The effects of herbicide and plant population on yield, yield components and seed quality of *Phaseolus vulgaris* L.

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Abstract

An experiment was conducted at Lincoln University, Canterbury, to examine the effects of plant populations and alachlor and bentazone herbicides on yield and seed quality of Sanilac navy beans and Greenpak green beans. Populations in the experiment ranged from 30-120 plants/m^2.

Seed yields were reasonably high at 260-312 g/m^2 and were generally not affected by the population or herbicide treatments. However, at high populations bentazone reduced the seed yield of Sanilac to 220 g/m^2.

At harvest, seed moisture content for alachlor treated Sanilac plants ranged from 57-78%, indicating a delay in maturity. At that stage, the crop was unsuitable for machine harvesting. The results suggest that bean growers should use caution when applying alachlor to bean crops.

Additional key words: beans, alachlor, bentazone

Introduction

Navy beans (*Phaseolus vulgaris* L.) can yield well in most seasons in Canterbury (Love *et al*., 1988). In 1986 New Zealand imported about 2000 t of dried beans from the U.S.A. (Department of Statistics, 1987). The cost of these imported beans to the N.Z. manufacturer was about $1240/t (Hill, 1987). At this price and with a yield potential of about 3 t/ha, the crop could fill a very profitable niche for specialist growers in the Canterbury region. However, there are serious problems with harvesting navy beans because of short plant height, pods which may touch the ground and produce discoloured seed, and pods which shatter easily. Additionally, there may be problems with delayed maturity in wet seasons resulting in late harvests and seeds with high moisture contents (Love *et al*., 1988).

Apart from harvesting problems, navy beans may also suffer severe yield loss due to weed competition. Wilson *et al*. (1980) reported that in Nebraska, U.S.A., bean yields were reduced by 208 kg/ha for every 1000 kg/ha weed dry matter present. Generally, the crop is most sensitive to weed competition during the first 5 to 7 weeks after emergence (Dawson, 1964). Additionally, weeds harvested with the crop may cause staining of seeds thereby lowering seed quality and the price farmers receive.

Previous unpublished results of navy bean experiments conducted by students at Lincoln University have shown that both trifluralin and bentazone provide good weed control. In Canterbury, alachlor is not normally applied as grass weeds are not usually a problem. Although the chemical is not registered for use on Phaseolus beans in New Zealand, there are reports of its use overseas (Quakenbush and Wilson, 1981).

In the experiments reported in an earlier paper (Love *et al*,. 1988), the effects on yield of shelter, irrigation and plant population were examined. The results indicated that high populations of about 100 plants/m^2 increased both seed yield and pod height above ground compared to more normal populations of 50-60 plants /m^2. The experiment reported here further examined the effects on yield, plant height, pod height of a range of crop populations. Additionally, the effects of two herbicides on navy beans (cv. Sanilac) and green beans (cv. Greenpak) were examined.

Materials and Methods

An experiment was conducted in 1985/86 at Lincoln University on a Wakanui silt loam. The responses of navy bean and green bean crops to four plant population and two herbicide treatments were measured.

The crop was sown on 22 November 1985 with disulfoton at 20 kg a.i./ha. The site had been cultivated in October and 50 mm of irrigation applied on 31 October. To ensure good weed control, trifluralin was applied at 920 g a.i./ha. Seed was inoculated with Rhizobium strain PDD 3305 prior to sowing. The soil was fertile as shown by MAF Quick Test values in July 1985 of 5.6, 12, 16, 33 and 36 for pH, Ca, K, Olsen P and Mg respectively. The crop was irrigated on 6 January, 16 January and 10 February 1986 with 30, 50 and 60 mm of water respectively. Irrigation was scheduled using an evapotranspiration based water budget.

The experiment was a split-plot design with 5 replicates of a 2 x 2 factorial as the main plots. Main plot factors were: cultivar (1. Sanilac navy bean and 2. Greenpak green bean) and herbicide (1. Alachlor applied pre-emergence at 1.5 kg a.i. in 360 *l* of water per ha on 2 December, and 2. Bentazone applied at the 2-4 true leaf stage at 1.4 kg a.i. in 500 l of water per ha on 3 January. The subplot factor was target population (30, 60, 90 and 120 plants/m^2). Each subplot was one 1.5 metre drill width with 10 rows 12 metres long.

The present experiment contained no untreated or hand weeded plots. However, a neighbouring experiment examined herbicide effects on weed species in bean crops and included plots with no weed control, trifluralin only, trifluralin plus alachlor and trifluralin plus bentazone. In addition, experiments over the preceding five seasons indicated the yield potential of navy beans at Lincoln.

Plant populations were counted on 18 December (26 days after sowing (das)), 24 March (122 das) and on 8 April (137 das). Ground cover was scored visually on 8 anuary (47 das) on a 0-10 scale, with 0 and 10 equivalent to zero and full ground cover respectively.

On 24 and 25 March two 0.45 m^2 samples were taken from each plot and the plants were counted. From each sample 10 plant sub samples were selected and the number of pods, fresh and dry weights of pods, number of seeds and fresh and dry weights of seed were recorded. The number of discoloured seeds was also recorded. Yield was calculated as:

Yield = plants/m^2 x pods/plant x seed/pod x individual seed weight

Data were subjected to analysis of variance. Linear and quadratic responses to actual plant populations were fitted separately to Sanilac and Greenpak.

Results

Plant establishment differed among cultivars, so populations were different at each treatment level, (Table 1). Although allowance was made for germination rates of 98% and 88% for Greenpak and Sanilac respectively, field emergence was not consistent.

For both cultivars, there were no significant responses of seed yield to either plant population or the two herbicides (Table 1). Mean overall seed yield was about 290 g/m^2. There was, however, a significant interaction between population of Sanilac and herbicide treatment. With bentazone, yield of Sanilac was lower at high populations while with alachlor, a small non-significant yield increase occurred as population increased (Table 2). There was no significant response of Greenpak to change in population.

Both alachlor and bentazone herbicides appeared to increase yields when compared to unsprayed control plots in the adjacent experiment. Sanilac and Greenpak yields with no herbicide application at 51 and 45 plants/m^2 respectively were 233 and 219 g/m^2.

Seed moisture content at harvest, a measure of maturity, was markedly affected by the population and herbicide treatments for both cultivars (Table 1). Greenpak showed a highly significant linear decrease with increasing population. The significant interaction between Sanilac population and herbicide treatment (Table 2) indicates that with bentazone seed moisture content was very consistent. However, with alachlor Sanilac was much more immature at harvest, especially at the lower plant populations. Moisture content dropped from 78% to 57% as population increased. On the other hand, Greenpak had a higher moisture content with bentazone application (Table 3). With this chemical, increasing population dropped the moisture content from 55 to 31 while with alachlor the drop was only from 39 to 31.

Ground cover, a measure of crop development, was significantly different between cultivar and herbicide treatments (Table 1). As expected, high populations resulted in increased ground cover. However, the interaction between bean cultivar and herbicide treatment was of more interest. There was a considerable reduction in ground cover with alachlor, which was more marked with Sanilac. Ground cover of alachlor treated Sanilac was 3.5 compared with 7.0 for bentazone treated Sanilac plants. There was no difference with Greenpak.

Components of yield are presented in Table 4. The number of plants/m^2 in the sample was different for each cultivar. For Sanilac the range was from 30.9 to 104.8 while for the larger seeded Greenpak the range was smaller from 22.0 to 82.6 plants/m^2. The herbicide treatments had no effect on this component. The only significant interaction showed the number of Sanilac pods per plant dropped from 16.0 to 3.5 with bentazone

Table 1. Oven dry seed yield, seed moisture content at harvest and early ground cover for Sanilac navy beans and Greenpak green beans.

	Plant Population (plants/m²) Target	Plant Population (plants/m²) Actual	Seed yield (g/m²)	Seed moisture (%)	Ground cover[1] (Score)
Cultivar (C)					
Sanilac (S)	30	28	288	54.4	2.75
	60	57	312	50.5	4.90
	90	80	261	48.0	6.10
	120	104	266	42.6	7.15
Significance[2]			NS	l	L
Greenpak (G)	30	20	307	47.1	2.80
	60	45	352	38.2	5.45
	90	60	283	34.7	6.60
	120	80	260	31.3	7.90
Significance			NS	L	L,Q
SEM			22.0	2.90	0.168
Herbicide (H)					
Bentazone			292	34.7	6.46
Alachlor			290	52.0	4.45
Significance			NS	**	**
SEM			13.0	4.22	0.129
CV(%)			23.9	21.1	9.7
Significant interactions			S(l)[3]xH	S(l)xH	HxC, G(l)xH

[1] Ground cover was scored on 8 January with 0 = nil cover and 10 = full cover.
[2] l, L, Q indicates significant linear and quadratic responses at the $P < 0.05$ (lowercase) and $P < 0.01$ (uppercase) respectively. ** indicates a significant difference at $P < 0.01$.
[3] (l) indicates a significant interaction involving the linear response.

Table 2. The interaction of plant population and herbicide on oven dry seed yield (g/m²) and seed moisture content at harvest (%) of Sanilac navy beans.

Population (Plants/m²)	Bentazone		Alachlor	
	Yield	Moisture	Yield	Moisture
28	306	31	271	78
57	336	30	288	71
80	239	28	282	68
104	222	29	309	57
SEM	32	4.1	32	4.1

Table 3. The interaction of plant population and herbicide on seed moisture content of Greenpak beans.

Population (plants/m²)	Bentazone	Alachlor
20	55	39
45	41	36
60	34	36
80	31	31

SEM = 4.1 within columns, 6.9 otherwise

Table 4. Yield components for Sanilac and Greenpak beans in Canterbury, 1985/86.

		Sample size (plants/m^2)	Pods per plant	Seeds per pod	Oven dry thousand seed weight (g)
Cultivar (C)					
Sanilac (S) (Plants/m^2)	28	30.9	15.45	3.68	162
	57	59.9	8.88	3.56	166
	80	81.9	6.07	3.36	162
	104	104.8	4.64	3.44	162
Significance[1]		L	L,Q	1	NS
Greenpak (G) (Plants/m^2)	20	22.0	11.01	3.80	332
	45	52.2	6.01	3.52	322
	60	64.0	4.27	3.36	313
	80	82.6	3.47	3.00	312
Significance		L	L,Q	L	L
SEM		3.73	0.422	0.098	5.6
Herbicide (H)					
Bentazone		61.8	7.17	3.60	245
Alachlor		62.8	7.77	3.33	238
Significance		NS	NS	**	NS
SEM		2.20	0.321	0.038	5.2
CV %		19.0	17.9	9.0	7.4
Significant interactions		-	S(l)[2]xH	-	-

[1] l, L, Q indicates significant linear and quadratic responses at $P < 0.05$ (lower case), $P < 0.01$ (upper case) respectively. ** indicates a significant response at $P < 0.01$.

[2] (l) indicates a significant interaction involving the linear response.

as compared with 15.0 to 5.7 with alachlor. Greenpak pods per plant dropped 68% from low to high population.

With increasing population, the number of seeds/pod dropped 6% for Sanilac and 21% for Greenpak. Bentazone treated plants averaged 0.27 more seeds/pod than alachlor treated plants. This change would have a 7% effect on yield.

Seed weight of Sanilac was unaffected by population change but seeds were smaller at the higher populations in Greenpak. Sanilac seed at 162 mg was only half the weight of Greenpak.

Two indicators of seed quality and harvestability are presented in Table 5. For Sanilac 10% of the pods were touching the ground but less than 2% of the seed was classified as diseased. However, in Greenpak up to 40% of the pods were touching the ground. The interaction between herbicide and bean cultivar showed that the number of diseased seeds in Greenpak was much greater than in Sanilac. With Greenpak, there were 3.7 and 2.9 diseased seeds per plant for bentazone and alachlor treated plants respectively with Sanilac there were only 0.5 and 0.6 diseased seeds per plant. Twenty percent of the seed in the low population bentazone treated Greenpak were classified as diseased.

Discussion

Plant population

As in the work reported by Love *et al.* (1988) responses to changes in plant population were inconsistent. In both bean cultivars, yields ranged from 260 to 312 g/m^2 but the variations were not related to plant population. However, the significant herbicide by population interaction in Sanilac indicated that the yield at high population was depressed when bentazone was

Table 5. Numbers of diseased seeds and pods touching the ground for Sanilac and Greenpak beans.

		Diseased seeds per plant	Pods per plant touching ground
Cultivar (C)			
Sanilac (S) (Plants/m^2)	28	1.2	1.5
	57	0.5	0.9
	80	0.2	0.5
	104	0.3	0.4
Significance[1]		1	L
Greenpak (G) (Plants/m^2)	20	6.9	3.9
	45	2.8	2.5
	60	2.0	1.3
	80	1.5	1.0
Significance		L,Q	L
SEM		0.33	0.20
Herbicide (H)			
Bentazone		2.1	1.3
Alachlor		1.7	1.6
Significance		NS	NS
SEM		0.17	0.11
CV %		54.1	41.8
Significant interactions		G(l)[2]xH, HxC	-

[1] l, L, Q indicates significant linear and quadratic responses at $P < 0.05$ (lower case), $P < 0.01$ (upper case) respectively.
[2] (l) indicates a significant interaction involving the linear response.

applied (Table 2). The linear decrease indicated that with this herbicide, lower populations in the range of about 30 to 60 plants/m^2 would result in the highest yields. With application of alachlor there was no significant change in yield over the four populations. These results suggest that bean growers should be able to attain high yields at relatively low plant populations. If correct, this would significantly reduce establishment costs. In February, 1988 navy bean seed was selling for between 1150 and \$1200/t. At these prices, a population of 100 plants/m^2 would cost approximately \$246/ha for seed, while a population of 30 plants/m^2 would cost only about \$74/ha for seed.

The inconsistent response of navy bean seed yield to plant population has been reported previously. Lucas and Milbourn (1976) found an asymptotic relationship between seed yield and plant population with two different cultivars. However in one experiment they found no change in seed yield over populations ranging from 15 to 44 plants/m^2. (Scarisbrick *et al.*, 1976). Lack of response to increase in population may be due to cool temperatures limiting growth. In Canterbury, mean minimum daily temperatures in December, January and February are 10.4, 11.5 and 11.4°C respectively. For a crop such as neans with a base temperature of 10.6°C for the sowing to emergence phase (Angus *et al.*, 1980) these temperatures may well be low enough to limit growth and mask potential population effects. Further evidence that cool temperatures may limit the response to population comes from the work of Hardwick *et al.*, (1978) who showed that cold tolerant *Phaseolus vulgaris* lines yielded best at up to 4.7 t/ha.

The other possible explanation for the inconsistent response of yield to plant population is the plasticity of navy bean plants. They are able to alter yield components and compensate for low populations. As reported in the previous paper (Love *et al.*, 1988), the number of pods per plant may be more than double at low populations when compared with high populations.

Herbicide

While the herbicides had little effect on yield (Table 1), as mentioned previously, there was a significant interaction between herbicide and population in their effects on Sanilac. The reduction in Sanilac seed yield at high population with bentazone is difficult to explain. Four to five days after application of bentazone, Sanilac beans had severe leaf burning. The reduced yield at higher populations may have been due to a greater proportion of damage to plants which by harvest were considerably smaller than plants at low populations.

The most significant effect of the herbicides was on crop maturity as demonstrated by the seed moisture content and crop cover results (Tables 1, 2 and 3). The results in table 2 show that with Sanilac, at all populations seed moisture content at harvest was extremely high, varying from 57 to 78%.

There are reports of alachlor damaging navy beans (Wilson *et al.*, 1980; Quakenbush and Wilson, 1981). While neither of these papers reported yield losses due to crop damage, Quakenbush and Wilson (1981) found that all herbicides tested, including alachlor reduced plant height when compared to an untreated control. In this experiment, bentazone burnt leaves of both cultivars but recovery was nearly complete except in the high population Sanilac plots as mentioned before. This confirms previous unpublished work at Lincoln University which has shown that bentazone may cause scorching, but no apparent yield loss. The most serious damage was caused by alachlor on Sanilac. Averaged over all populations, seed moisture content was 68% for alachlor treated Sanilac, but for bentazone treated Sanilac and Greenpak the value was 35%. This alachlor damage was further emphasised by the low ground cover in alachlor treated Sanilac.

Alachlor is used primarily to control annual grasses and some broadleaf weeds, and is usually applied post sowing and pre-emergence. While the chemical has been deregistered in the United States and Australia, as of December 1991 it was still listed in New Zealand. The difference in damage levels between Sanilac and Greenpak may have been due to differing times of emergence of the two cultivars. Alachlor was applied within 2-3 days of emergence instead of immediately post sowing. A delay of this length between sowing and spraying is not recommended. While dates were not recorded, it seems likely that the increased damage to Sanilac caused by alachlor may have been due to earlier emergence or more rapid germination before emergence. The long term nature of the damage is clearly seen in Table 1.

These results may have implications for bean growers. While yields were unaffected, delays in maturity may cause serious losses of seed quality. Delays in harvest in Canterbury are likely in wetter than average seasons (Love *et al.*, 1988). A wet season combined with alachlor induced delay could cause problems for growers. Results from this work suggest that, in Canterbury, caution is very important when applying alachlor to beans.

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