Influence of plant population on yields of vining pea cultivars with contrasting seed sizes

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Abstract

A field experiment was conducted to test the hypothesis that yields of vining pea cultivars with small seed sizes could be increased by sowing them at higher plant populations than are used for conventional cultivars. The yields and economic returns of four cultivars with contrasting seed sizes were compared when sown at five plant populations.

Even though the cultivars had very different seed sizes, with mean values ranging from about 110 to 250 mg dry weight, they all exhibited similar vining yield responses to plant population. Maximum yields were reached at populations of about 100 plants/m^2, but optimum economic returns were achieved with populations as low as 75 plants/m^2. Both yield and economic return were insensitive to population above these minimum values.

Thus there was no evidence that it may be necessary to adjust plant populations to obtain optimum yields and economic returns for cultivars with different seed sizes. Therefore, the current recommendation of aiming for about 110 plants/m^2 should be retained for all cultivars tested.

Additional key words: Pisum sativum *L., economic return, seed rate, seed weight.*

Introduction

In recent years there has been a steady trend in New Zealand towards the use of vining pea cultivars which produce smaller peas at the vining stage than older or more traditional cultivars. Bolero, a cultivar which produces predominantly medium sized green peas, has become widely adopted for process pea cropping, and constituted almost 20% of the New Zealand vining pea area in the 1990-91 season. Several other cultivars which produce predominantly small to medium sized peas have been tested on a commercial scale, but in many cases their yields have been lower than those of the more conventional cultivars. The lower yield potential of cultivars which produce smaller peas is probably the main reason they are not grown more extensively in New Zealand. In the United Kingdom, a premium is paid to encourage growers to grow the very small 'petit pois' cultivars, in order to compensate for their lower yields.

We proposed that the yields of cultivars with smaller seed sizes could be increased by sowing them at higher plant populations than are used for conventional cultivars. Previous research in New Zealand on the effects of plant population on yields of vining pea crops has all been done using the outdated cultivar Victory Freezer which has predominantly medium to large seeds. White and Anderson (1974) found that populations ranging from 180 to 370 plants/m^2 produced significantly higher yields than populations of 118 plants/m^2 or less. However, Anderson and White (1974b) and White *et al.* (1982), found that populations greater than about 105 to 110 plants/m^2 gave no yield advantage.

Research into optimum plant populations for vining pea crops in Europe, Britain and North America was reviewed by Murphy (1975), and a diverse range of results was found. He concluded that there were two main groups of responses: one where a low population (75 to 100 plants/m^2) was optimal; and the other where higher populations (120 to 160 plants/m^2) were favoured. Murphy suggested that cultivar interactions, climatic and soil type factors may contribute to the separation into the two categories. In his own experiments, Murphy (1975) used three cultivars in trials conducted over three seasons and found that populations from about 70 to 100 plants/m^2 were optimal.

The Processors and Growers Research Organisation (Biddle *et al.*, 1988) recommends populations of 90 to 100 plants/m^2 for vining peas grown in Great Britain. In New Zealand, 110 plants/m^2 is recommended as a target population for growers. However, these values are for cultivars with larger seed sizes. To examine the hypothesis that plant populations should be adjusted to compensate for different seed sizes, a field experiment was conducted in which four cultivars with contrasting seed sizes were compared at five populations. The objective was to determine the optimum population for maximum biological and economic yield of each cultivar, and whether the optimum values differed among cultivars.

Materials and Methods

Treatments and trial design

The four cultivars were sown at five seed rates in a field experiment arranged in a randomised complete block design with four replicates.

The cultivars selected for the experiment were: Pania, the main cultivar grown in New Zealand until recently - a thousand seed weight (TSW) of 247 g and a medium to large green pea sieve size; Bolero, now the main cultivar grown for processing in New Zealand - a medium seed weight (TSW = 196 g) and a small to medium sieve size; Trounce, a new cultivar with powdery mildew resistance which has a comparatively heavy seed (TSW = 245 g) and a small to medium sieve size; and Argona, a Dutch bred cultivar which has only been grown experimentally in New Zealand which has light seed (TSW = 110 g) and a small sieve size.

The five seed rates used were intended to span the range from low to very high populations for all the cultivars. Because of the hypothesis that smaller seeded cultivars would have higher optimum populations than larger seeded ones, no attempt was made to establish the same populations for all the cultivars. The five rates ranged from 100 to 500 kg/ha in 100 kg/ha increments.

Crop establishment and management

The experiment was planted on 1 November 1990 in a Templeton silt loam on the DSIR Crop Research farm at Lincoln. A 9-row Wintersteiger Øyjord cone seeder was used to plant 13 m long plots which were later trimmed to 12 m. The row spacing was 0.15 m.

Good weed control was achieved by pre-plant incorporation of trifluralin (Treflan) into the seedbed at 2 l of product (0.8 kg/l a.i.) per ha, and a post emergence application of a mixture of cyanazine (Bladex) and MCPB (Shell MCPB) at 2.5 l and 1.4 l of product (1.25 and 0.56 kg/l a.i.) per ha respectively. No fertiliser was applied but good crop growth was maintained by two irrigations which were scheduled according to the results of water budget calculations.

Vining harvest

Five weeks after planting a harvest sampling area consisting of a 3.8 m length of the inner seven rows was defined in each plot. Thus the sub-plot was 1.05 m wide and had an area of 4 m^2. At the same time, the plant population was counted in a 2 m^2 quadrat within the sampling area in each plot.

As each treatment approached maturity, ripeness was monitored by visual and tactile methods, and finally by measuring the tenderometer reading (TR) of peas from plants taken from just outside the harvest sampling area in each plot. A mean TR of 100 to 110 was aimed for.

At harvest all plants from the sampling area were pulled by hand and passed into a stationary miniature viner to separate the green peas from the pods and vines[1]. All peas smaller than 7.1 mm diameter were removed from the sample by a screen in the viner. The peas were then cleaned and weighed to determine yield. The maturity was determined by taking the mean TR of three separate sub-samples.

The yield was adjusted to TR 105 using the formula based on the yield correction scale given by Wraight (1976). The net return for each treatment was calculated by multiplying the yield by an average of the payment received by vining pea growers in the 1990-91 season for peas in grades 3 and 4 (0.3581 cents per kg), and subtracting the cost of the seed at $1.19 per kg. Vining pea growers pay a standard price for seed which is set by the processor and is the same for all cultivars.

Within each treatment the sample from the replicate with a maturity closest to TR 105 was identified and a 500 g sub-sample was graded to estimate its sieve size. Size grading was accomplished using an electrically powered shaker box which divided the sample into three fractions: large (peas 10.3 mm diameter or larger); medium (8.7 to 10.3 mm diameter); and small (7.1 to 8.7 mm diameter). The average sieve size (ASS) was calculated from the following formula:

$$ASS = \frac{(\%large \times 2.5) + (\%medium \times 4.5) + (\%small \times 6.5)}{100}$$

Thus the value of ASS is a weighted single figure index of pea size. Differences among treatments in ASS were not analysed statistically, because only a single measurement was made for each one.

[1] The viner is not a miniature version of a modern commercial viner: It has no adjustment options to enhance the efficiency of separating peas from pods and vines in cultivars which are difficult to vine.

Yield components and vine length

Fifteen plants were selected randomly from each plot and measurements made of vine length and principal yield components which included the number of pods on each plant, and the number and weight of peas per plant.

Results and Discussion

Yield components and vine length

The seed rate treatments affected the morphology of the plants and all the yield components, and the effects differed among the cultivars (Table 1).

There were only minor vine length differences among the cultivars, but significant differences were found within the seedrate treatments. Plants from the lowest seedrate were also significantly taller than those in the 200 kg/ha treatment, and plants in the three higher seed rate treatments were substantially shorter than those in the two lower seedrate treatments.

The principal effect of increasing the seed rate was to increase the plant population. It is the primary yield component and is also the one that can be managed directly by growers. The mean plant population differed among cultivars in a predictable way, reflecting their seed size differences. However, the strong statistical interaction indicated that cultivar responses to seed rate were different. The slopes of their near-linear responses were similar for Pania, Trounce and Bolero, but the response for Argona was very different (Figure 1).

The number of pods per plant decreased as seed rate increased, but was higher on the larger seeded cultivars at equivalent rates. This suggested that plant population was a more appropriate independent variable than seed rate when analysing yield component responses. When compared on this basis, the cultivars all had the same response of pods per plant to plant population (Figure 2). These results illustrate the strong plasticity between the first two yield components by showing that there was a steep decline of pods per plant to about 120 plants/m^2 and only a slow decline thereafter.

The mean number of peas per pod declined with increasing seed rate but was only slightly different among cultivars, with Argona having significantly fewer than the other three. As with pods per plant, differences among cultivars were not apparent when the response was analysed in terms of equivalent plant populations, showing again that population is the more appropriate independent variable (Figure 3).

The number of peas per m^2 is the net population yield component, and is the product of the first three. It differed among the cultivars, and was strongly dependent on their different plant populations. However, it was independent of the seed rate treatments except at the lowest rate. There was no statistical interaction, so the

Table 1. Effects of cultivar and seed rate treatments on vine length, yield components and calculated yield.

Treatment	Vine length (cms)	Plants per m^2		Pods per plant	Peas per pod	Peas per m^2	Fresh pea wt. (mg)	Average sieve size	Calculated pea yield (kg/ha)
Cultivar									
Pania	35.7	100		3.9	5.0	1660	570	4.8	9460
Trounce	36.1	113		4.3	5.1	2050	426	4.2	8810
Bolero	37.7	144		3.3	4.9	1890	468	4.4	8900
Argona	34.8	235		3.2	4.5	2760	257	2.6	7120
	**	***		***	***	***	***		***
$LSD_{(0.01)}$	2.0	20		0.3	0.3	290	25		1390
Seed Rate (SR)									
		Argona	Others						
100	42.0	84	42	6.2	5.6	1740	377	4.1	6320
200	38.1	147	82	4.2	5.4	2130	416	4.0	8540
300	33.9	245	124	3.0	4.8	2150	453	4.0	8980
400	33.5	324	155	2.8	4.4	2280	447	3.9	9630
500	32.8	376	191	2.3	4.2	2150	457	4.0	9390
	***	***		***	***	***	***		***
$LSD_{(0.01)}$	2.2	22		0.4	0.4	325	28		1560
Cult. x SR	n.s.	***		n.s.	n.s.	n.s.	***		n.s.
C.V.(%)	6.6	16.0		10.3	7.5	16.6	7.0		19.3

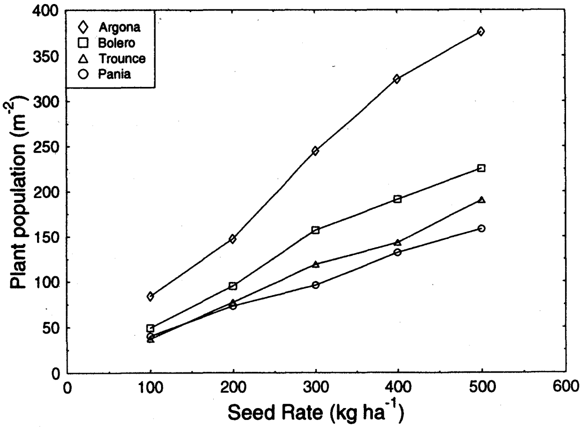

Figure 1. Effect of seed rate on plant population for the four contrasting cultivars.

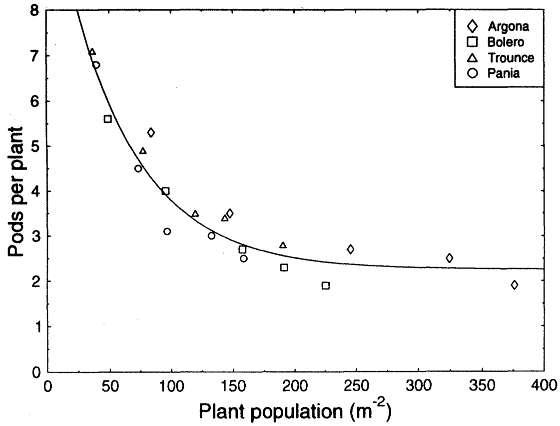

Figure 2. Relationship between pod number per plant and plant population for the four contrasting cultivars.

pea population was stable among seed rates for every cultivar. Plasticity among the population yield components therefore compensated for a wide range of plant population differences in all cultivars.

The final yield component is mean fresh pea weight. There were substantial differences among the cultivars which corresponded with their seed size classifications. Pania had the heaviest seeds and Argona the lightest, with Trounce and Bolero intermediate. Average sieve sizes followed the same pattern. The response to seed rate differed among cultivars. Argona pea weight was constant but the others all increased to varying degrees.

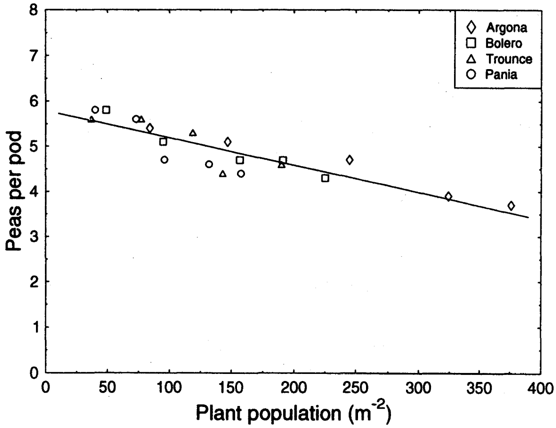

Figure 3. Relationship between number of peas per pod and plant population for the four contrasting cultivars.

Average sieve size was unaffected by the seed rate.

Yield and economic return

Two separate estimates were made of fresh pea yields.

Firstly, yield was calculated as the product of the four yield components. The values and statistical variation were both very high (Table 1). Differences between Pania, Trounce and Bolero were not significant but the yield of Argona was substantially lower. There was no difference between the four higher seed rates, but the yield from the 100 kg/ha treatment was significantly lower.

The second set of yield estimates (adjusted to TR 105) was obtained from the vining harvest. Their absolute values were more realistic and variability was lower. They were about 30% lower than the calculated yields for Pania, Trounce and Bolero but about 70% lower for Argona (Table 2).

The most likely reason for the lower yields is seed loss in the vining process. Losses were judged to be low and reasonably consistent for Pania, Trounce and Bolero, but unacceptably high for Argona. It was observed that a significantly larger (but unmeasured) proportion of the Argona pods were not fully opened by the viner, and still contained peas when they were ejected. It was not possible to adjust the viner to improve its ability to remove peas from the pods of Argona which are tougher than the other cultivars.

Another possible reason for the lower yields from vining relative to those calculated to from yield components is errors in the yield component estimates. Plant populations were counted at the seedling stage, so plant mortality which may have occurred between then and harvest was not accounted for. Also, yield component measurements were done on randomly selected plants and it could be that sampling was unintentionally biased towards larger, high-yielding individuals. There is usually a high degree of inter-plant variability in pea crops (Ambrose and Hedley, 1984) and it is difficult to obtain a representative range of sample plants. The most common bias is away from small, low-yielding plants. Finally, samples for yield component analysis were taken several days after the vining harvests, and pea weight would normally increase with increased maturity during that period (Anderson and White, 1974a).

Argona was excluded from the statistical analyses because of the large discrepancy in its vining yield. As with the first estimates, the yields of the other three cultivars were not significantly different. However, the yield response to seed rate was slightly different. Yields increased up to the 300 kg/ha seed rate then remained stable.

Table 2. Effects of cultivar and seed rate treatments on viner (machine) yields and net economic returns.

	Viner pea yield (kg/ha)		Net economic
Treatment	Without Argona[1]	With Argona[2]	return ($/ha)
Cultivar			
Pania	6120	6120	1830
Trounce	6160	6160	1850
Bolero	5890	5890	1750
Argona	(2020)	5150	1490
	n.s.	***	***
$LSD_{(0.01)}$	460	510	180
Seed Rate (SR)			
100	4420	4490	1490
200	5860	5640	1780
300	6550	6290	1890
400	6800	6510	1850
500	6640	6210	1630
	***	***	***
$LSD_{(0.01)}$	590	570	200
Cult. x SR	n.s.	*	*
C.V.(%)	8.9	10.4	12.6

[1] Argona result excluded from statistical analysis.
[2] Estimated Argona yields included in statistical analysis.

The value of the results was limited by the failure to obtain reliable vining results for Argona. For Argona, therefore we calculated estimates of these values by assuming that the linear relationship between vining and calculated yields for the other three cultivars could also be applied to Argona. The regression for Pania, Trounce and Bolero was:

$$Y = 1713 + 0.48X \qquad R^2 = 71\%$$

where Y and X are the vining and calculated yields respectively. This equation was then used to estimate vining yields for Argona, and these were included in a re-analysis of the vining yields. The resulting relative yields of the cultivars, which stayed the same, and the yield response to seed rate are shown in Table 2. Net returns were calculated using these results. The return from Argona was lower than for the other cultivars, which were all similar (Table 2).

The responses to seed rate of viner yield and net return differed among the cultivars, as indicated by the significant statistical interactions (Table 2). These were interpreted by relating them to plant population as the independent variable (Figures 4 and 5).

The results in Figure 4 show that Pania, Trounce and Bolero had very similar responses to plant population, although the maximum yields for Bolero were slightly lower. Their optimum yields were achieved at a population of around 100 plants/m^2. In contrast, yields of Argona were largely independent of population. Its optimum could not be identified, but is unlikely to be much below 100 plants/m^2.

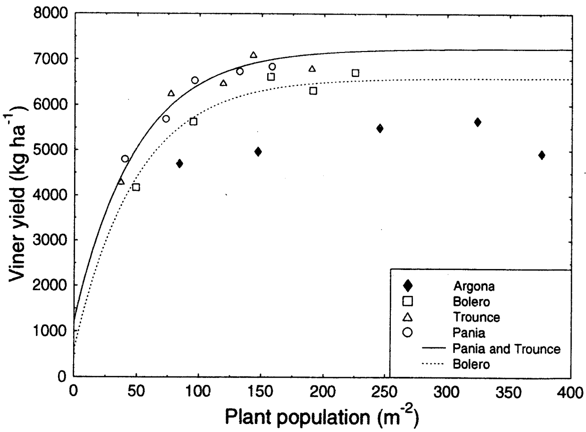

Figure 4. Effect of plant population on viner pea yields of the four contrasting cultivars.

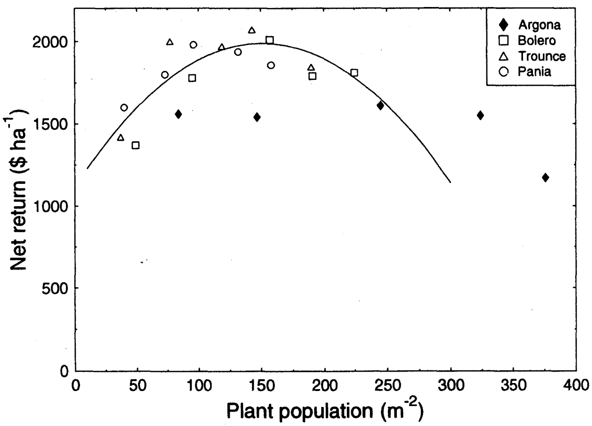

Figure 5. Relationship between net economic return and plant population for the four contrasting cultivars. Line of best fit applies to Bolero, Trounce and Pania only.

There was considerable variation in the responses of net return to plant population (Figure 5). Pania, Trounce and Bolero had similar responses. Their profitability was insensitive to population above a minimum of about 75 plants/m^2. The profitability of Argona was also independent of population, except that net return declined at the highest population. There was no clear indication of a minimum population but, again, it is unlikely to be much below 100 plants/m^2.

Conclusions

In this experiment the optimum viner yield for all the cultivars was achieved at a population in the region of 100 plants/m^2. This agrees with most of the results cited earlier (i.e. Anderson and White, 1974b; Biddle *et al.*, 1988; Murphy, 1975; White *et al.*, 1982), confirming the plasticity of the pea plant, and its ability to compensate within yield components over the range of populations used in this experiment. We therefore reject the hypothesis that it may be necessary to vary plant populations to obtain optimum yields for cultivars with different seed sizes.

Maximum profitability in this experiment was achieved at populations from as low as 75 plants/m^2 for most cultivars, but there was no economic disadvantage from using higher populations. However, populations higher than the minimum have the advantage of biological insurance against factors which could reduce yields by causing plant mortality, such as disease and weed competition. Also, better yield stability is more likely at higher populations because yield components are less sensitive to population variations.

The yield and net return for Argona were much lower than for the other cultivars tested.

Therefore, for practical purposes, we conclude that the current recommendation of aiming for about 110 plants/m^2 for all cultivars should be retained. Our results showed no basis for different recommendations for cultivars with different seed sizes. Although plant population is preferable to seed rate as a basis for sowing recommendations, a seed rate should be calculated for each seedline, taking seed size into account, in order to achieve the target population.

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