet (GK) in Hungary (Home-Grown Cereals Authority Descriptive List Spring Linseed 2005).

Linseed is a self-fertile annual which can be grown in temperate regions. It may be spring or autumn planted (Kelly & George 1998), although it is only spring sown in New Zealand. Linseed can tolerate a wide range of soil types and fertility levels, but requires reasonable soil moisture during development due to its shallow root system and dry weather at harvest (Claridge 1972). Current commercial production practice in New Zealand involves planting untreated seed at a rate of 40-65 kg/ha into finely worked seed-beds. Woodhead and Neilson (1976) found that the addition of fertiliser is not normally necessary if planting into moderate to high fertility sites and, in fact, the addition of nitrogen may even be undesirable for oil seed production. Gabiana (2005) found that 150kg/ha N reduced oil content by 2%. However it is still common practice for growers to apply a base fertiliser pre-planting containing phosphorus and potassium and up to 60 kg/ha N may be applied post-emergence. Weeds are controlled with 2-methyl-4-chlorophenoxyacetic acid (MCPA), but no fungicides or insecticides are normally applied. Crops may be desiccated and combined directly or windrowed (N. Brooks pers. comm. 2006). Lodging is a problem only in highly fertile soils or where excessive rainfall occurs. Early or isolated crops may experience severe seed losses at the time of harvest due to birds.

The aim of this study was to evaluate new genetic material for its suitability as an oilseed crop for production in Canterbury, New Zealand with an emphasis on its use for the food ingredient and human health market.

Methods

In 2006 three trial sites were established at three different locations within the mid-Canterbury region. In 2007 four trial sites were established at new locations, but only one of these was harvested due to excessive bird damage at three sites. All trial sites were situated within commercial fields of linseed. Crop husbandry was the same for all sites except for pre-plant base fertilisers, which were applied by the co-operating grower. Specific site details are listed in Table 1. A summary of climatic conditions for the Ashburton region over the period of the trials is presented in Table 2.

At each location, the trial was arranged in a randomised complete block design of four replicates with each block containing four cultivars: Hinu, Bilton, Biltstar and Juliet. Untreated seed was sown without fertiliser using a belt-cone plot-seeder. Seeding rate was calculated separately for each cultivar according to thousand seed weight (TSW), germination and an estimated 85% emergence rate, with a target population of 200 plants/m^2. High yields achieved in year one indicated that the plant populations established were sufficient so the same target population was used for year two. Plots consisted of 9 rows with 15 cm spacing, each plot totalling 15 m^2.

Table 1 Specific trial site information for the four harvested trials.

Trial Site	Location	Soil Type*	Sowing rate	Harvest Date	Irrigation
1	Eiffelton	Waterton Silt Loam	02.11.06	07.03.07	No
2	Dorie	Chertsey Shallow Silt Loam	06.11.06	16.03.07	Yes
3	Ashburton Forks	Mayfield Silt Loam	06.11.06	15.05.07	No
4	Ashburton	Lismore Stony Silt Loam	29.10.07	14.04.08	Yes

*Soil type classification from Soil Bureau-Bulletin 14 (Kear *et al*. 1967).

Table 2 Comparison of the long-term mean (LTM) climatic conditions and those experienced during trialling in 2006-07 and 2007-08 for Ashburton (National Institute of Weather & Atmospheric Research, Station 4764).

Month	Max Air Temp (ºC)	LTM* Max Temp (ºC)	Min Air Temp (ºC)	LTM Min Temp (ºC)	Rainfall (mm)	LTM Rainfall (mm)
Nov 2006	18.5	18.2	7.4	7.2	119.6	54.1
Nov 2007	18.7		6.6		29.8	
Dec 2006	17.7	20.4	7.6	9.3	146.6	60.1
Dec2007	20.9		9.8		51.4	
Jan 2007	20.3	22.2	10.2	10.5	31.8	54.8
Jan 2008	24.4		10.9		29.0	
Feb 2007	21.2	21.9	10.9	10.6	30.2	53.1
Feb 2008	21.9		11.2		119.4	
Mar 2007	23.0	19.8	9.9	8.9	46.4	66.9
Mar 2008	21.2		9.3		26.2	
April 2007	16.5	17.0	6.3	6.3	43.2	60.1
April 2008	17.4		6.2		36.6	

*Long-term mean temperature and rainfall recorded from 1971-2000.

Plant populations were estimated when plants had 3-4 pairs of leaves, with counts done on three areas of 0.25 m^2 in each plot. The number of basal stems and flower buds were assessed when plots were at 10-20% flowering, by destructive counts on ten plants per plot. Weeds were controlled with 2 l/ha MCPA (375 g ai/l MCPA) in 200 l/ha water when crops were between 10 cm tall and flower bud formation. As sites had different crop histories, all plots received a post-emergent broadcast application of 250 kg/ha Cropmaster 15 (15:10:10:8) prior to forecast rain to ensure that nutrient availability was not limiting.

All plots were desiccated 14-21 days prior to harvest with 4 l/ha glyphosate (360 g ai/l glyphosate) in 200 l/ha water. This was applied when a minimum of 80% of the capsules across the trial area were golden brown in colour and senescence of the top third of the stem had occurred. Plots were harvested with a Wintersteiger Elite plot harvester. The entire plot sample was collected and dressed using a Westrup seed cleaner. The machine dressed (MD) sample was weighed and the moisture content (MC) determined using a Precisa XM60 Moisture Analyser set at 125ºC. Final MD yields were corrected to 8% MC. TSW was determined by counting and weighing three replicates of 100 seeds per plot and scaling up to 1,000 seeds.

Oil quality analysis was conducted on one MD seed sample from each plot giving four replicates per cultivar per site. Seed from Site 3 was not analysed as the seed quality had deteriorated due to the very late harvest at this site. The oil content was determined using the American Oil Chemists' Society (AOCS) method Am 2-93 (AOCS 2000). The α-linolenic acid content in the edible fats and oils was determined by capillary GLC was conducted using the AOCS official method Ce 1e-91 (AOCS 2001). Fatty acids are reported as a percentage of total fatty acids.

Analysis of variance was conducted on individual trials and across trials using Genstat 11. Established plant population was used as a covariate in the across trial analysis. However, when population was adjusted to a common 228 plants/m^2 there was little change in mean yield or oil quality results and so unadjusted means are presented. A log transformation of yield data placed undue emphasis on the low yielding trial in 2007-08, so untransformed yield means are presented.

Results and Discussion

Plant establishment was variable among sites, with higher than expected establishment at Site 4 in 2007-08. However when results were averaged across sites, there were no significant differences in established plant numbers among cultivars (Table 3). Research on the impact of plant population on yield is conflicting, although in general linseed yields are reported to be relatively stable over a wide range of plant densities and cultivars (Albrechtsen & Dybing 1973; Gubbels 1978). Site 4 had the highest mean population across cultivars (287 plants/m^2) but the lowest average yield (940 kg/ha), suggesting that factors other than plant population influenced final yield. Gabiana (2005) reported the highest seed yield in the lowest population tested of 238 plants/m^2 and that oil yield decreased by 22% at the highest population tested (769 plants/m^2).

As expected there were some differences in the agronomic traits measured (Table 4). Basal stem numbers ranged from 3.0 for Bilton to 3.9 stems/plant for Biltstar when averaged across trials. Basal stem number for these two cultivars differed significantly ($P<0.05$) from one another but not from Hinu or Juliet. On average the number of flower buds/plant ranged from 53.8 to 64.8, with no significant difference among cultivars. Gubbels (1978) also found that there was a cultivar effect on basal branch numbers, but no effect of cultivar on capsule number/plant. Hinu and Bilton had the smallest seed (6.05 g and 5.76 g TSW), with Juliet being intermediate (6.90 g TSW) while Biltstar was by far the largest (7.65 g TSW).

Historically linseed yields have ranged from 749 kg/ha (Claridge 1972) to 2,400 kg/ha (Woodhouse & Neilson 1976). Linseed yields were very good in 2006-07, but relatively low in the one site harvested in 2007-08 (Table 5). When seed yield was analysed (combined) across sites there was no significant difference ($P<0.05$) between Bilton (2,996 kg/ha), Biltstar (2,770 kg/ha) and Juliet (3,012 kg/ha). However, Bilton and Juliet gave superior yields to Hinu (2,596 kg/ha). Bilton significantly out yielded all other cultivars at Site 4, which was a challenging growing site. Soil types varied across sites and climatic conditions varied markedly between years. High yields were recorded at Site 1 (mean site yield of 4,132 kg/ha), which was on a relatively heavy Waterton silt loam; this was a dryland site, but rainfall in both November and December 2006 were over twice the long-term mean (Table 2), presumably enough to carry the crop through the drier months of January and February until harvest in early March. In contrast, Site 4 (mean site yield of 940 kg/ha) was on a shallow Lismore stony silt loam, which was very free draining. This soil type, combined with hot, dry weather conditions over the flowering and grain fill period of December 2007 and January 2008 (Table 2) resulted in a lower than normal yield, even though approximately 200 mm of irrigation was applied during this period. Linseed is a shallow rooting crop, and yield is adversely affected when uniform soil moisture is not available (Keating 1970; Johnston *et al.* 2002). Effects of location and climate on linseed yields have previously been reported, for example, Gubbels (1977) found that year and location influenced linseed yield more than different production practices. Diepenbrock *et al.* (1995) reported that the average yield of linseed at a given location in a specific year is strongly affected by the respective weather conditions. These results reflect the wide range of conditions linseed is grown under in Canterbury and the range of yields that can be expected. Both new cultivars performed well, with an indication that cv. Bilton may be the most adaptable to a wide range of sites, especially in dry years. The two key oil quality parameters measured were total oil content and ALA content (Table 6). There were significant differences ($P<0.05$) in both total oil and ALA content among cultivars. Hinu and Bilton had significantly lower total oil contents (39.5% and 39.8% respectively) than Biltstar (40.7%), and Hinu had significantly lower oil content than Juliet (40.3%). Bilton and Juliet had significantly lower ALA content (58.5% and 59.5% respectively) than Hinu (60.9%) and Biltstar (62.1%). Total oil yield/ha can be calculated by multiplying seed yield by oil content. Oil yield ranged from 1,023 kg/ha to 1,163 kg/ha but did not differ significantly among cultivars. Results for oil content are consistent with those reported by Green and Marshall (1981) who found that high oil content was consistently associated with larger seeds. There was no relationship between oil content and linolenic acid (Table 6), although Green and Marshall (1981) reported a negative correlation between oil content and linolenic acid.

These results suggest that all four cultivars may have a place in Canterbury for oilseed production depending on the end use and grower payment system. If production contracts were based on a flat per ton payment then growers would be best to grow Bilton, Biltstar or Juliet, Bilton being the best option on light soil types. If a small-seeded type was specifically requested, then Bilton would be the best option. If a payment system were based on oil content, the superior cultivars would be Biltstar or Juliet, whereas if a market premium for ALA content was available, then Biltstar or Hinu would be preferred. Seed yield is more variable and is influenced to a much greater extent by the production environment, especially soil type, than is oil quality. The best returns could be expected from crops grown on heavy soil types with access to irrigation in dry years. Isolation of fields from other arable crops with similar maturity should be avoided to reduce the risk of seed losses to birds at harvest time. It may be preferable to plant trial plots within commercial fields up to a week earlier than the surrounding field to ensure trial sites are not lost to birds. Other deterrents such as bird netting, bird scarers and chemical repellents may also need to be employed.

Table 3 Plant establishment (plants/m^2) summary across trial sites.

Cultivar	Site 1 (2006-07)	Site 2 (2006-07)	Site 3 (2006-07)	Site 4 (2007-08)	Mean
Hinu	237	165	220	263	221
Bilton	241	172	237	343	248
Biltstar	246	169	197	268	220
Juliet	226	200	189	272	222
Mean	238	177	211	287	
LSD P<0.05*	43	38	51	86	36

*The LSD represents the comparison between cultivars within a column excluding the mean.

Table 4 Summary across trials of agronomic traits measured.

Cultivar	Basal Stems (stems/plant)	Flower Buds (buds/plant)	Thousand Seed Weight** (g)
Hinu	3.3	64.8	6.05
Bilton	3.0	56.6	5.76
Biltstar	3.9	53.8	7.65
Juliet	3.6	54.5	6.90
LSD P<0.05	0.6	11.9	0.49

**Analysis of trial Sites 1, 2 & 4 only.

Table 5 Seed yield (kg/ha @ 8% seed moisture content) for each trial and across trials at actual established plant populations.

Cultivar	Site 1 (2006-07)	Site 2 (2006-07)	Site 3 (2006-07)	Site 4 (2007-08)	Mean
Hinu	4115	2770	2833	664	2596
Bilton	4103	2892	3669	1319	2996
Biltstar	3949	2937	3278	916	2770
Juliet	4360	3230	3576	882	3012
Mean	4132	2957	3339	940	
LSD P<0.05*	359	420	465	387	327

*The LSD represents the comparison between cultivars within a column excluding the mean.

Table 6 Oil content, α-linolenic acid content and total oil yield analysed summarised across three trial sites (Site 1, 2 & 4).

Cultivar	Oil Content (%)	Oil Yield (kg/ha)	α-linolenic acid Content (% TFA*)
Hinu	39.5	1023	60.9
Bilton	39.8	1123	58.5
Biltstar	40.7	1082	62.1
Juliet	40.3	1163	59.5
LSD $P<0.05$	0.6	153	1.2

*Total fatty acid.

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