Low input weed management in field peas

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Abstract

Two trials were conducted on a Templeton silt loam soil at Lincoln University, New Zealand in 2007-08. The aim was to compare the competitive ability of different pea canopy architectures as influenced by genotype, population, sowing date and their interaction as a means of low input weed control strategy. The first experiment had three sowing dates, two pea genotypes (Pro 7035 and Midichi) and two herbicide treatments. Experiment 2 treatments were a factorial combination of four pea populations and three sown artificial weed populations. A significant sowing date x pea genotype interaction showed that in the August sowing genotype had no effect on seed yield. However, in September sown plots Pro 7035 yielded 559 g m^{-2}, which was 40% more than Midichi, and in the October sowing, the difference was 87% more. Herbicide-sprayed peas produced 19% more seed (508 g m^{-2}) than unsprayed plants. When no weeds were sown, the highest pea total dry matter of 1,129 g m^{-2} occurred at 200 plants m^{-2}. This was more than twice (513 g m^{-2}) the yield of the lowest population (50 plants m^{-2}). There was distinct variation in the weed spectrum over time. *Coronopus didymus, Stellaria media* and *Lolium* spp. were present in relatively large numbers throughout the season. Some weeds only occurred late in the season meaning they could be successfully controlled by early sowing. It could be concluded that it is possible to obtain high pea yields by using the right sowing date and appropriate seed rate as a means of low input weed management strategy.

Additional keywords: genotype, low input, population, sowing date, cyanazine, weed spectrum, semi-leafless

Introduction

The poor ability of pea crops to compete with weeds (Melander, 1993; Lutman, *et al*., 1994) is the major drawback of growing them under low input or organic systems. Weeds can cause severe yield losses if crops are not monitored closely, particularly during the early stages of weed emergence (Freeman, 1987). Generally, poor weed management results in weed accumulation and a larger weed seed bank. Farmers usually use conventional herbicides to manage weeds; low input farmers try to use lower amounts of conventional herbicides. The use of synthetic herbicides is not allowed in organic production systems. Organic farmers currently rely mostly on cultural control methods. Weed control is therefore a real constraint in these systems.

Some methods to control weeds under low input systems include intercropping and crop rotation (Zimdahl, 2007), use of competitive crop genotypes (Radosevich *et al*., 1997, Isaac 2001; Blackshaw *et al*., 2007), mechanical and hand weeding, use of appropriate sowing date and, often, high sowing rates (McDonald *et al*., 2007). Several crops show genotypic differences in their competitive ability (Burnside, 1972; McDonald *et al*., 2007) mostly related to plant architecture, leaf area, leaf angle, plant stature, seed and seedling vigour. Also different weed species have different competitive abilities with crops (Harker *et al*., 2007).

Viability of low input and organic systems depends on achieving acceptable yields. Freeman (1987) stressed that consistent yields of around 4 t ha^{-1} are necessary for field peas to be a viable crop. According to Moot (1993), White and Hill (1999), these high pea yields are achievable under favourable conditions despite peas' poor yield stability (McKenzie, 1987; Moot and McNeil, 1995).

The research objective of this work was to compare the competitive ability of different pea canopy architectures as influenced by genotype, population, sowing date and their interaction as a means of low input weed control strategy.

Materials and Methods

Two trials were conducted in 2007-08 on a Templeton silt loam soil (New Zealand Soil Bureau, 1968) at the Horticulture Research Area, Lincoln University, Canterbury, New Zealand (43° 38'S, 172° 28'E.). MAF soil quick tests were done to establish actual soil available nutrient levels (Table 1). All the nutrient levels were in the acceptable range for growing peas and the pH was also optimal.

Table 1: MAF soil quick test for the trial site (paddocks H14 and H3, Horticulture Research Area, Lincoln University).

Experiment	pH	Olsen-soluble P (μg ml^{-1})	Ca	Mg	K	Na	Sulphate (μg g^{-1})
1 and 2	6	15	7	21	10	6	4

Ca, Mg, K, and Na as mg g^{-1} of soil.

In experiment 1, treatments were arranged in a split plot design with three replicates. Main plots were sown on 9 August, 13 September and 15 October 2007. Sub-plots were a factorial combination of two pea genotypes, conventional (Pro 7035) and semi-leafless (Midichi) and two herbicide treatments (cyanazine at 0 and 500 g active ingredient ha^{-1}) applied before emergence. The total number of plots was 54 (36 plots with peas and 18 no pea control plots). Each plot was 2.1 m wide x 10 m long. Experiment 2 was sown on 13 September and the treatments were a factorial combination of four pea populations (0, 0.5 x recommended sowing rate, recommended sowing rate (100 plants m^{-2}), 2.0 x recommended sowing rate), and three sown artificial weed populations (0, 1/3 recommended (referred to here as lower rate) and 2/3 recommended (referred to here as higher rate) of each weed. The sown artificial weeds were a mixture of rapeseed (*Brassica napus* L.), Italian ryegrass (*Lolium multiflorum* Lam.) and common vetch (*Vicia sativa* L.) which had recommended sowing rates of 3, 25 and 30 kg ha^{-1} respectively when sown as crops and this translated to 100, 833 and 75 seeds m^{-2} respectively. This was a good representation of a broad spectrum of weeds commonly found in most fields. The experiment design was a randomised complete block with three replicates. The total number of plots was 36. Each plot was 2.1 m x 6 m long. The field pea variety used was Midichi (a semi-leafless type).

Husbandry

Irrigation was applied based on crop requirement as determined by Time Domain Reflectometry (TDR) in the 0-20 cm soil layer, when the soil reached 50% of field capacity based on the first sowing date. A mini boom irrigator applied 30 mm of water at each irrigation. A total of 120 mm was applied to both experiments. The peas were sprayed with cyproconazole at 250 ml ha^{-1} to combat powdery mildew (*Erysiphe* spp.) and with copper oxychloride at 1 kg ha^{-1} for downy mildew in both experiments.

Measurements and analysis

A 0.2 m^2 sample was taken from each plot using a 0.1 m^2 quadrat every 7-10 days throughout the season starting from three weeks after crop emergence. This was used for crop and weed dry matter measurements. Samples were dried in a forced draught oven for 24-48 h at 60°C to a constant weight and then weighed. Final harvests were taken when crops reached a moisture content of 15-18%. Final total dry matter (TDM) and seed yield were estimated from 1 m^2 quadrat samples. Plants were cut at ground level and weighed. They were hand threshed and the seeds weighed. Weed counts were taken three times during the growing season and this was at 10 weeks after emergence of each sowing date. Weeds were sorted by taxa (species or genus depending on similarity) and counted. Uncommon taxa were pooled and their total count recorded.

All data were subjected to analysis of variance (ANOVA). Genstat v.10.1. (Lawes Agricultural Trust (Rothamsted Experimental Station, UK) was used for statistical analysis. Means were separated at the 5% level of significance using least significance difference (LSD) for sowing date, herbicide, genotype, population and interaction effects.

Results

Climate

Climate data was from the Broadfields Meteorological Station, Lincoln University located about 1.5 km from the experimental site. The 2007-08 growing season was generally dry, with January rainfall being just 38% of the long-term average (Figure 1). Substantial rain fell at the end of the season in February (104 mm). The season was generally cool and all mean temperatures, except in September, were lower than long-term means (Figure 2).

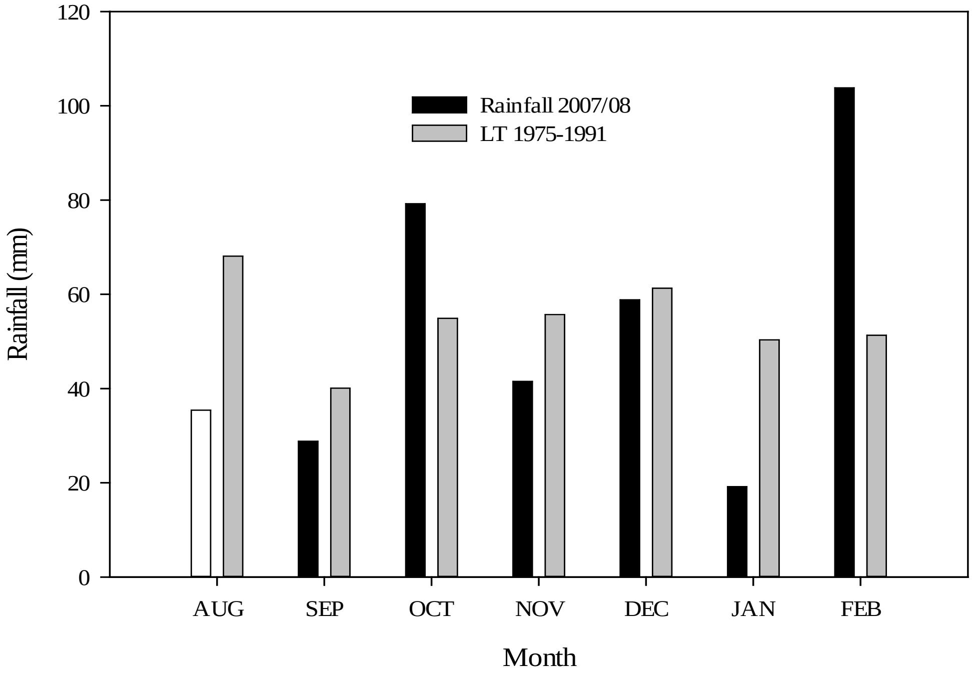

Figure 1: Rainfall data for Broadfields, Canterbury, in the 2007-08 growing season and long term mean 1975-1991.

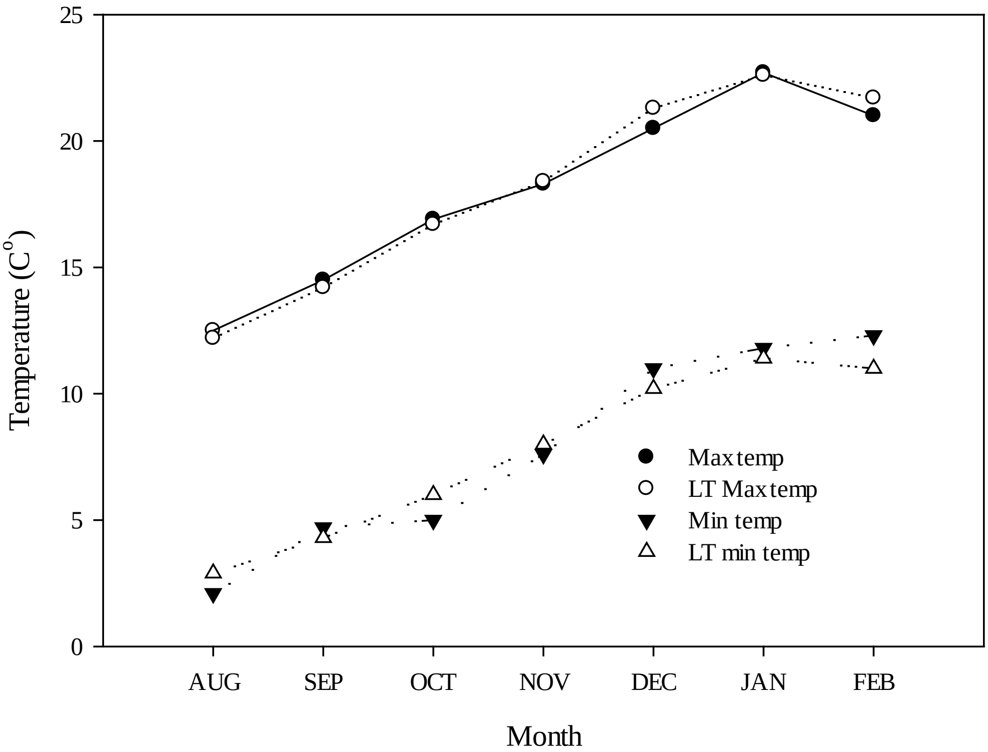

Figure 2: Temperature data for Broadfields, Canterbury, in the 2007-08 growing season and the long-term mean 1975-1991.

Crop yield and harvest index

TDM at final harvest of the August and September sowings were not significantly different (mean 1,018 g m^{-2}) but they were significantly higher than from the October sowing and cyanazine sprayed plots produced 21% more TDM than unsprayed plots (788 g m^{-2}) (Table 2). There was no significant difference in the mean TDM produced by the two pea cultivars Midichi and Pro 7035 (mean 941 g m^{-2}).

Table 2: Total dry matter, seed yield, crop harvest indices at final harvest of field peas grown in Canterbury in the 2007-08 growing season (Experiment 1).

	TDM (g m^{-2})	Seed yield (g m^{-2})	CHI
Sowing date (S)			
August	1005a	572a	0.57a
September	1031a	479a	0.47ab
October	788b	354b	0.44b
Significance	*	**	**
LSD	192.9	94.7	0.04
Herbicide (H)			
0 g active ingredient ha^{-1}	852	428	0.50
500 g active ingredient ha^{-1}	1030	508	0.49
Significance	***	***	NS
LSD	94.4	43.8	-
Pea type (T)			
Midichi	911	398	0.43
Pro 7035	971	539	0.56
Significance	NS	***	***
LSD	-	43.8	0.02
CV (%)	14.3	13.4	5.6
Significant interactions	Nil	SxT*	SxT***

Herbicide sprayed peas produced 19% more seed (508 g m^{-2}) than the unsprayed plants (Table 2). A significant ($P<0.05$) sowing date x pea genotype interaction showed that in the August sowing genotype had no effect on seed yield (Table 3). However, in September sown plots Pro 7035 yielded 559 g m^{-2}, which was 40% more than Midichi, and in the October sowing, the difference was 87% more.

Herbicide had no effect on crop harvest index (CHI). Pro 7035 had a higher CHI than Midichi (0.56). There was a significant sowing date x genotype interaction for CHI (Table 4). This showed that in an August sowing there was less difference in CHI between the two cultivars than at the other two sowing dates.

Table 3: The sowing date x pea genotype interaction on seed yield of field peas grown in Canterbury in the 2007-08 growing season (Experiment 1).

	Sowing date		
Pea genotype	August	September	October
Midichi	547ab	400c	246d
Pro 7035	597a	559a	461ac
Significance		*	
LSD		96.2	
CV (%)		13.4	

Table 4: The sowing date x pea genotype interaction on CHI of field peas grown in Canterbury in the 2007-08 growing season (Experiment 1).

	Sowing date		
Pea genotype	August	September	October
Midichi	0.47b	0.32d	0.30d
Pro 7035	0.55a	0.42c	0.48b
Significance		**	
LSD		0.05	
CV (%)		7.5	

In experiment 2, dry matter accumulation was directly proportional to pea population throughout the season and growth curves for each population had a typical sigmoidal shape (Figure 3). The highest pea TDM was achieved at 200 plants m^{-2} (1,120 g m^{-2}), which was more than twice the yield of the lowest pea population (513 g m^{-2}) with sown weeds (Table 5). The control treatment (no-sown weeds) had the highest pea DM throughout the season. The low weed rate and the high weed rate treatments had similar DM accumulation throughout. However, the two were significantly different from the control treatment (Figure 4).

In experiment 2 seed yield increased significantly ($P<0.001$) as pea population increased (Table 5). Two hundred pea plants m^{-2} gave the highest mean seed yield at 409 g m^{-2} and 50 pea plants m^{-2} the lowest at 197 g m^{-2}. Conversely, the control treatment gave the highest mean seed yield of 390 g m^{-2}. CHI did not vary and the grand mean was 0.39.

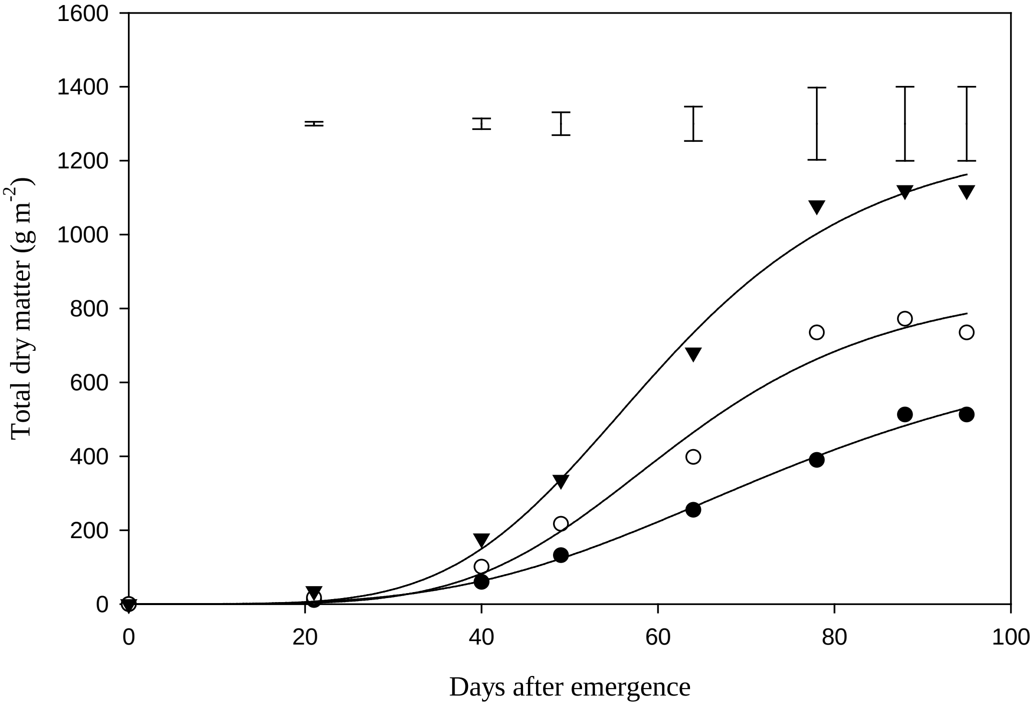

Figure 3: Total dry matter accumulation of field peas, over time, grown in Canterbury in the 2007-08 growing season, pea population (●) = 50 plants m^{-2}; (○) = 100 plants m^{-2}; (▼) = 200 plants m^{-2}. (Bars are LSD at P<0.05).

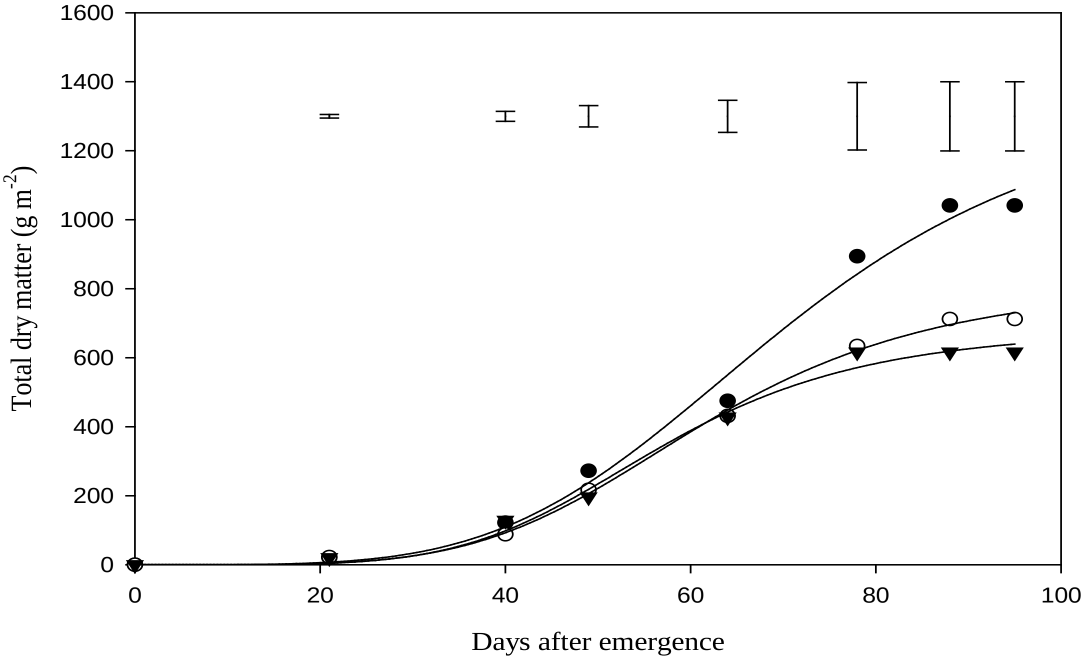

Figure 4: Total dry matter accumulation of field pea, over time, grown in Canterbury in the 2007-08 growing season, sown artificial weed population (●) = Nil; (○) = Low rate weed population; (▼) = High rate weed population. (Bars are LSD at P<0.05).

Table 5: Total dry matter, seed yield and crop harvest index (CHI)) at final harvest of field peas grown in Canterbury in the 2007-08 growing season (Experiment 2).

	Total dry matter (g m^{-2})	Seed yield (g m^{-2})	CHI
Pea population (P) (plants m^{-2})			
50	513c	197c	0.39
100	735b	294b	0.40
200	1,120a	409a	0.37
Significance	***	***	NS
LSD	200.4	71	-
Sown weed population (W)			
Nil	1,041a	390a	0.37
Low weed rate	712b	284b	0.31
High weed rate	616b	226b	0.28
Significance	***	***	NS
LSD	200.4	71.0	-
CV (%)	25.4	23.7	10.4
Significant interactions	Nil	Nil	Nil

Total Weed Dry Matter

In experiment 1 there was no difference in weed DM accumulation in response to pea genotype throughout until harvest when the no pea treatment plots had the highest weed DM (Figure 5). Throughout the season there was more weed DM in unsprayed plots than in sprayed plots (Figure 6). In experiment 2, weed DM always increased with decreased pea population throughout the season (Figure 7). At final harvest, there was a 31% reduction in weed DM with an increase in pea population from 0 to 50 plants m^{-2} and a similar percentage decrease from 50 to 100 plants m^{-2} (Table 6). Overall, there was a 51% reduction in weed dry matter from 50 to 200 plants m^{-2}. With sown weeds there was an increase in weed DM with increased weed population. The no-sown-weed control plots had the lowest weed biomass throughout the season (Figure 8). However, weed DM in the two sown weed treatments were not significantly different from each other but were significantly different from the no-sown weed treatment throughout the season.

Weed Counts

There was distinct variation in the weed spectrum over time in experiment 1. Tables 7, 8 and 9 show weed counts for each sowing date. Generally, weed counts were lower in sprayed than in unsprayed plots and there were several significant herbicide x pea genotype interactions on most major weeds. To summarise the interactions, significant differences of weed counts between the cyanazine sprayed plots and unsprayed plots was highest in the no pea control plots, followed by Midichi plots and the lowest was in Pro 7035.

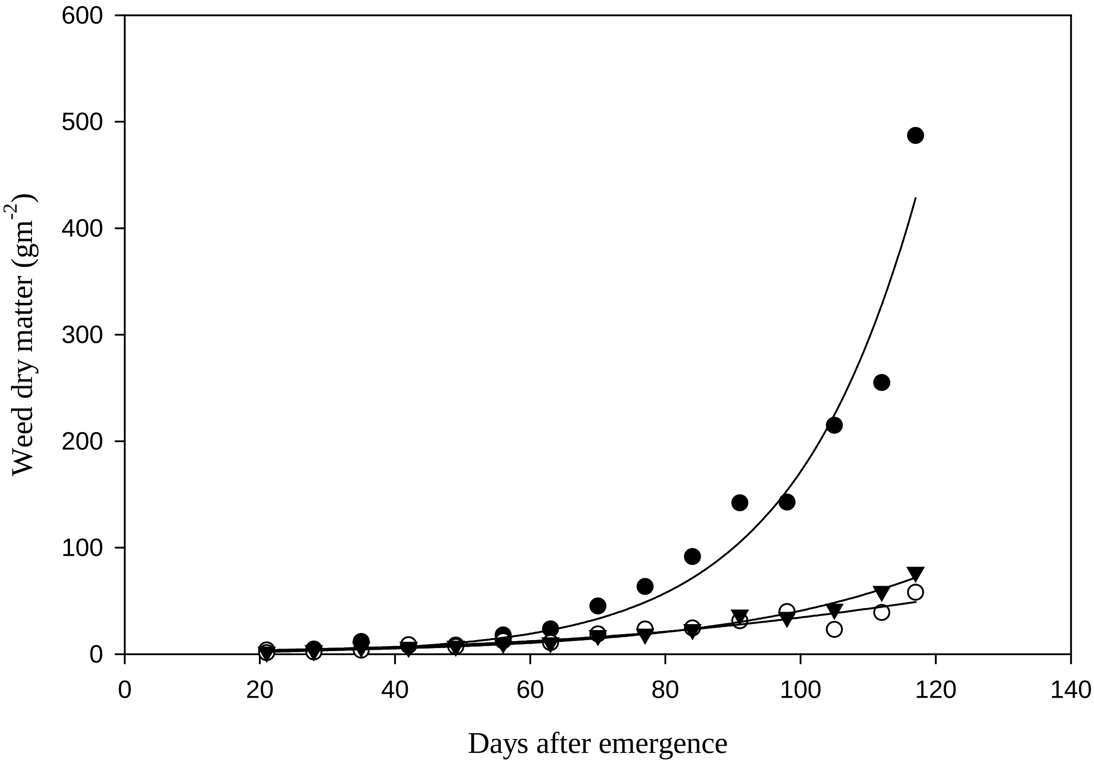

Figure 5: Weed dry matter accumulation of field pea over time grown in Canterbury in the 2007-08 growing season, variety (●) = no pea; (○) = Midichi; (▼) = Pro 7035.

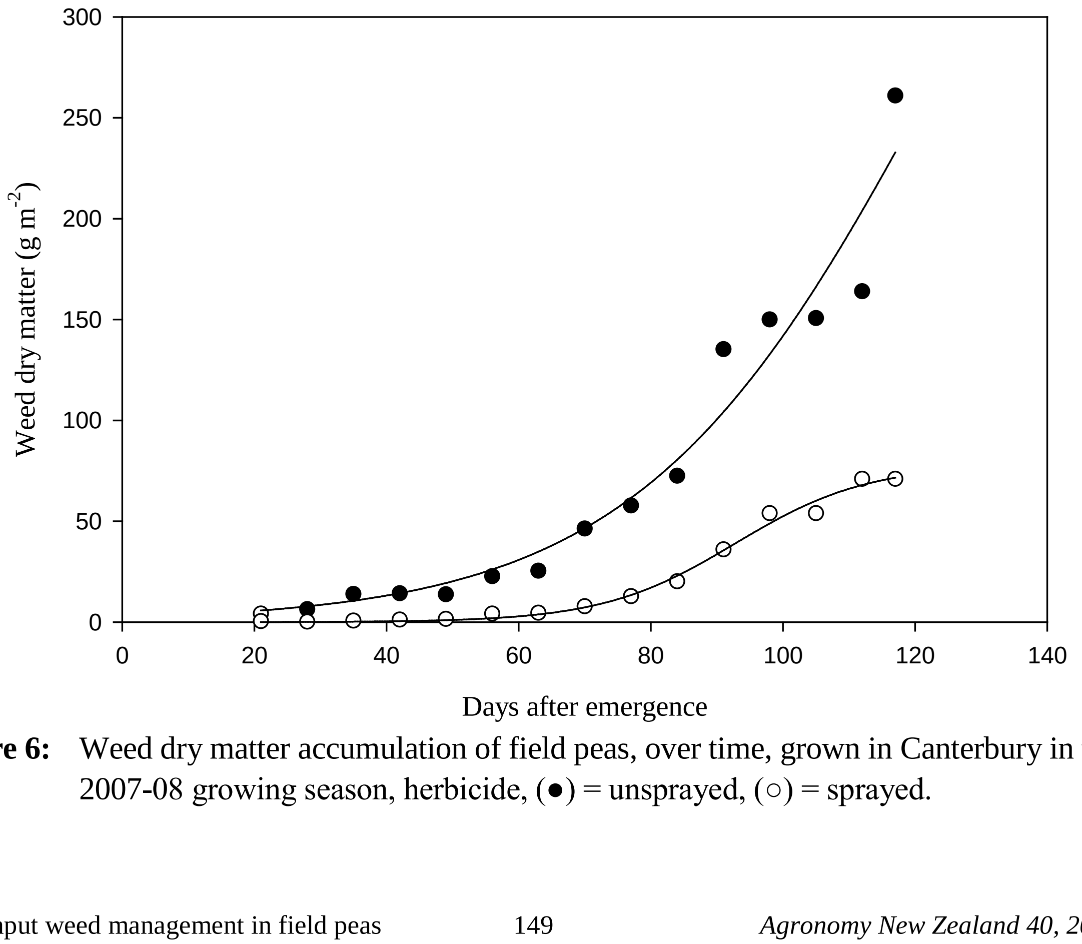

Figure 6: Weed dry matter accumulation of field peas, over time, grown in Canterbury in the 2007-08 growing season, herbicide, (●) = unsprayed, (○) = sprayed.

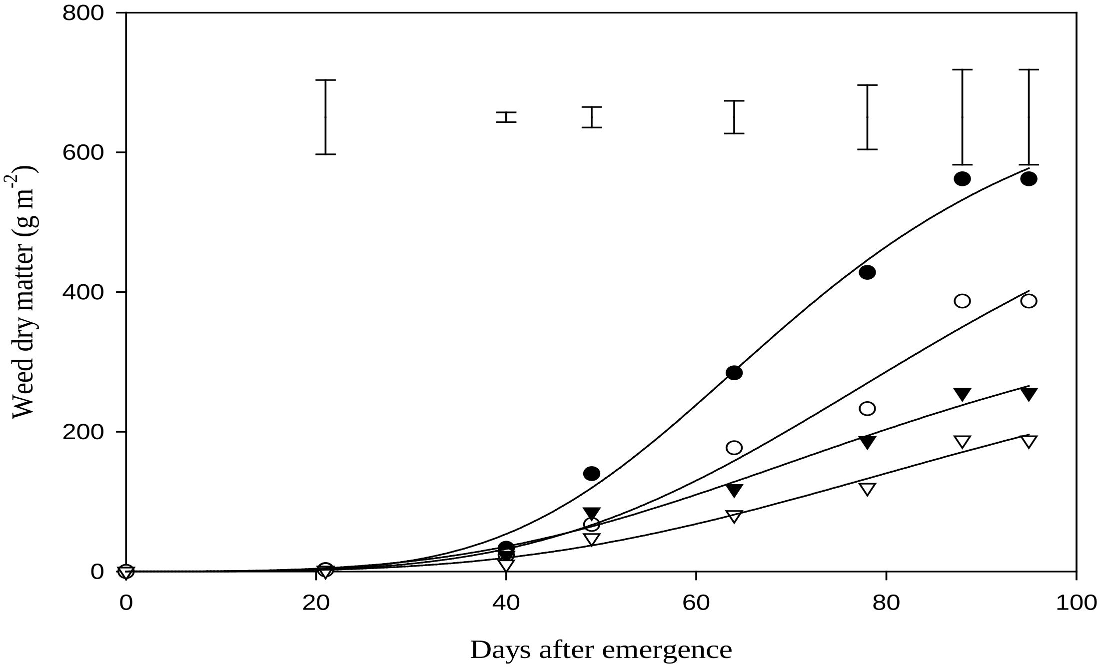

Figure 7: Weeds total weed dry matter accumulation in field peas, over time, grown in Canterbury in the 2007-08 growing season, pea population, (●) = 0 plants m^{-2}; (○) = 50 plants m^{-2}; (▼) = 100 plants m^{-2}; (∇) = 200 plants m^{-2}, Bars are LSD at $P<0.05$).

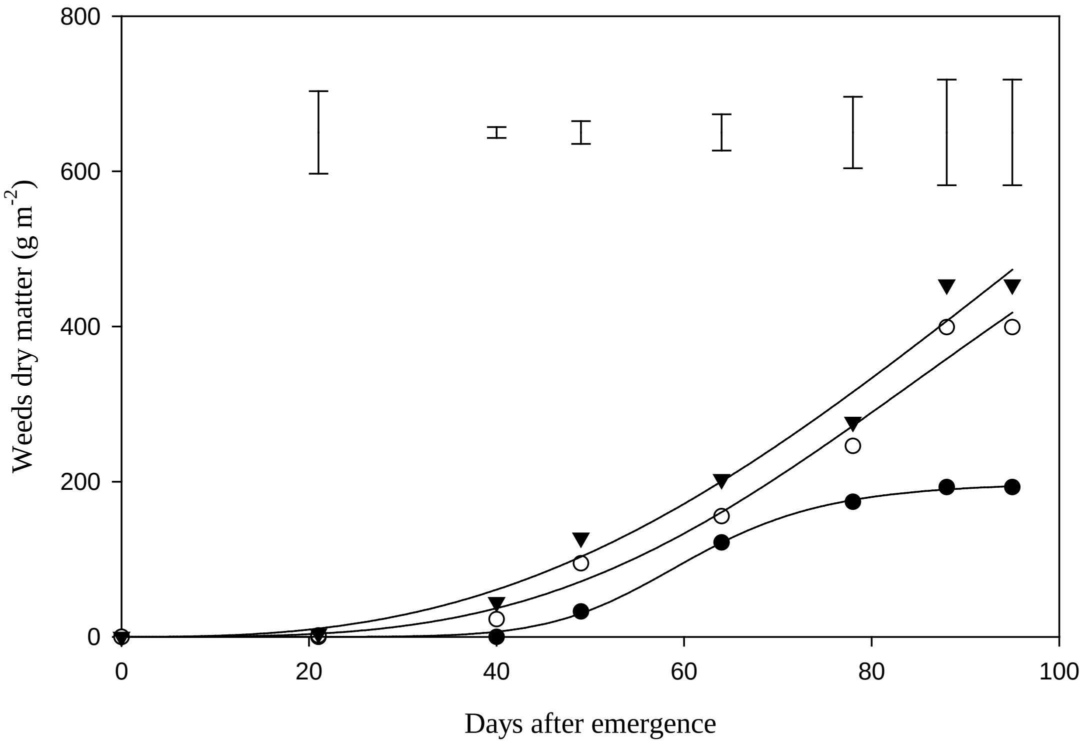

Figure 8: Weed total dry matter accumulation in field peas, over time, grown in Canterbury in the 2007-08 growing season, sown artificial weed population, (●) = nil; (○) = low rate weed population; (▼) = high rate weed population. Bars are LSD at $P<0.05$.

Table 6: Weed total dry matter (g m^{-2}) at final harvest of field peas grown in Canterbury in the 2007-08 growing season (Experiment 2).

Pea population (P) (plants m^{-2})	Weed total dry matter (g m^{-2})
0	562a
50	387b
100	256ac
200	188c
Significance	***
LSD	136
Sown weed population (W)	
Nil	193b
Low weed rate	399a
High weed rate	454a
Significance	***
LSD	118
CV (%)	40
Significant interactions	Nil

Table 7: The density of weeds (m^{-2}) present after 10 weeks in field peas sown on 9 August 2007 (Experiment 1).

	Coronopus spp.	*Lolium* spp.	*Spergula arvensis*	*Stellaria media*	*Stachys* spp.	Others	*Achillea millefolium*	Total count
Herbicide (H)								
0 g active ingredient ha^{-1}	233	43	29	112	18.9	42	3	524
500 g active ingredient ha^{-1}	39	9	1	40	3.3	19	2	116
Significance	***	***	**	*	NS	NS	NS	***
LSD	19	14	18	63	-	-	-	95
Type (T)								
No pea	128	20	13	68	15	33	5	282
Midichi	147	22	12	95	10	25	3	372
Pro 7035	133	37	20	65	8.3	33	0	307
Significance	NS	NS	NS	NS	NS	NS	NS	NS
LSD	-	-	-	-	-	-	-	-
Grand mean	136	26	15	76	11	31	3	320
CV (%)	45	52	112	78	160	67	204	28
Significant interactions	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Table 8: The density of weeds (m^{-2}) present after 10 weeks in field peas sown on 13 September 2007 (Experiment 1).

	Coronopus spp.	*Lolium* spp.	*Spergula arvensis*	*Stellaria media*	*Chenopodium* spp.	*Achillea millefolium*	*Urtica urens*	*Rumex* spp.	*Capsella bursa-pastoris*	Others	Total count
Herbicide (H)											
0 g active ingredient ha^{-1}	64	2	7	34	13	1	22	35	10	22	209
500 g active ingredient ha^{-1}	12	3	1	2	4	2	6	3	2	21	55
Significance	***	NS	*	***	*	NS	***	***	*	NS	***
LSD	11	-	5	7	9	-	5	6	6	-	26
Type (T)											
No Pea	59	2	7	17	17	1	19	30.6	6	26	184
Midichi	21	3	3	22	3	2	22	16	1	8	101
Pro 7035	34	1	2	16	6	2	1	9	11	29	111
Significance	***	NS	NS	NS	***	NS	***	***	*	**	***
LSD	14	-	-	-	11	-	6	7	8	13	32
Grand mean	38	2	4	18	8	2	14	19	6	21	132
CV (%)	54	134	231	71	199	299	67	55	187	90	36
Significant interactions	HxT*	HxT*	Nil	HxT*	Nil	Nil	HxT***	HxT***	Nil	HxT**	HxT**

Table 9: The density of weeds (m^{-2}) present after 10 weeks in field peas sown on 15 October 2007 (Experiment 1).

	Coronopus spp.	*Chenopodium* spp.	*Rumex* spp.	*Lolium* spp.	*Stellaria media*	*Solanum* spp.	*Trifolium repens*	Others	Total count
Herbicide (H)									
0 g active ingredient ha^{-1}	61	17	26	20	19	27	66	31	266
500 g active ingredient ha^{-1}	22	7	3	9	9	8	27	9	93
Significance	**	NS	***	NS	NS	NS	NS	NS	*
LSD	23	-	10	-	-	-	-	-	105
Type (T)									
No pea	53	12	18	5	12	23	77	20	220
Midichi	40	15	17	23	10	15	10	18	148
Pro 7035	32	8	8	15	20	13	52	22	170
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD	-	-	-	-	-	-	-	-	-
Grand mean	42	12	14	14	14	17	46	20	179
CV (%)	54	172		148	155	137	144	129	56
Significant interactions	Nil	Nil	HxT*	Nil	Nil	Nil	Nil	Nil	Nil

Discussion

A significant ($P<0.05$) sowing date x genotype interaction showed that in the August sowing genotype had no effect on seed yield. However in September sown plots the Pro 7035 seed yield of 559 g m^{-2} was 40% more than that Midichi. By October it was 87% more. This highlights the need to select a suitable genotype for use at different times in the season. Early in the season both genotypes could be used without yield reduction. As the season progressed, it was better to use a fully leafed genotype to smother the increased weed spectrum and numbers associated with the later sowing date, although both pea types were significantly better than the control no pea plots.

Genotype had no effect on seed yield in August because there were fewer weeds, which were slow growing because of the low temperatures. This gave both pea genotypes (base temperature 4°C) the same competitive advantage over the weeds and hence the effect of weeds was not evident in this sowing. However, there was an increase in weed spectrum and quantity as the season progressed, possibly, attributable to increased temperatures. As a result the effect of weeds and the differences in the competitive ability against them of the different pea genotypes became evident.

Herbicide was effective in reducing weeds. Sprayed plots had a mean seed yield of 508 g m^{-2}, which was 19% more than the mean of unsprayed plots. This shows the effect of weeds on crop yield through competition for nutrients, light, space, and water.

Seed yield increased significantly ($P<0.001$) as pea population increased. At 200 plants m^{-2} the highest mean seed yield of 409 g m^{-2} was obtained and at 50 plants m^{-2} it was the lowest (197 g m^{-2}). Similarly, Townley-Smith and Wright (1994) reported pea yield increases and weed dry weight reduction by raising field pea density from 50 to 100 seeds m^{-2}, but concluded that increasing the seeding rate over 100 seeds m^{-2} would be unlikely to give a better result. The authors suggest a 70% increase in the seeding rate (150 seeds m^{-2} compared with normal 90 seeds m^{-2}) was costly in peas and could not always be compensated for by higher yield. Martin *et al.* (1992) reported that increased plant density above 150 plants m^{-2} was not associated with a higher seed yield, although it did increase straw production. Similarly, White and Hill (1999) recommended an optimum population of 70 plants m^{-2} on shallow soils, 90 plants m^{-2} on deeper soils and 100-120 plants m^{-2} for irrigated pea crops in New Zealand. McKenzie *et al.* (1999) reported optimum dry pea populations of 90-100 plants m^{-2} but did not specify growing conditions.

Weed DM production was inversely proportional to pea population from 42 days after emergence until final harvest (Figure 7). Increased pea population gave the crop a greater competitive advantage against weeds and a relatively higher TDM production and seed yield. The nil-sown artificial weed treatment gave the highest mean seed yield of 390 g m^{-2} because it had only a few weeds and hence experienced the least competition. The reduction in pea TDM with increased weeds was basically because of competition for light and nutrients. Peas can clearly out compete weeds for light if sown at a higher than normally recommended population (McDonald *et al*., 2007).

Marx and Hagedorn (1961) reported that higher seeding rates of peas are effective in reducing weed development and Farshatov (1973) found that increasing sowing rates of peas from 100-140 plants m^{-2} reduced the weed population 2.5 fold. In this research there was a 31% reduction in weed DM with increased pea population from 0 to 50 plants m^{-2} and a similar percentage reduction from 50 to 100 plants m^{-2}. Overall there was a 51% reduction from 50 to 200 pea plants m^{-2}. Grevsen, (2003) found a similar weed reduction and reported that increasing the seeding rate from the normal 90 to 150 seeds m^{-2} reduced the dry weight of weed plants at harvest by 50% in 1997 and by 30% in 1998. Results of this research support weed DM reductions as a result of crop population increases.

Environmental effects such as temperature might have caused the variation of weed spectrum at the different sowing dates. Lesser swine-cress (*Coronopus didymus*), *Lolium* spp. and common chickweed (*Stellaria media*) were found throughout the season. Cox, 1977 classified *Coronopus didymus* as an early weed. *Stellaria media* grew well over a wide range of environments. Even early in the season, when temperatures were quite low, it was present in large numbers. This could be due to its low base temperature, estimated at -3.3°C (Storkey and Cussans, 2000). Zimdahl (2007) reported that common chickweed survives well in cold climates because it continues to grow in winter without injury. Another weed of similar interest recorded was lamb's quarter (*Chenopodium album*). *Chenopodium album* is one of the most widely distributed weed species in the world and ranks among the top three important weeds of cereals in New Zealand (White and Hill, 1999; Isaac 2001). Contrary to the findings of Myers *et al.* (2004) that it is an early weed in United States of America, in this research it occurred during mid- to late season. Cox, 1977 classified it as a late weed in New Zealand. Yarrow (*Achillea millefolium*) emerged early and during mid-season, and could have had a major role in reducing the yield of early sown peas. It is considered as a common, successful, hard-line weed on arable land in New Zealand (Bourdôt and Field, 1988). Hartley *et al.* (1984) reported that the success of this weed is also attributed to its persistent, vigorous rhizomes. Bourdôt and Butler (1985) reported that it grew throughout the year and spread laterally, by rhizome extension, particularly in the winter months in Canterbury.

In this research late weeds were white clover (*Trifolium repens*) and nightshade (*Solanum* spp.). Nightshades have a base temperate of 6°C (Olivier and Annandale, 1998) and this explains why they usually grow late in the season when temperatures are warmer. Myers *et al.* (2004) also reported nightshades were late weeds. Isaac (2001) reported higher *Trifolium repens* counts in late sown crops than in early sown crops confirming that it is a late weed.

Conclusions

The following conclusions were drawn out of the research:

1. There was a significant sowing date x genotype on seed yield that indicated the need to use specific genotypes for different sowing times.
2. Pea yield could be increased by increasing pea population especially in weedy environments.
3. Weed spectrum changed over the season.
4. Early sowing could possibly control problem weeds of peas (particularly *Solanum* spp.) by avoiding competition from this weed.
5. Pea genotype alone did not have any direct effect on weed suppression.

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