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FINAL REPORT

OF

PROJECT No FV176a

STARTER FERTILISERS FOR TRANSPLANTED LETTUCE ON PEAT SOIL

Project title:	**Starter fertilisers for transplanted lettuce on peat soil**
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PRACTICAL SECTION FOR GROWERS

Objectives and background

The horticultural industry depends heavily on high inputs of fertilisers to achieve economic crop yields of the quality demanded by its customers. However, crops seldom recover all the nutrients applied and there is increasing public concern that their intensive use could lead to environmental damage. As a consequence, there is a need to develop fertiliser strategies that reduce inputs while not compromising yield or quality.

One technique, achieving commercial acceptance, is based on targeting fertilisers more accurately. HDC and MAFF-funded research has shown that there is considerable potential for reducing fertilisers inputs by injecting small amounts of liquid NP, or NPK fertilisers (known as starter fertilisers) close to seeds at drilling, or around the roots of transplants. In many experiments, fertiliser is not only used more efficiently but there is a concomitant increase in marketable yield and earlier maturity.

Most of the early work was carried out on mineral soils, so there were uncertainties of the value of starter fertilisers under the different nutrient regimes prevailing on peat soils. The aim of this project was to maximise iceberg production of open-grown lettuce on a Lancashire peat soil, using minimal fertiliser inputs.

Summary of results

Spot applications of a high phosphate starter fertiliser solution, supplemented by various rates of pre-plant broadcast fertiliser, were applied at transplanting to block-raised lettuce, cv. Saladin. As an alternative to applying the starter solution to the soil below the block, one treatment investigated pre-soaking the blocks in the solution.

In comparison to recommended rates of broadcast fertiliser, the benefits of starter fertiliser can be summarised as follows:

- At an early harvest (about 7 weeks after planting), the total untrimmed fresh weight of plants receiving starter fertiliser was increased by 50%, from 35.7 to 55.0 t ha^{-1}.
- Mean trimmed head weights at about 7 weeks were increased by 75%, from 280 to 490 g.
- At a final harvest, 10 days later, trimmed head weights were increased by 28%, from 505 to 648 g.

- At final harvest, the percentage of heads classed as 'iceberg' was increased from 74% to 99%, giving a marketable yield up from 26.5 to 42.9 t ha^{-1}.

- Maturity, based on average head weights, was about 10 days earlier.

- The benefits of starter fertiliser were not enhanced by supplementary broadcast fertiliser.

An unexpected feature of the results was the close similarity in the beneficial responses to soaking the block in starter solution pre-planting, compared with applying the same solution direct to the soil, despite the former procedure using 40% less solution.

Action points for growers

The work demonstrates, on a fertile peat soil, that high marketable yields of iceberg quality lettuce can be achieved with reduced inputs of fertiliser, and there are benefits of earlier maturity. It must be stressed, however, that these results are based on one year's results only, and might not be repeated on the very high PK status soils in some parts of Lancashire.

Practical and financial benefits from the study

The use of starter solutions as part of an overall fertiliser strategy will enable growers to demonstrate due diligence to customers, and the improvements in fertiliser use efficiency gives both economic and environmental benefits. The potential financial benefits will vary with the objectives of the individual grower, but there are opportunities for reducing fertiliser inputs, increasing yields and enhancing maturity and quality. For lettuce, a small increase in the proportion of the crop marketable as iceberg would markedly increase crop value.

For growers concerned that carrying the weight of liquid fertiliser on the transplanter may cause compaction problems on peaty soils, a pre-planting block application of starter solution, by the grower or plant raiser, may be an acceptable option, but further work is required to develop this approach into a practical system. Alternatively, it may be possible to use more concentrated starter solutions and reduce the volume applied from the transplanter, without reducing effectiveness.

EXPERIMENTAL SECTION

Introduction

Several crops, including lettuce, can suffer temporary nutrient deficiencies in the early stages of growth, even on well fertilised soils with high levels of residual nutrients. This is because the sparse root system of the seedling or transplant is unable to meet the high nutrient demand of the developing shoot. If this demand is not met, the resulting setback in early growth can irreversibly reduce final yield and quality (Burns, 1990).

Recent HDC (Project FV 41) and MAFF-funded studies have shown that targeting small amounts of liquid NP, or NPK, fertilisers - starter fertilisers - close to seeds at drilling, or around the roots of transplants, can overcome early deficiencies, giving yields of some crops that are higher than can be achieved with broadcast fertiliser alone. The technique was also shown to offer considerable opportunity for reducing fertiliser inputs without compromising yield or quality.

Initial trials and the development of the injection equipment for drilled crops were carried out on mineral soils but, following the development of a commercial prototype of the HRI injection system (FV 41a), the work was extended to a peat-loamy soil at ADAS Arthur Rickwood, in 1993. In a season in which response to broadcast nitrogen fertiliser was small, the yield of iceberg quality heads of lettuce was doubled when ammonium phosphate starter fertiliser was compared to broadcast ammonium nitrate, with the crop maturing a week earlier. Since the drilled crop now occupies only a small percentage of the lettuce area on peat, it was considered appropriate to extend the work by exploring the use of starter fertilisers with transplants on a Lancashire moss soil.

Special attachments are available for some commercial transplanters that automatically make spot applications of dilute fertiliser solutions around the transplant, but concern has been expressed that carrying the weight of liquid fertiliser on the transplanter may create compaction problems on peat soils. It is possible that this could be minimised by using concentrated solutions at low volume, or by using starter solutions as a pre-planting booster feed. The project described was designed to investigate these options, and to consider the feasibility of using placed granular fertiliser.

Materials and method

The experiment was carried out on a peat soil of the Longmoss series (Ragg *et al.*, 1984), at a single site near Garstang, Lancashire. The site had been cropped previously with a low N, long ley with soil nitrogen Index 1 (MAFF, 1993). The surface soil was analysed for pH (1:2.5 soil:water), bicarbonate extractable P, ammonium acetate exchangeable K, nitrate and ammonium N, see Table 1.

Table 1. Soil analysis prior to application of treatments.

	Available nutrients, µg g^{-1}			
pH	P	K	NO_3-N	NH_4-N
6.3	48 (4*)	118 (1*)	53	7

* ADAS index

The experimental site was ploughed one week before planting, and a uniform application of muriate of potash applied at 125 kg K_2O ha^{-1}. Lettuce cv. Saladin, in 43 mm peat blocks, were planted by hand, at 66,150 ha^{-1}, into 1.83 m beds on 24 July. Individual plots consisted of a 7.6 m length of bed containing 92 plants in four rows 355 mm apart, with plants 328 mm apart within the row. Husbandry followed good commercial practice, and 25 mm irrigation was applied immediately after planting, and about 13 mm a week later. Plots were hand-hoed and regular crop inspections indicated that no insecticides or fungicides were required.

There were 6 treatments arranged in five randomized blocks:

(1) Control - N and P broadcast at the recommended rate (MAFF, 1993)
(2) P broadcast at the recommended rate (zero N)
(3) Starter fertiliser solution plus N and P broadcast at the recommended rate
(4) Starter fertiliser solution only
(5) Starter fertiliser solution plus P broadcast at the recommended rate and N at half rate
(6) Starter fertiliser solution applied to the block pre-planting plus N and P broadcast at the recommended rate

The rate of nutrients applied in the individual broadcast and starter fertiliser treatments are shown in Table 2. Appropriate rates of broadcast fertiliser were spread by hand and incorporated to 100 mm depth by power harrow during bed preparation. The starter fertiliser used in treatments 3, 4 and 5 consisted of a spot application of Kemira's 10.52.17 water soluble fertiliser diluted to a 3.33% w/v strength solution, and applied at 30 ml per plant. This is the highest strength recommended by the manufaturers and was equivalent, at the spacings used, to about 2000 l $ha^{-1.}$ The solution was applied immediately before planting to the base of a dibbed hole using a hand-held dispensing pipette. To eliminate potential differences in water supply, plants in treatments 1 and 2, which received no starter solution, were treated with 30 ml of water applied in the same way. For treatment 6, the blocks were allowed to stand in the starter solution to a depth of 10 mm for 1.5 hours immediately before planting. This resulted in the absorption of an average of 17.5 ml of starter solution per block.

Table 2. Nutrient application rates.

Treatment code	Application rate, kg ha^{-1}		
	N	P_2O_5	K_2O*
1	100	25	
2		25	
3	107	59	11
4	7	34	11
5	57	59	11
6	104	45	6

*All treatments had an additional uniform application of 125 kg K_2O ha^{-1}

A random sample of plants was taken at transplanting, and the shoot dry matter analysed for nutrient content, see Table 3.

Table 3. Shoot analysis at transplanting.

Transplant analysis, %		
Organic-N	P	K
5.64	0.79	6.99

Sixteen plants, four from each row, were sampled 47 (9 September) and 57 (19 September) days after transplanting. The first harvest was taken when over half the lettuce on the best treatments were judged to have firm heads. A third harvest, planned for day 67, had to be abandoned when the crop was severely damaged by a heavy frost. Total shoot fresh weights (1st harvest only) and trimmed head weights (both harvests) were recorded for individual plants. A minimum trimmed head weight of 450 g was taken as the size criteria for 'iceberg' quality lettuce (Anon, 1983). Four guard plants per row were left at the ends of each plot, and two between harvest areas.

Results

The season was favourable to the growth of lettuce, and all plants established well and grew away quickly. However, a beneficial effect from the starter solution was apparent in the field within a fortnight of transplanting, and this observed difference was maintained through to the first and subsequent harvest, as shown in Table 4.

At the first harvest, about 7 weeks from transplanting, lettuce supplied with starter fertiliser alone (treatment 4) had a significantly greater total fresh weight and mean trimmed head weight in comparison with those receiving the recommended rates of broadcast N and P (control, treatment 1). On the control plots, no heads had attained iceberg size at the first harvest, whereas 65% had done so with the starter solution. By the second harvest, the trimmed head weights of the control plants had just attained the size of the starter-grown plants of 10 days earlier. At the second harvest, plants supplied with starter solution were significantly larger, by 28%, and 99% were of iceberg quality compared with only 74% of the controls. These large differences were reflected in a 62% increase in yield of iceberg heads, from 26.5 to 42.9 t ha^{-1}.

Table 4. Total fresh weight, trimmed fresh weight and yield of iceberg heads at harvest.

	Treatment code						LSD*
	1	2	3	4	5	6	
Harvest 1							
Total fresh weight (t ha^{-1})	35.7	39.6	55.0	53.7	50.8	49.1	7.52
Mean trimmed head weight (g)	280	319	495	490	444	425	83.0
Iceberg yield (heads > 450 g, t ha^{-1})	0.0	4.4	25.0	24.3	16.4	16.2	10.66
Harvest 2							
Mean trimmed head weight (g)	505	531	660	648	663	633	93.2
Iceberg yield (heads > 450 g, t ha^{-1})	26.5	29.8	43.0	42.9	40.5	40.6	9.18

* LSD Least significant difference $P < 0.05$

It was notable, at both harvests, that the benefits of starter solution alone (treatment 4) were not enhanced by additional broadcast N and P (treatments 3 and 5), and that there was no significant response to the level of broadcast N (treatment 1 compared with 2, or treatment 3 compared with 5). The benefits obtained by the pre-plant application of starter solution to the block (treatment 6) were not significantly different from those obtained by applying a 60% greater volume directly to the planting hole (treatment 3).

Discussion

These results clearly demonstrate that the application of an NPK starter fertiliser solution can increase the yield of crisp lettuce on a fertile peat soil. Starter fertiliser also advanced maturity, by about 10 days, increased mean trimmed head weights and resulted in a considerably higher percentage of heads in the 'iceberg' size grade.

In this experiment there was no response to broadcast N, possibly because of mineralisation from the grass/clover residues, but this was also a feature in the earlier work (FV 41) at ADAS Arthur Rickwood. Related MAFF-funded work into N use efficiency (Stone & Rowse, 1992) has also shown that high yields of lettuce can be obtained with reduced nitrogen inputs by using ammonium phosphate as a starter fertiliser. Since the starter solution contained nitrogen, phosphate and potash it is not possible to separate the individual nutrient effects, but it is known that in combined formulations there are positive interactions between anions (PO_4, NH_4) and cations (NO_3, K). Past work with lettuce (Costigan & Heavyside, 1988) would suggest, however, that the main effects of starter fertiliser are attributable to phosphate. In which case, the response on this soil might have been even greater earlier in the season when soil temperatures would have been lower and soil P consequently less available.

A striking feature of this experiment was the similarity in the beneficial effect of the pre-plant block application of starter solution and the corresponding treatment applied direct to the planting hole, despite the former using 40% less solution. The aim in using starter fertilisers is to provide a nutrient-rich environment in a zone close to the transplant, thereby enabling the plant to satisfy the high nutrient demand of the shoot at a time when root proliferation is limited. It might be expected that supplying a high concentration of nutrients in the block would be less effective in promoting root proliferation into the surrounding soil than supplying it as an enriched zone immediately below the block. In the absence of root measurements or observations, however, it is unknown whether this occurred in this experiment. Liquid feeds are often given pre-dispatch by the plant raiser to minimise nutrient stress, but Costigan & Heavyside (1988), in six lettuce experiments, were able to demonstrate that within wide limits (%N 1.8 - 5.6, %P 0.39 - 0.74, %K 2.5 - 7.7), plant nutrient analysis at transplanting had little effect on subsequent growth. Clearly, further work is required to investigate the potential of pre-plant treatments. In particular, to determine the optimum rate in relation to block size, application timing and formulation of the starter solution.

Past studies, and commercial experience, on mineral soils suggest that the response to starter fertilisers can be small on soils of high P status (Index 6 or 7). Consequently, in selecting a site for this experiment a site of lower P index was chosen. However, it became apparent during an extensive search for a site that many of the moss soils in Lancashire have indices of around 6. Despite this, growers are regularly applying fresh phosphate, contrary to current recommendations (MAFF, 1994), and claim to be obtaining a benefit. Either this is an insurance application and potentially wasteful, or conventional soil P analysis based on sodium bicarbonate extraction is a poor indicator of availability on peat soils. Much of the P in peat soils is bound in the organic matter and phosphate is released as this breaks down. It is likely, therefore, that the concentration of soil solution P might give a better indication of P availability. Costigan (1986) found, on 13 soils, including two Lancashire peats, that there was no response in early growth rates of lettuce to soil solution P concentrations above about 1 $\mu g\ ml^{-1}$. Starter solutions used by Costigan & Heavyside (1988) had no significant effect on the early growth and final yield of crisphead lettuce, in a single trial, on a peat soil of P Index 6 at Chat Moss, Lancashire. Uncertainties therefore remain as to the broader applicability of the results of the work reported here.

It had been the intention to investigate and test tines which could be used for positioning granular fertiliser close to the transplant in order to minimise weight carried on the transplanter. However, because of the presence of root residues from the freshly ploughed ley, which had been selected primarily for nutritional reasons, this was not feasible. If growers wish to explore this option, machinery is commercially available for placement of solid fertiliser products. Drill-mounted equipment, which delivers fertiliser to the side of and below the seed, is routinely used for crops such as maize. It should be practical to modify this for mounting on a transplanter, but the weight savings are likely to be small, and the block treatment discussed above may be a better option.

CONCLUSIONS

The experiment extended previous findings, based largely on mineral soils, that starter fertilisers used on a peat soil can:

- increase marketable yields of iceberg lettuce
- promote earlier maturity
- minimise fertiliser inputs

The results also suggest that there may be opportunities for using pre-planting starter treatments, applied to the block, to reduce weight carried on the transplanter and to save time and labour at planting associated with refilling fertiliser hoppers or tanks.

RECOMMENDATIONS

Although the results of this experiment are clear cut, they should be treated with caution. It must be appreciated that the work covered only one site and one season. Further experimentation is recommended:

1. to substantiate these results,

2. to extend the applicability of these results to other major peat sites and to other crops commercially important on peat soils,

3. to develop the pre-planting block treatment into a practical option

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