Yield responses of field and process peas to fertiliser application

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Abstract

Five field trials were conducted to determine the yield response of peas (*Pisum sativum* L.) to nitrogen (N), phosphorus (P) and potassium (K) availability, and to define the threshold soil N, P and K levels below which a yield response to fertiliser application is likely. The trials were conducted in a range of soil fertility conditions. All crops were irrigated. Six fertiliser treatments were applied to the field peas at planting: a zero control, two rates of a compound NPK fertiliser, and three treatments with N, P or K only. Only the first three treatments were applied to the process peas. There were no yield responses to fertiliser application at any of the sites. Even though soil fertility was generally low, nutrient availability was not a major yield determinant. Water availability appeared to be the main cause of yield differences among sites as they received differing amounts of irrigation and rainfall. The threshold levels for soil N, P and K below which yield reductions occur were not reached, indicating that a yield response is unlikely if available N, Olsen P and exchangeable K are above the minimum values in the trials which were 73 kg/ha, 10 µg/g and 60 µg/g respectively. Current high rates of fertiliser application to peas need to be reviewed because they are probably unnecessary and unprofitable, especially in higher fertility situations.

Additional key words: Pisum sativum *L., soil fertility, nitrogen, phosphorus, potassium, water availability*

Introduction

Current fertiliser recommendations for pea crops prescribe target soil phosphorus (P) and potassium (K) fertility levels that growers should aim for to avoid yield reductions caused by nutrient deficiencies. In a recent fertiliser industry publication, Morton *et al.* (1998) recommended that for optimum yields of both field and process peas, soil Olsen P should be in the 20-30 µg/g range and exchangeable K should be within or above the optimum range of 120-160 µg/g (equivalent to Quicktest K values of 6-8). Clarke *et al.* (1986) recommended that the Olsen P value should be in the 30-35 µg/g range for process peas on low P retention soils, with higher values on higher P retention soils. Clarke *et al.* (1986) also recommended that exchangeable K should be at least 120 µg/g, and as high as 200 µg/g on clay soils. Montgomery *et al.* (1987) advised that no fertiliser needed to be applied to field peas if the Olsen P value was above 15 µg/g and exchangeable K was 60 µg/g. Recommendations for nitrogen (N) fertiliser application are more vague. Although peas are legumes and can fix their own N, supplementary applications of N fertiliser are suggested when soils are cold and wet, or after a high yielding cereal crop when soil N levels are likely to be low (Montgomery *et al.*, 1987; Morton *et al.*, 1998).

These recommendations are based on sparse information about pea yield response to soil fertility level and/or fertiliser application. They have resulted in fertiliser applications to pea crops that could be unnecessary and produce no profitable yield responses, especially in higher fertility situations. For example, many process pea crops in Canterbury receive an application of a compound N, P and K fertiliser at planting. A typical application is 150 kg/ha of N:P:K = 8:15:15, although the amount is often adjusted depending on soil fertility test values and paddock history (S.J. McCormick, pers. comm.). Applications of P and K fertiliser to field pea crops are also common. The few published results from trials where the effects of N, P and K fertiliser application on pea yield have been measured showed that positive responses occurred only at low soil fertility levels. Furthermore, responses were small, inconsistent, and generally uneconomic (McLeod, 1987; Carter and Stoker, 1988; Wilson and Robson, 1998, unpublished results). These results suggest that fertiliser application to peas is seldom necessary, and that a yield response is unlikely provided soil fertility is maintained by adequate fertiliser application to other crops and pasture in the cropping rotation.

In view of the uncertainty about the fertiliser requirements of peas, the project described in this paper was commissioned by the Process Vegetable Sector of Vegfed and the Foundation for Arable Research (FAR), representing process and field pea growers respectively. The objective was to make it possible for growers to decide when a profitable response to fertiliser application is likely by (i) defining the yield response to N, P and K from both soil reserve and fertiliser sources, (ii) determining the threshold soil N, P and K levels above which yield responses are unlikely, and (iii) developing a system for using soil fertility information to forecast when profitable responses are likely, and how much and what type of fertiliser to apply.

Materials and Methods

The project was conducted in five commercial, irrigated field pea crops in central and mid Canterbury during the 1998-99 season (Table 1). The sites were selected in consultation with FAR and seed company representatives to obtain a range of N, P and K soil fertility levels. The choice of sites was limited by the small number of growers with irrigated field pea crops who were able to host the project. About 20 potential host growers were contacted and screening soil tests were done at 12 sites with diverse paddock histories and previous soil test results before the final five sites were selected.

Immediately before planting, a soil sample consisting of ten 0-15 cm cores was taken randomly from each plot at each site. Standard analytical procedures were used to measure exchangeable K, Olsen P, pH, and mineral N (NH_4 and NO_3) in the Crop & Food Research soil science laboratories at Lincoln. 'Readily available' N, which includes N mineralised during seven days of anaerobic incubation at 40°C (Keeney and Bremner, 1966), was determined by Analytical Research Laboratories Ltd, Napier. In addition, total N and organic C were measured on a composite sample from each site.

At each site, the experiment was sown with a small-plot cone seeder just before the surrounding crop of field peas was planted by the host grower. Plots were 10 m long and 1.35 m (nine rows) wide at four sites. Plots were 8 m long at site 2. The seeder was run over each plot twice. The fertiliser for each treatment was applied down-the-spout on the first run and the seed was planted on the second run. The sowing rate was calculated with the aim of establishing a population of 100 plants/m^2. Plots of the field pea cultivar, Primo, and the process pea cultivar, Bolero, were sown at each site.

There were 18 field pea plots per site, with three replicates of the following six treatments in a randomised complete block design:

T1: Control; no fertiliser.
T2: 200 kg/ha Cropmaster 15 (30 kg N/ha; 20 kg P/ha; 20 kg K/ha).
T3: 400 kg/ha Cropmaster 15 (60 kg N/ha; 40 kg P/ha; 40 kg K/ha).
T4: 300 kg/ha sulphate of ammonia (63 kg N/ha).
T5: 400 kg/ha superphosphate (36 kg P/ha).
T6: 100 kg/ha potassium sulphate (42 kg K/ha).

The sulphate forms were chosen for treatments T4, T5 and T6 so that the effects on the peas of N, P and K could be studied alone, with the sulphate common to all treatments. The amounts of N, P and K in T4, T5 and T6 respectively were similar to the corresponding amounts in the T3 composite fertiliser treatment.

The process peas were studied less intensively, with no separate measurement of response to individual nutrients. Therefore, there were nine process pea plots at each site, with three replicates of treatments T1, T2 and T3 in a randomised complete block design.

Table 1. Details of the five trial sites.

Site	Location	Soil type (all silt loams)	Sowing date	Harvest date: Process peas	Harvest date: Field peas
1	Eiffelton	Temuka	22 Sep	2 Jan	21 Jan
2	Dorie	Templeton	22 Sep	2 Jan	22 Jan
3	Seafield	Lismore	22 Sep	2 Jan	26 Jan
4	Kirwee	Lismore	15 Oct	8 Jan	4 Feb
5	Kirwee	Lismore	15 Oct	10 Jan	4 Feb

The experimental area was managed by the grower in the same way as the crop in the rest of the paddock except that no fertiliser was applied by the grower. All of the crops were irrigated.

The process pea plots were harvested when the peas were as close as practicable to a tenderometer reading (TR) of 105. A 4.3 m^2 sample area was harvested by hand from each plot. The plants were removed, counted and their total weight was measured. Each sample was taken to Crop & Food Research, Lincoln where the peas were removed with a mini-viner. The weight and TR of the peas from each sample were measured. Yields at TR = 105 were estimated with the standard adjustment formula used by pea processing companies. Yield components were measured on 20 representative plants collected from the remainder of each plot. The plants were separated into stover, pods and peas and the fresh and dry weights of each fraction were measured. The numbers of pods and peas were counted.

The field pea plots were harvested when the peas had reached physiological maturity (seed growth completed) but before the plants became too dry and brittle to handle, with the associated risk of seed loss. Whole plants were hand-harvested from a 4 m^2 area (3 m^2 at site 1) of the five centre rows of each plot. The plants were counted and their total weight was measured. A random sample of 50 plants was retained from each plot, weighed and taken back to Lincoln for processing. Yield and yield components were determined from measurements of numbers of peas and pods and of fresh and dry weights of stover, pods and peas.

Analysis of variance was used to determine statistically significant differences among treatments at each site. It was intended that yield responses to fertiliser application and total nutrient availability would be calculated, and that the results of the soil and plant analyses would be used to calculate a nutrient balance for each treatment in the field peas. In the across-site analyses, results from every plot were to be used in a composite analysis to develop a model of yield response to each of the three nutrients (N, P and K).

Results

Soil fertility

The five sites had a range of soil fertilities (Table 2). None had high values of all three nutrients. Sites 2 and 3 had the highest overall fertility levels and sites 4 and 5 were the least fertile. Available soil N ranged from low at site 4 to medium at sites 1 and 3. None had high levels of available N. The N values corresponded with the soil organic matter levels which were indicated by the total N and organic C percentages. Exchangeable K ranged from very low at site 1 to high at sites 2 and 3. Olsen P values ranged from low at sites 4 and 5 to moderate at site 3.

Process peas

Plant establishment and crop growth was good at all the sites. Mean site population at harvest ranged from 74 to 86 plants/m^2, and was not affected by the treatments.

Crop growth at site 1 was good until an irrigation pipe burst adjacent to the trial and flooded two of the three replicates when the crop was at the early pod-fill stage. The plants in these plots subsequently died so no information was obtained from them. The maximum value possible was obtained from the remaining undamaged replicate by harvesting two 4.3 m^2 areas from each plot instead of taking a single sample.

Crop growth was also good at site 2 even though there were weeds in the trial. This occurred because of a misunderstanding between the grower and spraying contractor which resulted in no herbicide being applied to the trial when the surrounding crop was sprayed. Most weeds were in the gaps between plots because

Table 2. Mean values of the soil test results from the five sites.

	Nitrogen						
Site	Available (kg/ha)	Mineral (kg/ha)	Total (%)	Org. C (%)	Olsen P (μg/g)	Exchangeable K (μg/g)	pH
1	100	23	0.30	3.4	16	60	6.0
2	87	75	0.30	3.3	19	260	5.9
3	93	79	0.30	3.4	22	260	5.6
4	73	35	0.20	2.7	10	100	5.4
5	82	59	0.20	2.6	11	120	5.7

within the plots the vigorously growing crop competed very effectively with the weeds. Therefore, the weeds were judged to have little influence on the response to the fertiliser treatments.

Yields adjusted to TR = 105 differed among sites, with mean values ranging from 5.8 to 10.7 t/ha in the trials at sites 4 and 2 respectively (Table 3). Yield did not respond positively to the fertiliser treatments at any of the sites, even though soil fertility was generally low at all the sites and also differed among the sites. At all sites, background variability had more effect on yield than the fertiliser treatments.

There were substantial TR differences among sites at harvest. The mean values for the trials at sites 1, 2 and 3 were 151, 129 and 96 respectively. These differences occurred even though the trials were planted and harvested on the same dates (Table 1), presumably because thermal time accumulated faster at sites 1 and 2. The mean TR values at harvest for sites 4 and 5 were 96 and 120 respectively.

The yield results from site 1 were not analysed statistically because they were judged to be too unreliable. In addition to the loss of two replicates caused by the flooding damage, the high TR value at harvest meant that there was too much uncertainty in the calculation to estimate yield at TR = 105.

The statistical analysis indicated a significant yield reduction caused by the fertiliser treatments at site 5 (Table 3). However, this had little practical significance because the analysis of variance also showed a highly significant yield difference among the three replicates in the trial. This difference across the trial site was much greater than the differences among the treatments.

While yield components were measured in all trials, no results are presented due to the lack of yield response to the fertiliser treatments.

Field peas

Plant establishment was good at all sites, except in one replicate of site 5. Mean populations at harvest were 84, 81 and 83 plants/m^2 at sites 1, 2 and 3 respectively. Populations were lower at sites 4 and 5 (71 and 67 plants/m^2 respectively) because some seed was lost to birds, and dry soil conditions after planting reduced establishment. One replicate of the trial at site 5 was not harvested because the population was reduced severely

Table 3. Effect of the fertiliser treatments on process pea yields (t/ha) adjusted to TR = 105.

Treatment	Site 1	Site 2	Site 3	Site 4	Site 5
T1 (Control)	5.85	11.18	9.86	5.77	7.15
T2 (low NPK)	7.82	10.40	11.29	5.92	6.92
T3 (high NPK)	6.70	10.64	10.21	5.66	6.58
F-prob	---	0.21	0.83	0.89	0.01
CV (%)	---	4.2	28.3	11.4	1.2
LSD $_{(P<0.05)}$	---	1.01	6.69	1.49	0.22

Table 4. Effect of the fertiliser treatments on seed yield (t/ha) of field peas.

Treatment	Site 1	Site 2	Site 3	Site 4	Site 5
T1 (Control)	2.96	4.06	2.57	2.37	2.96
T2 (low NPK)	3.03	3.69	3.18	2.12	1.88
T3 (high NPK)	3.09	3.76	2.78	2.13	1.62
T4 (N)	3.18	3.70	2.68	1.93	1.81
T5 (P)	3.12	4.37	2.48	2.08	2.58
T6 (K)	2.96	3.86	3.05	2.13	1.61
F-prob	---	0.74	0.77	0.84	0.48
CV (%)	---	16.1	24.2	18.2	37.2
LSD (P<0.05)	---	1.15	1.23	0.7	1.98

by bird damage. Plant population was not affected by the fertiliser treatments at any of the sites.

Crop growth was good at all sites, and plants compensated adequately for population reductions below the target of 100 plants/m^2. As with the process peas, the burst irrigation pipe at site 1 also flooded two replicates of the field pea trial and made them unharvestable. Two samples were harvested from each plot in the remaining undamaged replicate, but the results were not analysed statistically.

There were weeds in the trial at site 2 but, as for the process peas, they were judged to have little influence on the response to the fertiliser treatments. Most weeds were in the gaps between plots.

Seed yields differed among sites, with mean values ranging from 2.1 to 3.9 t/ha in the trials at sites 5 and 2 respectively (Table 4). As for the process peas, nutrient availability was not a major yield-determining factor. The fertiliser treatments did not significantly affect yield at any of the sites (Table 4), even though soil fertility was generally low at all the sites and also differed among the sites. At all sites, background variability had more effect on yield than the fertiliser treatments.

As for the process peas, yield component results are not presented due to the lack of yield response to the fertiliser treatments.

Discussion

The performance of the crops in the experiments was typical of process and field peas in Canterbury, allowing for the fact that yields measured in small plots are usually about 30% higher than comparable larger scale measurements. The process pea yields spanned the usual range for commercial crops where the average is just over 6.0 t/ha (S.J. McCormick, pers. comm.). The field pea crops also represented a typical cross-section of commercial crops. Although crop growth was good, seed yields were lower than usual because of low seed weight caused by shortened growth duration during seed fill. This was a common occurrence in field pea crops in the warm 1998-99 season.

The threshold soil N, P and K levels were not reached at any of the sites even though most of the soil fertility levels were generally low. The lack of any yield response supported previous observations that pea yield responses to fertiliser application are small and occur only when soil fertility is low (McLeod, 1987; Carter and Stoker, 1988; Wilson and Robson, 1998, unpublished results). The results indicate that nutrient availability was not a primary yield-limiting factor at any of the sites.

As found by Bennett and Webb (1987), other factors such as soil type and water availability had much more influence on pea yield. In these experiments water availability from rainfall, irrigation and soil reserves was probably the main cause of yield differences among sites. For example, the highest-yielding crop at site 2 was seldom exposed to damaging water deficit. It was on a Templeton soil, and the process peas received 95 mm of rainfall and five irrigations totaling 187 mm while the longer-duration field peas received 114 mm of rainfall and six irrigations totaling 227 mm. At the other end of the range, the crops at sites 4 and 5 were on a Lismore soil with lower water holding capacity, and the process peas received only 65 mm of rainfall and three irrigations totaling 120 mm (100 mm of rainfall and three irrigations totaling 120 mm for the field peas). Even at the most favourable site (2), where water availability was good throughout the season so that crop growth was excellent and yield potential was high, nutrition did not limit yield. Clearly, water management had a much greater effect on pea yield than fertiliser management.

The results reinforce the view that a pea yield response to fertiliser application is unlikely provided other crops and pasture in the cropping rotation receive adequate fertiliser. However, they do not support recent recommendations by Morton *et al.* (1998) that, for optimum pea performance, fertiliser should be applied to maintain Olsen P and exchangeable K values in the ranges 20-30 and 120-160 μg/g respectively. Our results indicate that a yield response is unlikely unless Olsen P and exchangeable K are below the minimum values in the experiments which were 10 and 60 μg/g respectively. For available N, no response was obtained down to the minimum observed value of 73 kg/ha.

The common practice of applying high rates of fertiliser to both process and field pea crops is probably unnecessary and unprofitable, especially in higher fertility situations. Fertiliser management practices for peas need to be reviewed. A soil test should be done to determine N, P and K levels, and fertiliser applied only if they are below the levels suggested above.

One aim of this project was to use the results from the trials to begin developing a system for forecasting the fertiliser requirements of pea crops. Several diverse sites were used instead of the traditional approach which usually produces precise, site-specific results that are difficult to translate into fertiliser forecasts for other situations. The multi-site approach, with less precision than usual for each site, was intended to make it possible to define the threshold soil N, P and K levels above which yield responses are unlikely to occur, and to quantify the responses below the thresholds. The lack of any yield responses meant that no progress was possible on this objective.

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