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Yield Response to Pea (*Pisum sativum* L.) Genotype, Population and Sowing Date

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Abstract: This research objective was to examine the effect of herbicide, genotype, population and sowing date on crop yield and weed growth in *Pisum sativum*. In 2007/08, cyanazine treated peas had a mean seed yield of 508 g m^{-2}, 19% more than in unsprayed plots. There was a significant sowing date by pea genotype interaction which showed that in the August sowing genotype had no effect on seed yield. However, in September Pro 7035 yielded 559 g m^{-2}, which was 40% more than Midichi. By the October sowing, it was 87% more. There was a distinct variation in weed spectrum, over time. It can be concluded that fully leafed peas and semi-leafless can be sown at similar plant populations and give similar yields under weed free conditions and that increased pea sowing rates increased total dry matter and seed yield in weedy environments. Fully leafed peas yielded more than semi-leafless peas when both were late sown. Increased pea sowing rate improved weed suppression.

Keywords: Genotype, yield, cyanazine, herbicide, weed spectrum, total dry matter, semi-leafless.

INTRODUCTION

Sustainable crop production requires growers to consider all agronomic and environmental aspects and optimise them to obtain optimum yields without degrading the environment. In organic production systems this can be difficult and growers try to control weeds by intercropping [1], crop rotation, mechanical and hand weeding, use of appropriate sowing date, competitive crop genotypes [2] and, often, high sowing rates. Sowing date is a major determinant of crop yield as it determines crop duration. The trend in crop production is for early sowing to optimise yield [3]. Yield is increased because crops have a longer growing season and photosynthesise for longer. Also early growth allows earlier canopy closure and a gives a greater competitive edge to the crop over some weed species.

Using the right crop genotype can also enhance crop yield. Crop genotype has an important role in a weed control strategy [4, 5]. Putnam [6] reported that the intensity of weed suppression depended principally on the morphology and rate of crop growth. Several crops show genotypic differences in their competitive ability [7, 8] and different weed species have different competitive abilities with crops [9]. Conscious use of crop interference was reported by Zimdahl [10] as an effective cultural weed control method. The use of a higher than normal seeding rate of 90 seed m^{-2}, for conventional growing, may be necessary to give a higher competitive ability in organic pea (*Pisum sativum* L.) production [10]. The research objective of this work was to examine the effect of field pea genotype, population and sowing date and their interactions on crop yield, yield components and weed growth.

MATERIALS AND METHODS

Trials were conducted on a Templeton silt loam soil [12] at the Horticulture Research Area, Lincoln University, Canterbury, New Zealand (43° 38'S, 172° 28'E.) in the 2006/07 and 2007/08 growing season. MAF soil quick tests were done to establish actual soil available nutrient levels and all were found to be within the recommended range for growing peas in New Zealand.

The 2006/07 experiment was a split plot design with three replicates. Main plots were two herbicide treatments (cyanazine at 0 or 500 g a.i. ha^{-1}). Sub-plots were a factorial combination of three field pea genotypes; conventional (Pro 7035), semi-leafless branched (Aragorn) and semi-leafless unbranched (Midichi) and three pea populations; 0.5 x the recommended sowing rate (50 plants m^{-2}), recommended sowing rate (100 plants m^{-2}) and 4.0 x recommended sowing rate (400 plants m^{-2}). Controls were plots without peas, which were sprayed or not sprayed with cyanazine. Plots were 2.1 m wide x 8 m long. In Experiment 2 treatments were also 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 a.i. ha^{-1}). The total number of plots was 54. Each plot was 2.1 m wide x 10 m long.

Husbandry

Land was prepared using conventional methods i.e. disking, rolling and harrowing. Soil was tilled to a depth 25 cm. In Experiment 1 a pre-emergence cyanazine spray of 500 g a.i.ha^{-1} was applied in 237 l water ha^{-1} to 30 of the 60 plots, to create main plots. Seed was drilled with an Öyjord cone seeder at a depth of 5 cm. In Experiment 1 seed was sown on 12 September 2006 in 15 cm rows with varying inter-row spacing to achieve the required pea populations of

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50, 100 and 400 peas m^{-2}. In Experiment 2, seed was sown in 15 cm rows and was sown at 100 plants m^{-2} at the sowing dates indicated above. Cyanazine was applied pre-emergence to target plots at 500 g a.i. ha^{-1} with a knapsack sprayer.

Wakil, a formulated mixture of Metalaxyl, Fludioxonil and Cymoxanil for control of *Peronospora* spp (downy mildew), *Pythium* spp and *Ascochyta* spp, was applied to all seed at the equivalent of 2 kg t^{-1} of seed before sowing. All sowing rates were corrected for the laboratory germination percentage and expected field emergence for each pea variety.

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. At each irrigation a mini boom irrigator applied 30 mm of water. A total of 90 mm was applied during the first season and 120 mm in the second season. In both seasons the peas were sprayed with Alto (cyproconazole) 100 SL at 250 ml ha^{-1} to combat powdery mildew (*Erysiphe* spp) and with copper oxychloride at 1 kg ha^{-1} for downy mildew.

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. Samples were used to measure pea and weed dry matter (DM). Samples were dried in a forced draught oven for 24 – 48 h at 60 °C to a constant weight and weighed. At 3 weeks after emergence (WACE) weeds were sorted by taxa (species or genus depending on similarity) and counted. Uncommon taxa were pooled and their total count recorded. A weed species was defined as major if it had a mean count of at least 10 weeds m^{-2} and as minor if it had a mean count of at least 2 plants m^{-2} but less than 10 plants m^{-2}. A weed species was defined as 'Others' if it had a mean of less than 2 counts m^{-2} and these were bulk-counted together.

At final harvest yield and yield components were measured. Final harvests were taken when crops reached a moisture content of 15 – 18%. Final total DM 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. Five plants were selected from the bulk sample and were used to calculate yield components.

All data were subjected to analysis of variance (ANOVA). Genstat 10.1. (Copyright 2007, Lawes Agricultural Trust, Rothamsted Experimental Station) was used for statistical analysis. Means were separated at the 5% level of significance using least significance difference (LSD) for herbicide main effects, population, type and interactions effect in the first season and for sowing date main effects, herbicide, genotype and interactions in the second season.

RESULTS

Climate

Climate data was from the Broadfields Meteorological Station, Lincoln University located about 1.5 km from the experimental site. The 2006/07 season was generally dry at the beginning. However, there was substantial rain in December (110.6 mm) and October (97.6 mm), when almost double the long-term average fell (Fig. **1**). In the 2007/08 growing season rainfall was below long-term average early in the season, August and September (Fig. **1**). Substantial rainfall was received in February doubling the long-term average. Both seasons were generally cooler than the long-term average. Solar radiation, vapour pressure deficit and evapotranspiration data for both seasons is presented in Table **1**.

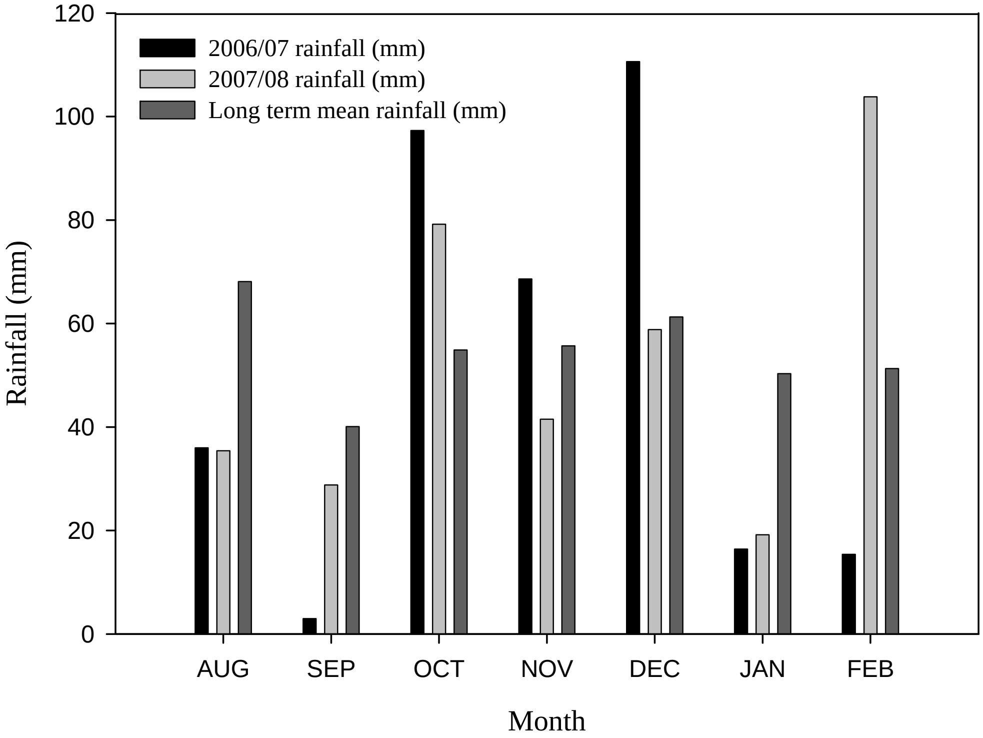

Fig. (1). Rainfall data for Canterbury in the 2006/07, 2007/08 growing seasons and long-term mean (1975 – 1991).

Table 1. Weather Data for the 2006/07 and 2007/08 Growing Seasons for Lincoln University, Canterbury

Month	Solar Radiation ($MJm^{-2}month^{-1}$)		Vapour Pressure (Pa)		Penman ET (mm)	
	2006/07	2007/08	2006/07	2007/08	2007/08	2007/08
September	375.1	369.9	9.2	9.2	87.5	73.9
October	542.9	570.0	9.4	9.0	120.8	123.5
November	633.3	705.5	10.8	11.0	127.7	131.8
December	648.8	711.2	11.3	13.6	126.1	141.2
January	585.5	698.4	13.7	14.3	115.2	151.7
February	511.1	530.2	14.1	14.2	102.8	113.7

Total Dry Matter

Until final harvest no factor influenced total dry matter (TDM) throughout the 2006/07 season. At final harvest, there was a significant ($p < 0.05$) herbicide by population interaction. This showed there was no significant difference in total DM in sprayed and unsprayed plots at 100 and 400 plants m^{-2} (Table **2**). However, at 50 plants m^{-2} the sprayed peas produced 30% more TDM (1,517 g m^{-2}) than unsprayed peas (1,162 g m^{-2}). In the 2007/08 season, total DM at final harvest of the August and September sowings were not significantly different from each other (mean 1,018 g m^{-2}) but they were significantly ($p < 0.05$) higher than in the October sowing (Table **3**). Sprayed plots produced 21% more TDM than unsprayed plots. 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. The Herbicide x Population Interaction on Total Dry Matter at Harvest, of Field Peas Grown in Canterbury in the 2006/07 Growing Season (g m^{-2})

		Population (plants/m^2)	
Herbicide (H)	50	100	400
0 g a.i. ha^{-1}	1162	1332	1269
500 g a.i. ha^{-1}	1517	1244	1287
Significance	*		
LSD	200.1		
CV (%)	19.1		

*$p<0.05$, **$p<0.01$, ***$p<0.001$

Seed Yield

In the 2006/07 season herbicide had no effect on seed yield and the overall mean was 673 g m^{-2}, (Table **4**). There

Table 3. Total Dry Matter, Seed Yield, Crop and Plant Harvest Indices at Final Harvest of Field Peas Grown in Canterbury in the 2007/08 Growing Season

	TDM (g m^{-2})	Seed Yield (g m^{-2})	CHI
Sowing date (S)			
August	1005 b	572 b	0.57 b
September	1031 b	479 b	0.47 ab
October	788 a	354 a	0.44 a
Significance	*	**	**
LSD	192.9	94.7	0.04
Herbicide (H)			
0 g a.i. ha^{-1}	852	428	0.50
500 g a.i. 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***

NS=Not significant at 0.05; *$p<0.05$, **$p<0.01$, ***$p<0.001$

was also no significant seed yield difference among the pea genotypes, Aragorn, Pro 7035 and Midichi. However there was a significant ($p < 0.05$) herbicide by population interaction (Table **5**). Herbicide had no effect on seed yield at 100 and 400 plants m^{-2} but at 50 plants m^{-2} cyanazine treated plots produced 829 g m^{-2} of seed, which was 30% more than the 637 g m^{-2}, produced in the no herbicide treatment.

Table 4. Total Dry Matter (TDM), Seed Yield, and Crop Harvest Index (HI) at Final Harvest (126 DAE) of Field Peas Grown in Canterbury in the 2006/07 Growing Season

	TDM (g m^{-2})	Seed yield (g m^{-2})	HI
Herbicide (H)			
0 g a.i.ha^{-1}	1,255	647	0.52
500 g a.i.ha^{-1}	1,349	700	0.52
Significance	NS	NS	NS
LSD	-	-	-
Population(P) (plants m^{-2})			
50	1,339	733 b	0.55 c
100	1,288	681 ab	0.53 b
400	1,278	606 a	0.47 a
Significance	NS	*	***
LSD	-	89	0.02
Genotype(T)			
Pro 7035	1,322	729	0.55 c
Aragorn	1,321	628	0.48 a
Midichi	1,262	663	0.52 b
Significance	NS	NS	***
LSD	-	-	0.02
CV (%)	19.1	19.5	6.1
Significant interactions	HxP*	HxP*	Nil

NS=Not significant at 0.05; *p<0.05, **p<0.01, ***p<0.001

Table 5. The Herbicide x Plant Population Interaction on Pea Seed Yield in Canterbury in the 2006/07 Growing Season (g m^{-2})

		Population (plants/m^2)	
Herbicide (H)	50	100	400
0 g a.i. ha^{-1}	637	710	592
500 g a.i. ha^{-1}	829	652	619
Significance	*		
LSD	112.7		
CV (%)	19.5		

*p<0.05, **p<0.01, ***p<0.001

In 2007/08, herbicide sprayed peas had a mean seed yield of 508 g m^{-2}. This was 19% more than the mean pea yield of the unsprayed plots (Table **3**). A significant ($p < 0.05$) sowing date x pea genotype interaction (Table **6**) showed that in the August sowing genotype had no effect on seed yield. However, in September plots sown in Pro 7035 yielded 559 g m^{-2}, which was 40% more than Midichi and in the October sowing, the difference was 87% more.

Table 6. The Sowing Date x Pea Genotype Interaction on Seed Yield of Field Peas Grown in Canterbury in the 2007/08 Growing Season

	Sowing Date		
Pea Genotype	August	September	October
Midichi	547 cd	400 b	246 a
Pro 7035	597 d	559 d	461 bc
Significance		*	
LSD		96.2	
CV (%)		13.4	

*p<0.05, **p<0.01, ***p<0.001

Crop Harvest Index

In both seasons herbicide had no effect on crop harvest index (CHI). In 2006/07 CHI was in the order: Aragorn (0.48) < Midichi (0.52) < Pro 7035(0.55). In 2007/08 Pro 7035 had a higher CHI than Midichi (0.56). In the 2007/08 season there was a significant sowing date x genotype interactions for CHI. This showed that in an August sowing there was less difference in CHI between the two cultivars than at the other two sowing dates.

Yield Components

Yield components are presented in Tables **7** and **8**. In the first season there was a significant ($p < 0.001$) reduction in the mean number of pods $plant^{-1}$ with increased pea population (Table **7**). Plants from plots sown at 50 plants m^{-2} gave the highest mean number of pods $plant^{-1}$ (13.42) and those at 400 plants m^{-2}, the lowest (3.37), a 75% drop. Cultivars Pro 7035 and Midichi had the same number of pods $plant^{-1}$ in the fist season and Pro 7035 had 19% more pods than Midichi in the second season. Herbicide alone had no significant effect on the mean number of pods $plant^{-1}$ in the first season but there was a significant ($p < 0.01$) herbicide x population interaction which showed no herbicide effect on pods $plant^{-1}$ at 100 and 400 plants m^{-2} (Table **9**). However, at 50 plants m^{-2} cyanazine treated plants produced 26% more pods $plant^{-1}$ than without the herbicide. In the second season herbicide sprayed peas produced 14% more pods $plant^{-1}$ than unsprayed peas and sowing date had no significant influence.

In the first season, Pro 7035 had the highest mean number of seeds pod^{-1} (4.58) and Midichi, the least (3.60). Similarly, in the second season Pro 7035 had 28% more seeds pod^{-1} (4.26) than Midichi (3.32). Herbicide and sowing date had no effect on seeds pod^{-1}.

Table 7. Yield Components of Field Peas Grown in Canterbury in the 2006/07 Growing Season

	Plants m^{-2}	**Pods Plant^{-1}**	**Seeds Pod^{-1}**	**TSW (g)**
Herbicide (H)				
0 g a.i.ha^{-1}	146.2	8.04	3.94	296
500 g a.i.ha^{-1}	131.6	8.61	3.94	282
Significance	NS	NS	NS	NS
LSD	-	-	-	-
Population (P) (plants m^{-2})				
50	48.8 a	13.42 c	4.35 b	299 b
100	92.9 b	8.19 b	4.21 ab	296 b
400	274.9 c	3.37 a	3.26 a	273 a
Significance	***	***	***	**
LSD	20.15	1.18	0.35	17.86
Type (T)				
Pro 7035	138.2	8.19 ab	4.58 b	263 b
Aragorn	132.3	9.67 b	3.65 a	245 a
Midichi	146.2	7.12 a	3.60 a	360 c
Significance	NS	***	***	***
LSD	-	1.18	0.35	17.86
CV%	21.4	20.9	13.2	9.1
Significant interactions	Nil	HxP**	Nil	Nil

NS=Not significant at 0.05; *$p<0.05$, **$p<0.01$, ***$p<0.001$

Table 8. Yield Components of Field Peas Grown in Canterbury in the 2007/08 Growing Season

	Plants m^{-2}	**Pods plant^{-1}**	**Seeds pod^{-1}**	**TSW (g)**	**Seeds plant^{-1}**
Sowing date (S)					
August	116	4.73	3.82	325.0 c	18.23
September	117	4.80	3.67	293.3 b	18.20
October	97	4.82	3.89	250.8 a	19.22
Significance	NS	NS	NS	***	NS
LSD	-	-	-	11.02	-
Herbicide (H)					
0 g a.i. ha^{-1}	107	4.47	3.65	295.0	16.58
500 g a.i. ha^{-1}	113	5.10	3.93	284.4	20.52
Significance	NS	*	NS	NS	*
LSD	-	0.52	-	-	3.19
Pea genotype (T)					
Midichi	107	4.36	3.32	327.8	14.68
Pro 7035	113	5.21	4.26	251.7	22.42
Significance	NS	**	***	***	***
LSD	-	0.52	0.39	13.07	3.19
CV (%)	12.0	15.4	14.6	6.4	24.6
Significant interactions	SxH*	Nil	Nil	SxT**	Nil

NS=Not significant at 0.05; *$p<0.05$, **$p<0.01$, ***$p<0.001$

In the first season, the two lowest populations had the same thousand seed weight (TSW) (297 g), which was higher ($p < 0.01$) than the TSW at the highest plant population (273 g). Aragorn had the lowest TSW at 245 g,

Table 9. The Interaction of Herbicide by Population on Pods Plant^{-1} of Field Peas Grown in Canterbury in the 2006/07 Growing Season

	Population (plants m^{-2})		
Herbicide	50	100	400
0 g a.i. ha^{-1}	11.89 c	8.58 b	3.64 a
500 g a.i. ha^{-1}	14.96 d	7.80 b	3.09 a
Significance		**	
LSD		2.44	
CV (%)		20.9	

*p<0.05, **p<0.01, ***p<0.001

followed by Pro 7035 at 264 g and Midichi at 360 g. In the second season, there was a sowing date x pea genotype interaction on TSW (Table **10**). Midichi had a higher TSW than Pro 7035 at all sowings. However, the greatest difference (41%) was in the August sowing, by the October sowing the difference was only 22%.

Table 10. The Sowing Date x Pea Genotype Interaction on the TSW (g) of Field Peas Grown in Canterbury in the 2007/08 Growing Season

Type	Sowing date		
	August	September	October
Midichi	380.0 d	328.0 c	275.0 b
Pro 7035	270.0 b	258.3 b	226.7 a
Significance		**	
LSD		17.82	
CV (%)		6.4	

*p<0.05, **p<0.01, ***p<0.001

Weed Counts

Pea genotype had no effect and herbicide had little effect on weed counts in the first season (Table **11**). However, there was four times more *Coronopus* spp plants in sprayed than in unsprayed plots and then forty seven times more *Stachys* spp plants at 21 DAE. Generally weed counts were inversely proportional to crop population except for *Coronopus* spp.

In the second season there was distinct variation in the weed spectrum over time. Tables **12**, **13** and **14** show the major, minor and other weeds in the October, November and December counts. 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, differences in 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.

Total Weed Dry Matter

In the first season, weed DM increased throughout the growing season. After the first harvest at 21 DAE the trend was for there to be more weed DM in unsprayed plots than in sprayed plots up to 84 DAE. However, from 84 DAE to 126 DAE there was no difference in weed DM. Pea population

Table 11. Weed Counts m^{-2} at 21 DAE of Field Peas Grown in Canterbury in the 2006/07 Growing Season

	Weed Species					
	Coronopus spp.	*Chenopodium* spp.	*Lolium* spp.	*Stachys* spp.	Others	Total Counts (All spp)
Herbicide (H)						
0 g a.i. ha^{-1}	53.2	9.62	2.22	9.5	10.9	36.1
500 g a.i. ha^{-1}	11.5	0.37	0.37	0.2	2.8	9.4
Significance	*	NS	NS	*	NS	NS
LSD	31.0	-	-	8.77	-	-
Population (P) (plants m^{-2})						
50	1.9 a	8.70 c	2.40 b	0.6 a	13.3 c	44.4 c
100	50.1 b	5.92 b	1.11 ab	9.2 b	6.3 b	20.9 b
400	45.0 b	0.37 a	0.37 a	4.8 ab	0.9 a	3.1 a
Significance	***	***	*	*	***	***
LSD	20.93	4.15	1.4	5.8	5.2	17.32
Type (T)						
Pro 7035	25.0	7.40	0.56	3.7	8.3	27.7
Aragorn	26.8	4.63	1.85	5.5	6.3	20.9
Midichi	45.1	2.96	1.48	5.4	5.9	19.7
Significance	NS	NS	NS	NS	NS	NS
LSD	-	-	-	-	-	-
CV (%)	95.4	122.2	158.9	175.2	111.9	111.9
Significant interactions	Nil	Nil	Nil	Nil	Nil	Nil

*p<0.05, **p<0.01, ***p<0.001

had a highly significant effect ($p < 0.001$) on weed DM in plots sown at the two high pea populations. At only two harvests was there a difference in response to pea genotype. In the second season 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. Throughout the season there was more weed DM in unsprayed plots than in sprayed plots.

Table 12. October Weed Counts (m^{-2}) in Field Peas Grown in Canterbury in the 2007/08 Growing Season

	Coronopus spp.	*Lolium* spp	*Spergula arvensis*	*Stellaria media*	*Stachys* spp.	Others	*Achillea millefolium*	Total Count
Herbicide (H)								
0 g a.i. ha^{-1}	233	43	29	112	18.9	42	3	524
500 g a.i. ha^{-1}	39	9	1	40	3.3	19	2	116
Significance	***	***	**	*	NS	NS	NS	***
LSD		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

NS=Not significant at 0.05; *p<0.05, **p<0.01, ***p<0.001

Table 13. November Weed Counts (m^{-2}) of Field Peas Grown in Canterbury in the 2007/08 Growing Season

	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 a.i. ha^{-1}	64	2	7	34	13	1	22	35	10	22	209
500 g a.i. 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**

NS=Not significant at 0.05.

*p<0.05, **p<0.01, ***p<0.001

Table 14. December Weed Counts (m^{-2}) of Field Peas Grown in Canterbury in 2007/08 Growing Season

	***Coronopus* spp.**	***Chenopodium* spp.**	***Rumex* spp.**	***Lolium* spp.**	***Stellaria media***	***Solanum* spp.**	***Trifolium* spp.**	**Others**	**Total Counts**
Herbicide (H)									
0 g a.i. ha^{-1}	61	17	26	20	19	27	66	31	266
500 g a.i. 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

NS=Not significant at 0.05; *p<0.05, **p<0.01, ***p<0.001

DISCUSSION

The highest population did not give a higher seed yield than the other two pea populations and it had the lowest HI in the 2006/07 season. There was evidence of self-thinning at 400 plants m^{-2} and this resulted in a final mean plant population of 275 plants m^{-2}. It is therefore advisable to use the lowest possible sowing rate when weed pressure is low because of compensatory effects of yield components. This is important as the greatest cost of pea production is the cost of seed [13]. The significant ($p < 0.05$) herbicide by population interaction on mean seed yield in 2006/07, indicated that herbicide had no effect on seed yield at 100 and 400 plants m^{-2} but did at 50 plants m^{-2}. Comparative studies in England [14] and Scotland [15] demonstrated that the optimum plant density for semi-leafless peas was not necessarily higher than that for conventionally leafed peas. Semi-leafless peas, like leafed peas, were relatively unresponsive to plant density. This is similar to the results obtained here where the semi-leafless peas gave seed yields similar to the leafed variety.

Despite the high yields obtained in this work, pea yields are often reported to be variable [16-19] and this is usually due to variability in harvest index or climatic variability. In this research early sowing increased yield. McKenzie [20] reported that in temperate countries, even with dependable rainfall, early sowing allows crops to produce large plants which can produce and support many pods, and which intercept maximum solar radiation through longer duration and more rapid early spring growth. The results of this experiment support this. The August sowing gave the highest seed yield (572 g m^{-2}), which was 62% more than the lowest yield in October. Taweekul [21] reported similar results on the positive influence of early sowing of peas. Her September sown peas yielded 521 g m^{-2}, which was 90% more than in a November sowing.

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, plots sown in Pro 7035 had a seed yield of 559 g m^{-2} which was 40% more than the yield of Midichi. By October it was 87% more. This highlights the need to select a suitable genotype to use at different times in the season. Early in the season both genotypes could be used without yield loss. But as the season progressed the Pro 7035 smothered some larger weeds. Both pea types were significantly better than the control no pea plots.

Generally, variation in the number of pods plant^{-1} depends on species [22]. Aragorn had the highest number of pods plant^{-1} (9.67) and Midichi, the least (7.12). This was probably because Aragon produced the most flowering nodes, a genetically controlled heritable characteristic [19, 23].

The significant ($p < 0.01$) herbicide x population interaction on pods plant^{-1} shows that there was no effect of herbicide on pods plant^{-1} at 100 and 400 plants m^{-2}. This was probably because of the reduced weed influence at the two higher populations. However, at 50 plants m^{-2} cyanazine treated plants produced 26% more pods plant^{-1} than unsprayed plants because the effect of weeds was more pronounced in unsprayed plots.

There was a significant ($p < 0.001$) reduction in the mean number of pods plant^{-1} with increased plant population. Plots with 50 plants m^{-2} had the highest mean number of pods plant^{-1} (13.42) and 400 plants m^{-2}, the least (3.37), a drop of 75%. Dapaah *et al.,* [24] found that a low plant population of pinto beans (*Phaseolus vulgaris*) gave more pods plant^{-1} in a

November sowing in Canterbury. The reduction in pods plant^{-1} at high density was due to increased interplant competition. McKenzie *et al*., [25] reported the same trend in pods plant^{-1} and seeds pod^{-1} in a population study with lentils. McKenzie and Hill [26] also reported that pods plant^{-1} decreased as plant population increased in chickpea (*Cicer arietinum*).

Pro 7035 had the highest mean number of seeds pod^{-1} (4.58) and Midichi, the lowest (3.60). As with pods plant^{-1}, this is a heritable characteristic that is genetically controlled [19, 23] although it can be affected by agronomic conditions [27].

There was a reduction in weeds with increased pea crop population. Similar weed reductions in response to increased crop population were reported by Townley-Smith and Wright [28], Lemerle *et al*., [29], and Grevsen [11]. This confirms the need to use high seed rates when weed pressure is high and when chemical weed control cannot be used. Higher crop populations, by suppressing weed growth, also deplete the weed seed bank for subsequent crops [11]. However weed count were not inversely proportional to crop population for *Coronopus* spp. and the exact reason could not be established on this experiment. Probably the crop smothering effect was masked by other more vulnerable weed species.

Although weeds can negatively affect crop yield, they are important ecological entities which play a crucial role in balancing ecosystems and making them stable. Because of this role they should not be entirely eradicated but reduced to levels, which have no effect on yield. For example, cultural methods like early sowing of peas can successfully control late weeds without the use of herbicides. Some weeds are relatively weak competitors and do not do much harm to crops and these weeds could be left to grow and their positive effects exploited e.g. soil protection and harbouring of natural pest enemies [5]. Gane [30] reported that relatively weak-growing weeds, such as *Spergula arvensis* and *Capsella bursa pastoris* were not aggressive and could be tolerated in reasonable numbers without affecting crop performance.

The results of this research indicate that weed suppression is possible by selecting the right pea genotype sown at an appropriate sowing rate on an optimum sowing date; and through an understanding of the weed spectrum and crop-weed interactions throughout the growing season. Avoidance of yield loss from weeds is important for short-term profits, while suppression of weed growth and weed seed production has longer-term implications for managing future weed populations [31] and future weed seed banks.

CONCLUSIONS

Fully leafed peas and semi-leafless can be sown at similar plant populations to achieve similar yields under weed free conditions and increased pea sowing rates increased TDM and seed yield in weedy environments. However, very high crop sowing rates (400 plants m^{-2}) resulted in reduced seed yield. Early sowing was shown to increase yield under this research particularly of the semi leafless Midichi. Cyanazine use increased yield particularly under low crop and later sowing dates. Weed spectrum changed over the season and increased pea sowing rate improved weed suppression. Herbicide use can enhance yield but could be replaced by other effective cultural methods e.g. early sowing, appropriate pea genotype and high sowing rates.

CONFLICT OF INTEREST

None declared.

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