Seed yield and quality of four cool tolerant soybean cultivars at five New Zealand locations

M.M. Rahman[1,3], J.G. Hampton[1], M.J. Hill[1] and N.B. Pyke[2]

[1]New Zealand Seed Technology Institute, P O Box 84, Lincoln University, Canterbury
[2]Foundation for Arable Research, P O Box 80, Lincoln, New Zealand
[3]Present address: Department of Agronomy, Bangladesh Agricultural University, Mymensingh – 2207, Bangladesh

Abstract

The seed yield and quality of four cool tolerant soybean (*Glycine max* (L.) Merrill) cultivars (Northern Conquest, Maypole, Alta, March) were assessed using a common trial design at five locations (Hastings, Cambridge, Nuhaka, Blenheim, Dorie) in a project organised by the Foundation for Arable Research. At each location the four cultivars were replicated four times in plots 2.4 x 5 m. Sowing date was 2 to 23 November 1999 depending on location, the target population was 50 plants/m^2, and row spacing was 30 cm. Seed yield ranged from 146 g/m^2 to 368 g/m^2 depending on cultivar and location. Average yields for all cultivars over all sites were from 250 – 280 g/m^2. The greatest yield (average 365 g/m^2) came from Hastings, while the lowest yields (204 – 210 g/m^2) came from Nuhaka and Dorie. The lower yield at Dorie was explained by a low plant population for three of the cultivars, but where comparable plant populations were achieved, yield differences were explained by differences in seed number. Seed protein content ranged from 36 – 43 %. Seed coat cracking was cultivar related, averaging 56 % in cv. Alta but only 3 % in cv. Northern Conquest. High quality (germination and vigour) seed was produced from the Dorie, Blenheim and Hastings trials; harvest/threshing problems significantly reduced seed quality from the Cambridge and Nuhaka trials. Further work is required to determine the agronomic requirements for high yields (ca. 300 g/m^2) of high quality soybean seed in New Zealand.

Additional Key Words: *Glycine max*, plant population, seed number, seed protein, germination, vigour

Introduction

Soybean (*Glycine max* [L.] Merrill) has previously been grown commercially in New Zealand (FAO, 1999) and an average yield of just over 3 t/ha was produced with US cultivars at different locations (Manning *et al.*, 1974; McCormick, 1976; Turnbull, 1976; Piggot *et al.*, 1980). However, seasonal yield variability with US cultivars in New Zealand's cool temperate environment discouraged further production of this crop (White and Hill, 1999). Experiments with soybeans in the South Island showed higher seed yield variability (Blair *et al.*, 1966; Dougherty, 1969; Hill *et al.*, 1977, 1978) than in the North Island (Manning *et al.*, 1974; Turnbull, 1976; McCormick and Anderson, 1981).

Two factors had created difficulties for soybean production in New Zealand. Firstly, the optimum sowing time for the US cultivars was established as late November. Earlier sowing was not possible because of a lack of cold tolerance during pod set that resulted in the high seasonal yield variability. Secondly, late November sown crops mature in April when the weather usually becomes cooler and the seed cannot be dried down naturally to a moisture content (ca. 15 %) suitable for machine harvesting (McCormick, 1974).

Later trials with the cold tolerant early maturing cultivars Fiskeby V (Sweden), Geiso (Germany) and BC-18-2-12 (Canada) showed less seasonal yield variability and gave yields similar to the US cultivar Amsoy 71 (McCormick and Anderson, 1981). However, the Swedish and Canadian cultivars were of short stature causing problems with machine harvesting, and therefore were not suitable for commercial production. The German cultivar Geiso was highly prone to lodging.

Soybean is now produced in many temperate countries such as Argentina, Canada, Sweden, Germany and the United Kingdom due to the greater availability of cool tolerant cultivars. The availability of four cool tolerant cultivars sourced from northern

Europe provided a further opportunity to test the possibility of soybean production in New Zealand.

The present experiment was therefore undertaken with the objective of examining the seed yield and quality of four cool tolerant soybean cultivars at different locations in New Zealand to assess their potential for commercial soybean production.

Materials and Methods

The experiment was conducted at three North Island sites (Cambridge, Hastings and Nuhaka) and two South Island sites (Blenheim and Dorie) in the 1999/2000 season (Table 1). At each site, the trial involved four cultivars (Northern Conquest, Maypole, Alta and March) each replicated four times in a randomised block design. The unit plot size was 2.4 m wide and 5.0 m long and the row-to-row distance was 30 cm.

Table 1. Geographic position and management practices at the different locations.

	Location				
	Hastings	**Cambridge**	**Nuhaka**	**Blenheim**	**Dorie**
Sowing date	9 Nov	2 Nov	16 Nov	23 Nov	9 Nov
Plot thinning[1]	22 Nov	15 Nov	6 Dec	N/A	N/A
Irrigation	Yes	No	No	Yes	Yes
Hand harvest	21 Mar	23 Mar	30 Mar	24 Mar-28 Apr[2]	30 Mar-13 Apr[2]
SMC at threshing	11-13%	10-13%	17-21%	10-13%	10-12%

[1]to one plant per position, [2]see text

Crop management at North Island sites

Trials were sown by hand (Table 1) placing two seeds per position using a 7 cm plant spacing within rows at all three sites. For each site fertiliser (N @ 20 kg/ha as urea, P @ 15 kg/ha as superphosphate and K @ 15 kg/ha as potassium sulphate) was applied by broadcasting after sowing and incorporated gently by raking. Plots were sprayed with 6 l/ha Lasso and 2 kg/ha Linuron herbicides after planting. Irrigation was applied only to the Hastings crop when estimated evapotranspiration (ET) reached 40 mm from the last irrigation, and 40 mm water was applied at each irrigation. Irrigation was not available at the other two sites. The plots were hand harvested (Table 1) by removing all plants from two meters of the four central rows from each plot. Plants were then dried in the laboratory at ambient temperature, before being threshed with a modified pea viner. Threshing was done when seed moisture content was 10-13 % for the crop at Cambridge, 11-13 % for the crop at Hastings and 17-21% for the crop at Nuhaka.

Crop management at South Island sites

The management practices applied at the two locations differed.

Dorie The trial was conducted on a Templeton silt loam soil for which soil test results taken in July 1999 were: pH = 5.9, Ca = 10, P = 57, K = 12, S(SO4) = 25, Mg = 18, and Na = 11 (expressed as µg/g soil). The trial was sown (Table 1) using a hand pushed Stanhay single row precision seeder, set to deliver 50 seeds m^{-2}. The trial received no fertilizer, herbicide, fungicide or insecticide. All weeds were hand removed. Soil moisture was monitored using Time Domain Reflectometry (TDR), and 35 mm irrigation water (via T-tape between rows) was applied on three occasions (28 December, 8 February and 2 March) when the soil moisture deficit was around 50 mm. The crop was harvested by hand cutting all plants from a 3m length of the four central rows. For cv. Northern Conquest this was on 30 March (23 % SMC) and for the other three cultivars on 13 April (cv. Maypole 37 % SMC, Alta 25 % SMC, March 34 % SMC). Plants were dried in the laboratory until the seed moisture content was 10-12 %, and threshed with a Kurtpelz Stationary Thresher.

Blenheim The pH of the soil was 5.9 and P and K were high. Fertilizer (Nitrophoska blue) was applied @ 170 kg/ha and herbicide (Treflan) was applied on the day of sowing (23 November). The crop was irrigated and at maturity was harvested by

hand cutting all plants from 3m of the four central rows. Harvesting of the crop for cv. Northern Conquest, Maypole, Alta and March was done on 24 March, 28 April, 6 April, and 28 April 2000, respectively. The plants were kept in a glasshouse for drying and were threshed with a small stationary thresher. At threshing seed moisture content was 10-13 %.

Measurement of yield and yield component data

At each location, five randomly selected plants were collected from outside the seed harvest area (but not from the border rows) to record the number of seeds per plant and individual seed weight. The total number of seeds from each plant was counted and total weight of that seed was measured. The seed weight was divided by the seed number to obtain individual seed weight. The plant population was calculated by counting all the plants from the harvested area. Moisture content of seeds was determined by the oven method (17 hours at 103 °C; ISTA, 1999). Seed yield and individual seed weight are expressed at 0 % SMC.

Seed quality assessment

Seeds from all the locations were sent to Lincoln University, placed in polyethylene bags and stored at 5 °C until required for quality testing.

Seed protein and oil content analysis. Seed protein content and oil content were determined in the analytical laboratory of the Animal and Food Science Division, Lincoln University. Seed protein content was determined by the Kjeldahl procedure using a Kjeltec Auto 1035/38 Sampler System (Tecator, Sweden). The oil content of seed was analysed as described in the Tecator Manual for Soxtec System HT6.

Seed coat cracking. Seed coat cracking was scored visually by randomly taking four sub-samples of 100 seeds per seed lot. A cracked seed was one where a crack was observed at any place on the seed coat (micropyle, either side of hilum, or any place on the seed coat).

Germination test. Germination percentage of each seed lot was assessed using internationally agreed methodology (four replicates of 50 seeds placed between paper (BP), 20/30 °C for 8 days; ISTA, 1999). After 8 days the number of normal or abnormal seedlings and remaining seeds was assessed (ISTA, 1999).

Vigour tests. Seed vigour was assessed using the accelerated ageing (AA) and conductivity tests (ISTA, 2001). For the AA test 42 g seed were held over 40ml water at 41 °C ± 0.3°C for 72 h, after which seeds were set to germinate as described above. Conductivity (4 replicates of 50 weighed seeds each in 250 ml deionised water at 20 °C for 24 h) was measured using a Radiometer conductivity meter (CDM 210).

Statistical analysis of data

Analysis of variance was done using a Genstat statistical package (Lawes Agricultural Trust, 1997). Means were separated by least significant difference at $P< 0.05$.

Results

Climate at the different locations

Weather data for the different locations were recorded at the nearest meteorological station (Table 2). The mean temperature for the period from November to March was highest at Cambridge (17.4 °C) and lowest at Dorie (14.7 °C). The highest mean monthly temperature was reached in February at all locations (Table 2), being highest at Cambridge (19.5 °C) and lowest at Dorie (16.2 °C). The total rainfall during November to March was highest at Nuhaka (512 mm) and lowest at Hastings (226 mm). Averaged over all the locations the lowest rainfall (15 mm) was in February and the highest (127 mm) in November. March rainfall increased over that of February at all locations. The highest March rainfall was at Nuhaka (170 mm) and the lowest at Marlborough (26 mm). Among the five locations, solar radiation from January on was lowest at Nuhaka (Table 2).

Seed yield and yield components

Seed yield ranged from 146 g/m^2 (cv. Alta at Nuhaka) to 368 g/m^2 (cv. Maypole and Alta at Hastings) (Table 3). Averaged over all five locations, seed yields were 256, 260, 255 and 284 g/m^2 for cv. Northern Conquest, Maypole, Alta and March respectively. Average yield over all cultivars was 365 g/m^2 at Hastings, which was 43, 78, 28 and 74 % greater than the yields recorded at Cambridge, Nuhaka, Blenheim and Dorie respectively. Yields at Hastings did not differ among the cultivars, but cv. March out yielded cv. Northern Conquest at Cambridge, Blenheim and Dorie, cv. Alta at Nuhaka, and cv. Maypole at Cambridge (Table 3). For cv. Northern Conquest, Alta and March, seed yield was significantly greater at Hastings cf. all other locations, while for cv. Maypole, yields did not differ between Hastings and Blenheim (Table 4).

Seed yield differences among the locations were explained by either plant population (Dorie) or seed numbers (Table 4). With the exception of cv. Northern Conquest, the plant population at Dorie was significantly lower than at all other locations. Individual seed weight did not differ with location for cv. Northern Conquest, Alta or March, but that for cv. Maypole was significantly higher at Nuhaka and Blenheim (Table 4). At comparable plant populations (i.e. 38-46 plants/m^2), the number of seeds per plant and therefore per m^2 was higher at Hastings than all other sites, with the exception of Blenheim for cv. Northern Conquest and March. Plants of cv. Maypole and March compensated for the low population at Dorie by increasing the number of seeds per plant (Table 4).

Table 2. Temperature, rainfall and solar radiation at five New Zealand locations from October 1999 to March 2000.

	Location				
Months and weather data	**Hastings**	**Cambridge**	**Nuhaka**	**Blenheim**	**Dorie[1]**
November					
Max/min temp. (°C)	20.5/11.3	21.3/10.4	18.1/12.3	19.3/11.1	18.1/7.5
Total rainfall (mm)	120.8	178.9	114.6	154.6	64.5
Solar rad. (MJ m^{-2}/d)	20.9	18.7	20.2	19.2	20.1
December					
Max/min temp. (°C)	21.0/10.8	23.3/10.0	18.7/12.8	19.8/9.8	20.9/8.6
Total rainfall (mm)	18.0	30.6	131.8	40.2	31.0
Solar rad. (MJ m^{-2}/d)	23.2	21.7	22.9	24.1	24.6
January					
Max/min temp. (°C)	23.1/12.1	24.6/11.7	20.1/14.5	20.7/12.2	21.8/10.3
Total rainfall (mm)	17.4	102.0	59.6	79.2	98.0
Solar rad. (MJ m^{-2}/d)	21.5	19.4	11.5	20.8	21.3
February					
Max/min temp. (°C)	24.7/11.4	26.1/12.8	20.7/15.0	22.6/12.1	24.0/10.4
Total rainfall (mm)	0.0	4.1	35.2	24.0	10.0
Solar rad. (MJ m^{-2}/d)	21.2	21.2	11.9	20.8	19.1
March					
Max/min temp (°C)	21.7/10.3	25.0/8.8	19.3/14.3	21.1/9.7	23.0/8.1
Total rainfall (mm)	69.8	26.5	170.4	26.0	62.0
Solar rad. (MJ m^{-2}/d)	14.7	17.0	7.3	18.0	16.7
Weather station	Hastings	Ruakura	Mahia	Blenheim	Lincoln

[1]A data logger was used for recording trial site temperatures and a rain gauge for rainfall measurement at the Dorie site. Solar radiation data were collected from the Broadfield meteorological station at Lincoln.

Table 3. Seed yield (g/m^2) of four soybean cultivars grown at five New Zealand locations in 1999/2000.

	Location				
Cultivar	**Hastings**	**Cambridge**	**Nuhaka**	**Blenheim**	**Dorie**
Northern Conquest	365	202	254	254	204
Maypole	368	217	211	308	197
Alta	368	309	146	281	172
March	359	293	209	295	266
LSD (P<0.05)	37.4	37.6	45.3	20.4	60.8
Significance	ns	**	***	***	*
CV(%)	2.2	9.2	13.8	4.5	18.6

Table 4. Effect of location on seed yield and yield components in four soybean cultivars in 1999/2000.

Yield & components	Location					LSD (P<0.05)	Sign	CV%
	Hastings	Cambridge	Nuhaka	Blenheim	Dorie			
Cv. Northern Conquest								
seed yield (g/m^2)	365	202	254	254	204	67.8	***	16.2
plants/m^2	45	43	42	42	43	3.9	ns	5.8
seeds/plant	51	30	32	45	37	6.1	*	22.3
seeds/m^2 [1]	2296	1268	1329	1908	1573	563.4	**	21.8
ISW (mg) [2]	159.3	172.5	196.5	144.0	135.5	47.3	ns	19.0
Cv. Maypole								
seed yield (g/m^2)	368	217	211	308	197	75.7	***	18.9
plants/m^2	44	44	38	40	19	5.3	***	7.5
seeds/plant	56	30	29	41	75	15.3	***	20.7
seeds/m^2	2469	1317	1073	1757	1413	576.2	***	22.5
ISW (mg)	152.8	164.8	205.5	197.8	158.0	30.6	**	11.3
Cv. Alta								
seed yield (g/m^2)	368	309	146	281	172	53.8	***	13.7
plants/m^2	44	44	44	38	31	6.5	**	10.5
seeds/plant	56	40	18	45	33	12.3	***	20.4
seeds/m^2	2466	1782	803	1600	984	640.6	***	26.2
ISW (mg)	152.5	175.5	193.0	193.8	195.3	38.0	ns	13.6
Cv. March								
Seed yield (g/m^2)	359	293	209	295	266	54.0	***	12.3
plants/m^2	44	46	40	39	30	8.4	**	13.7
seeds/plant	54	38	31	50	55	14.3	**	19.7
seeds/m^2	2384	1727	1240	1890	1639	578.7	**	20.6
ISW (mg)	153.3	170.5	185.5	174.8	163.8	30.7	ns	11.8

[1] calculated data
[2] individual seed weight

Among cultivars, there were no differences in seeds per plant or per m^2 at Hastings, Cambridge, Nuhaka or Blenheim, and individual seed weight did not differ among cultivars at Cambridge, Hastings or Nuhaka (analysis not presented).

Seed quality

The trials at Hastings, Blenheim and Dorie produced the highest quality seed, with both germination and vigour being consistently higher in all four cultivars than that from seed produced at Cambridge and Nuhaka (Table 5). For example, the average germination (all cultivars) for the former three locations was 92 %, which for the latter two it was 75 %. Seed vigour, as assessed by the accelerated ageing test, did not differ within cultivar for seed produced at Hastings, Blenheim or Dorie, but conductivity was significantly lower in cv. Northern Conquest and Maypole for seed produced at Dorie (Table 5).

Among cultivars germination did not differ at Cambridge, Hastings, Nuhaka or Dorie, but was reduced for cv. March at Blenheim (analysis not presented). Vigour differed among cultivars at all locations except Nuhaka.

Seed coat cracking

There were significant differences among the cultivars for seed coat cracking at all five locations (Table 6). Cv. Alta had the greatest percentage of seed coat cracking at all locations (mean = 56 %), while cv. Northern Conquest had the lowest (mean = 3 %). Cv. Maypole and March had 13 and 16 % seed coat cracking respectively. There were no significant effects of location on seed coat cracking (analysis not presented).

Table 5. Effect of location on seed quality in four soybean cultivars in 1999/2000.

Quality components	Location Hastings	Cambridge	Nuhaka	Blenheim	Dorie	LSD (P<0.05)	Sign	CV(%)
Cv. Northern Conquest								
germination (%)	85	72	75	96	95	9.3	***	7.2
post-AA[1] germination (%)	77	54	67	93	92	16.8	***	14.2
conductivity (µS/cm/g)	29.7	45.9	28.6	25.2	15.0	7.2	***	16.1
Cv. Maypole								
germination (%)	97	81	75	95	92	8.7	***	6.4
post-AA germination (%)	91	35	73	88	92	10.7	***	9.2
conductivity (µS/cm/g)	20.3	33.1	25.3	25.9	17.4	2.8	***	7.6
Cv. Alta								
germination (%)	96	82	61	94	89	11.3	***	8.7
post-AA germination (%)	79	11	53	81	90	13.1	***	13.5
conductivity (µS/cm/g)	17.1	39.7	30.5	24.1	16.7	6.9	***	17.6
Cv. March								
germination (%)	95	82	70	86	90	5.4	***	4.2
post-AA germination (%)	82	35	63	82	91	20.3	***	18.6
conductivity (µS/cm/g)	19.9	38.9	26.7	26.5	17.8	3.7	***	9.4

[1]accelerated ageing

Table 6. Effect of soybean cultivar on the percentage of seed coats with cracking at five New Zealand locations in 1999/2000.

	Location				
Cultivar	**Hastings**	**Cambridge**	**Nuhaka**	**Blenheim**	**Dorie**
Northern Conquest	2(9)[1]	7(15)	3(10)	3(10)	2(9)
Maypole	7(15)	22(28)	17(24)	12(20)	8(16)
Alta	57(49)	60(51)	64(53)	48(44)	49(45)
March	15(22)	18(25)	19(26)	18(25)	10(18)
LSD (P<0.05)	6.4	9.0	6.5	1.9	5.8
Significance	***	***	***	***	***
CV. (%)	16.9	19.0	14.3	4.8	16.8

[1]figures in parenthesis are arc-sine transformed values

Table 7. Effect of soybean cultivar on seed protein content (%) at three locations and seed oil content (%) at Dorie in 1999/2000.

	Location			
Cultivar	**Hastings**	**Blenheim**	**Dorie**	
	% protein	**% protein**	**% protein**	**% oil**
Northern Conquest	36.3	37.8	36.9	18.7
Maypole	37.5	42.9	41.1	17.6
Alta	37.2	39.4	38.5	18.2
March	38.2	40.8	42.0	16.3
LSD (P<0.05)	1.76	2.29	1.60	0.93
Significance	ns	*	***	**
CV. (%)	1.5	1.8	2.5	3.3

Seed protein and oil content

Seed protein content differed with cultivar at Blenheim and Dorie but not at Hastings (Table 7). Cv. Maypole had a higher protein content than cv. Northern Conquest and Alta at Blenheim, while cv. March had a higher protein content than these two cultivars at Dorie. Protein content did not differ significantly with location.

Cv. March had a lower oil content than the other three cultivars (Table 7). There was a significant negative correlation between seed protein and oil content at Dorie ($r = -0.822^{**}$).

Discussion

Trials in the North Island between 1974 and 1980 produced soybean seed yields ranging from 100 to 600 g/m^2 with an average of 250 g/m^2 (Piggot *et al.*, 1980). In the South Island yields ranged from 170 to 270 g/m^2 depending on cultivar (Blair *et al.*, 1966; Hill *et al.*, 1978). In the present series of experiments, the mean yield for all cultivars for the three North Island locations was 275 g/m^2, while for the two South Island locations it was 247 g/m^2. Yields were location dependent, with the mean at Hastings for example being 365 g/m^2, and that at Dorie being 210 g/m^2. However, while there was yield variation, the yields obtained compare favourably with international soybean yields (Kane *et al.*, 1997; Tompkins and Snipe, 1997).

At each location, the target plant population was 50 plants/m^2 (Nikki Johnson, FAR, personal communication, 1999). This was not met at any location, and population was particularly low for three of the cultivars at Dorie, probably because of a combination of low soil temperature at sowing and low vigour seed (Rahman, 2002). Initially the targeted population was considered to be too low; for example in the UK Turff and Leurs (1999) recommended a plant density of 60-70 plants /m^2 for cv. Northern Conquest. However, Rahman (2002)

has subsequently shown that for cv. Northern Conquest and March grown at Lincoln seed yield plateaued at a population of 52 plants/m^2 with no significant increase as population was increased to 70 plants/m^2. Yields in this latter trial at 50 plants/m^2 were 305 g/m^2 for cv. Northern Conquest and 410 g/m^2 for cv. March (Rahman, 2002).

Sowing date ranged from 2 to 23 November. Piggot *et al.* (1980) had recommended mid-November or later for sowing soybean in New Zealand, because of the yield variability associated with earlier sowings. However, the greatest yield in these trials came from Hastings where the trial was sown on 9 November, and Rahman (2002) has shown that in Canterbury, yields of around 250 g/m^2 were obtained following sowings of cv. Northern Conquest and March on 2 and 17 October. Sowing after mid-November resulted in a decreased yield and increasing difficulties with seed desiccation to harvest readiness (i.e. ca. 15 % seed moisture content) (Rahman, 2002).

At the locations where comparable plant populations were achieved (i.e. from 38 to 46 plants/m^2), seed yield differences were explained by significant differences in seed number per plant. Seed numbers in soybean respond to a variety of changes in the plant's environment including temperature, water availability, solar radiation and soil fertility (Egli, 1998). At Cambridge and Nuhaka for example, seed numbers per plant were lower for all cultivars than for the same cultivars at Hastings. The reason, or reasons, for this is not clear. While Hastings received little rain during November to January, the crop was irrigated to avoid moisture stress. Temperatures did not differ markedly among the three sites, but Nuhaka received only about half the solar radiation during January and February that Hastings and Cambridge received. What can be concluded is that these cool tolerant soybean cultivars have the potential to yield well in New Zealand, but an improved understanding is still required of the agronomic requirements of the crop in the New Zealand environment.

Seed protein content ranged from 36 to 43 % for the four cultivars. This compares favourably with the average of 40 % protein for 70 years of soybean production in the USA (Wilcox and Guodong, 1997). Seed oil content from the Dorie crop was 16-19 %, slightly lower than the 20-27 % reported elsewhere (Burton, 1997). However in agreement with previous reports (e.g. Smith et al., 1989; Ramgiry and Raha, 1997), oil content was negatively related to protein content.

Soybean seed coat cracking results from the separation of the epidermis (palisade cells) and hypodermal (hourglass cells) tissue which exposes the underlying parenchyma tissues (Wolf and Baker, 1972). Seed coat cracking is primarily a genetically controlled phenomenon (Yaklich and Barla-Szabo, 1993) and this was supported in the present study, where among the locations, cracking in cv. Alta ranged from 48-64 % cf 2-7% in cv. Northern Conquest.

Quality of the seed produced was significantly affected by trial location and/or management of the crop. At Dorie, Hastings and Blenheim, germination was 85 % or higher (mostly over 90 %) for all four cultivars, and at Dorie in particular, seed vigour was high. This contrasted with the poor quality seed produced from the Cambridge and Nuhaka locations. This result from the latter two locations came from threshing damage, as evidenced by the production of abnormal seedlings during the germination test (Rahman, pers.comm.). Seeds from the Nuhaka trial were threshed at a SMC of 17-21 %, well above the 15 % recommended for soybean (Burton, 1997). Severe seed mechanical damage had also occurred to the Cambridge seed lots, as indicated by both the reduced germination and very high conductivity values. Why this occurred is not known, as the SMC at threshing (10-13 %) was similar to the SMCs at threshing at the Dorie, Hastings and Blenheim sites.

At Dorie, Hastings and Blenheim, where mechanical damage did not occur, the seed produced was mostly consistently high in germination, and AA test results did not differ significantly. However, seed vigour as assessed by conductivity was consistently higher for seed produced at Dorie. This physiological damage (the deterioration of cell membranes) is influenced by the environment during seed maturation, being accelerated by alternate drying and wetting (weathering), hot dry weather, and warm humid weather (Hampton, 2000). It is possible therefore that the environments at Hastings (warm, humid) and Blenheim (hot, dry) were more conducive to seed physiological damage than the environment at Dorie, but this would need confirmation by further study.

Conclusions

- The soybean yields produced at all five locations compared favourably with reported international yields.
- The cool tolerant cultivars allowed successful establishment in early November.
- The effect of plant population on seed yield of these cultivars needs to be determined.
- Seed quality was high following harvest at three locations, but low at the other two locations because of mechanical damage induced during threshing.

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