Project title:	Maximising yield through optimal establishment and agronomy of modern asparagus crops
Project number:	FV 437
Project leader:	Dr Lizzie Sagoo, ADAS UK Ltd
Report:	Annual report 2015
Previous report:	None
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Date project commenced:	1 April 2014
Date project completed (or expected completion date):	31 March 2017

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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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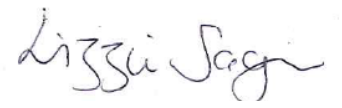

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GROWER SUMMARY

Headlines

- Two field experiments were successfully set up at a single site in Lincolnshire in 2014 to identify the optimum nitrogen and phosphorus fertiliser treatments that are necessary at establishment in order to achieve maximum yields from new asparagus plantations.

- To date the crop, pest and disease assessments showed no significant statistical differences between treatments. In addition there were no visual symptoms of nutrient deficiency and fern tissue analysis showed macro and micro nutrient concentrations to be within the range reported in HDC factsheet 14/13 ‘Asparagus nutrient management’.

Background

Asparagus is a high value crop to which the land is committed for ten years or more. Soil structure, pH and nutrient indices all have to be ideal or corrected at the time of establishment to enable optimum returns to be obtained for the duration of the plantation. Correct levels of nitrogen (N) and phosphorus (P) need to be applied at planting to ensure good growth and establishment. There has been little work on nutrition of the asparagus crop since HDC project FV 152 (1996; study of N responses) and HDC project FV 153 (1996; study on P and potassium (K)). Phosphorus has been shown to be an important nutrient for root growth and mass and it can influence later yields, as shown in work carried out on asparagus by Dan Drost in the USA.

The aim of this project is to identify optimum N and P fertiliser treatments at establishment which will result in maximum yields from new asparagus plantations. The specific objectives are to:

a) Establish a field experiment to investigate the optimum rate of N at establishment in Year 1,
b) Determine the appropriate rate of N at or above current RB209 recommendations for Year 2 using the plots established in Year 1,
c) Establish a field experiment to investigate placement of P in Year 1,

d) In each experiment, assess plots annually for spear yield (except year 1), nutrient concentrations in the fern, pest and disease incidence, root biomass, and canopy size.

Summary

Two field experiments were established in 2014 at a single location near Boston (Lincolnshire) to assess (i) the effects of N fertiliser rate, and (ii) the effect of placement of P fertiliser close to the crown in a new plantation. The site was planted with 'A' grade crowns of the variety Guelph Millennium on the 13/05/2014. Soil samples were taken prior to planting in February 2014; the site was SNS index 0 (37 kg/ha SMN), P index 4, K index 2 and Mg index 2.

The N response experiment included 5 application rates plus a control: 0, 50, 100, 150, 200 and 250 kg N/ha (applied as ammonium nitrate, AN). There were 4 replicates of each treatment arranged in a randomized block design.

A second factor will be studied in the second year to determine if current RB209 recommendations of applying 120 kg N/ha in the first year following establishment are sufficient for modern asparagus varieties, or if a 25% higher rate is needed. These will be arranged as sub-plots within the main plots in year 2.

The P response experiment included 4 treatments:

1. Control – no P fertiliser
2. 'Placed' P – 58 kg/ha P_2O_5 (as Di-ammonium phosphate - DAP)
3. 'Corrective' P (i.e. RB209 recommended rate) – (75 kg/ha P_2O_5 as Triple superphosphate - TSP)
4. 'Placed' P (58 kg/ha P_2O_5 as DAP) plus 'corrective' P (75 kg/ha P_2O_5 as TSP)

The P response experiment included 3 replicates of each treatment arranged in a randomized block design. 'Corrective' P application rate was based on RB209 recommended rates for establishment year at soil P index 4 (75 kg/ha P_2O_5) and was broadcast as TSP prior to planting. Placed P was applied as DAP during ridging following planting using a modified Horstine applicator (as shown in the image below):

Horstine applicator, modified to place fertilizer in the furrow with the asparagus crowns © ADAS

The N and P experiments were monitored during 2014 for:

- Pest and diseases,
- Canopy size (i.e. fern cover) by surface reflectance measurement (CropScan),
- Crown population, spear numbers per crown and average thickness of spears per crown,
- Fern tissue analysis (N, P, K, Mg, Ca, B, S, Cu, Zn, Fe and Mn),
- Soil nutrients – topsoil and SMN (0-90 cm) from across the site prior to treatment application in February 2014, and additional SMN (0-90cm) samples from each N treatment in November 2014,
- Root biomass production (0-90 cm soil cores taken in January 2015).

The crop, pest and disease assessments from the first year of the experiments showed no significant statistical differences between treatments. There were no visual symptoms of nutrient deficiency and fern tissue analysis showed macro and micro nutrient concentrations were within the range reported in HDC factsheet 14/13 ‘Asparagus nutrient management’ (Drost, 2013).

Root cores were taken in January 2015 to assess root biomass; laboratory analysis is on-going and the results will be presented in the annual report for year 2 of the project.

Soil mineral N sampling from the N response experiment in November 2014 showed a statistically significant linear increase in SMN with increasing fertiliser N rates. Soil mineral N on the zero N control treatment in November 2014 was 165 kg/ha N, increasing to 247 kg

N/ha on the 150 kg N/ha fertiliser N rate (i.e. RB209 recommended rate) and to 344 kg N/ha on the highest fertiliser N rate of 250 kg N/ha; indicating that the majority of fertiliser N applied was not taken up by the crop and remained within the soil at the end of the growing season and at risk of loss via nitrate leaching.

The crop, soil and root assessments taken in this establishment year have provided comprehensive baseline information for comparison with subsequent years. Measurements in years 2 and 3 of the experiment will assess the impact of N and P treatments at establishment on subsequent asparagus yields.

Financial Benefits

None to date, harvesting will take place from 2015 onwards.

Action Points

None to date.

SCIENCE SECTION

Introduction

Asparagus is an herbaceous perennial crop that is grown for the spears that it produces during the spring and early summer. In the UK asparagus is planted as crowns that consist of buds, which grow into spears or ferns, and storage roots. The growth cycle of the asparagus crop involves a type of recycling system of carbohydrates (CHO) (Figure 1), where CHOs are depleted as ferns and spears are produced, and then as the ferns photosynthesize and produce sugars, which are translocated to the roots, the CHO supply is replenished for spear production (Wilson *et al.*, 2005).

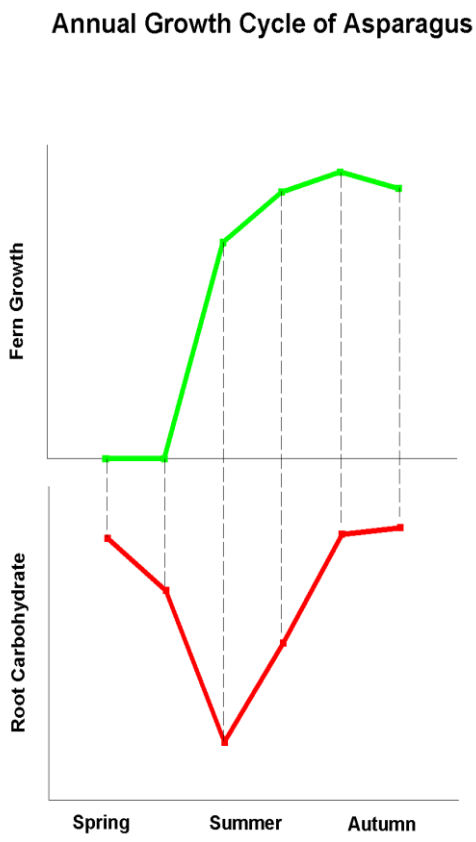

Figure 1. A graphic description on the annual carbohydrate transfer throughout the asparagus growth cycle. Source: Wilson *et al*. (2005).

Asparagus is a high value crop, to which the land will be committed for ten years or more. Hence, it is important to ensure good soil structure and adequate crop nutrition at establishment to maximize economic returns from the plantation.

Due to the high initial investment required to establish the crop (*c*.£5,000/ha), growers need confidence that they can sustain economic and high quality production over several years. Growers in the UK, and globally, know that that the best and highest yielding crops are those that were well established in year 1. Premature loss in asparagus productivity ('decline') is widespread and can shorten the economic life of a crop by 7 years, with associated financial losses due to poor returns on original investment, lower prices obtained for reduced spear dimension and the extra expense of re-planting crops more frequently.

Fertiliser recommendations for asparagus are given in the RB209 Fertiliser Manual (Defra, 2010), however there has been little work on nutrition of the asparagus crop in the UK to support these recommendations since FV 152 (1996 Study of N responses) and P and K (1996: FV 153), and none at establishment (FV 152 and FV 153 were both on established crops). For asparagus, the total N offtake in harvested spears is relatively low at *c*.40 kg

N/ha, however, the amount of N stored in the roots and crowns can be over 700 kg N/ha (Ledgard *et al*., 1994); this N reserve in productive crops is built up during the establishment phase, making early N nutrition critical. In general terms, N favours vegetative growth in crops; therefore, it is assumed that greater applications of N will induce the growth of ferns, and thus photosynthesis for carbohydrate production. However, in asparagus, it is believed that prolonged applications of N may disrupt the dormancy cycle by putting too much energy into fern growth. It is advisable, then, to be aware of timing and put on a larger proportion of the total application earlier to induce good fern growth.

Recent reviews by HDC (Drost, 2013) have indicated that P nutrition is critical in years 1 and 2 to establishing productive crowns, yet there are no UK data to support current P fertiliser recommendations. Phosphorus is, in contrast to N, a relatively immobile nutrient in the soil and many growers believe that placement of P within the bed would be beneficial. Placement of P fertiliser near to the asparagus crown has the potential to be more effective than either incorporation or top dressing of P fertiliser, and has been shown to greatly increase the efficiency of P use in other crops (Kirkby and Johnston, 2008).

The overall aim of this experimental work is to identify optimum N and P treatments at establishment for maximum yield from new asparagus plantations. This report covers the investigation for year 1. Specific objectives were to:

- Establish a field experiment to investigate the optimum rate of N at establishment in Year 1,
- Determine the appropriate rate of N at or above current RB209 recommendations for Year 2 using the plots established in Year1,
- Establish a field experiment to investigate placement of P in Year 1,
- In each experiment, assess plots annually for spear yield (except year 1), nutrient concentrations in the fern, pest and disease incidence, root biomass, and canopy size.

Materials and methods

Field site

The N and P response field experiments were set up in 2014 at a single site near Boston in Lincolnshire. Representative soil samples were taken from across the experimental site in February 2014 prior to planting at two depths (0-30 cm and 30-60 cm) and analysed for pH, P, K, Mg and organic matter (OM). Additional soil mineral N (SMN) samples were taken to 90 cm (in 30 cm sections; 0-30 cm, 30-60 cm and 60-90 cm) (Table 1). The site was planted

on 13/05/2014 by the host grower with the variety Guelph Millennium ('A' grade crowns; 31,000 crowns/ha).

Table 1. Site soil analysis (February 2014)

Analysis	Sample depth	Result	Index
pH	0-30 cm	7.8	-
	30-60 cm	7.6	
Extractable P	0-30 cm	52 mg/l	Index 4
	30-60 cm	17 mg/l	
Extractable K	0-30 cm	141 mg/l	Index 2-
	30-60 cm	75 mg/l	
Extractable Mg	0-30 cm	75 mg/l	Index 2
	30-60 cm	68 mg/l	
Soil organic matter (loss on ignition)	0-30 cm	2.2%	-
	30-60 cm	1.3%	
SMN	0-30 cm	15 kg/ha	
	30-60 cm	11 kg/ha	
	60-90 cm	11 kg/ha	
	Sum 0-90 cm	37 kg/ha	Index 0

Treatments

Nitrogen response study

In the establishment year, there were 6 N treatments (0, 50, 100, 150, 200 & 250 kg N/ha) applied as ammonium nitrate (AN; 34.5%N). Nitrogen fertiliser applications were split with the first application immediately following planting (mid-May) and the second approximately 6 weeks later (late June) (Table 2).

Table 2. Nitrogen fertiliser application

Treatment No.	1st Application (kg N/ha)	2nd Application (kg N/ha)	Total N applied (kg N/ha)
1	0	0	0
2	0	50	50
3	50	50	100
4	50	100	150
5	50	150	200
6	50	200	250

A second factor will be studied in the second year to determine if current RB209 recommendations of applying 120 kg N/ha in the first year after establishment are sufficient for modern asparagus varieties, or if a higher rate is needed. These additional treatments will be arranged as sub-plots within the main plots in year 2 (2015) (Table 3).

The N response treatments are arranged as a fully factorial (6 N rates year 1 x 2 N rates year 2) design, with four replicates of each treatments. Plots were 6 x 20 m (establishment year) and will be divided into 6 x 10 m plots for inclusion of the second treatment factor in year 2.

Table 3. Nitrogen response trial treatments

Treatment Level Yr 1	**1**		**2**		**3**		**4**		**5**		**6**	
Year 1 rate (kg N/ha)	0		50		100		150		200		250	
Treatment Level Yr 2	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Year 2 rates (kg N/ha)	120*	150	120	150	120	150	120	150	120	150	120	150

Other nutrients were applied to the N response experimental area to ensure no other nutrients were limiting growth;

- 75 kg/ha P_2O_5 (as TSP) was broadcast prior to planting,
- 200 kg/ha K_2O (as muriate of potash) split with 50% applied prior to planting and 50% 6 weeks later,
- 100 kg/ha Kieserite, supplying 50 kg/ha SO_3 and 25 kg/ha MgO applied 6 weeks after planting.

Phosphorus placement trial

The main treatment factor is the placement of 'corrective' P (i.e. at RB209 recommended rate) broadcast as TSP prior to planting (mid-April), with a second factor of placement of soluble P at planting (applied as di-ammonium phosphate (DAP; 18% N and 46% P_2O_5) (Table 4). The placed DAP was applied in narrow bands either side of the crown at ridging using a Horstine applicator (Figure 2). The P placement treatments are arranged as a fully randomized factorial (2 x 2) design, with three replicates of each treatments and plots 6 x 10 m.

Table 4. Phosphorus fertiliser applications

Treatment	**Corrective P applied before planting (kg P_2O_5/ha applied as TSP)**		**Placed P applied at planting (kg P_2O_5/ha as DAP)**	
1 (control)	1	No Corrective P	1	No placed P
2	1	No Corrective P	2	+ Placed P (58 kg/ha)
3	2	+ Corrective P (75 kg/ha)	1	No placed P
4	2	+ Corrective P (75 kg/ha)	2	+ Placed P (58 kg/ha)

Figure 2. Horstine applicator, modified to place fertilizer in the furrow with the asparagus crowns.

Other nutrients were applied as follows to the P placement experiment area to ensure no other nutrients were limiting growth;

- 150 kg/ha N (as AN) split 1/3 prior to planting and 2/3 6 weeks later.
- 200 kg/ha K_2O (as muriate of potash) split with 50% applied prior to planting and 50% 6 weeks later.
- 100 kg/ha Kieserite, supplying 50 kg/ha SO_3 and 25 kg/ha MgO applied 6 weeks after planting.

Methods, Assessments and Records

Crop measurements and fern tissue analysis

Crown populations, spear numbers per crown and average thickness of spears per crown were assessed in August and October 2014. Fern tissues samples were taken from all treatments for analysis of N, P, K, Mg, Ca, B, Fe, S, Mn, Zn and Cu on 08/08/2014, 09/09/2014 and 09/10/2014.

Canopy size (spectral reflectance)

Canopy spectral reflectance was measured to estimate canopy size from all treatments in August 2014 using the hand held CropScan sensor (Figure 3). CropScan measures spectral reflectance at specific wavelengths to calculate the Normalised Difference Vegetation Index (NDVI); NDVI relates to the size of the crop's green canopy, biomass and chlorophyll content, with higher values relating to a

Figure 3. Use of the CropScan (in winter wheat)

greater canopy size. The CropScan assessment was included in this project as it is a rapid and non-destructive method of comparing biomass production between treatments.

Pest and Disease Assessments

The trial area was regularly monitored for evidence of pest and disease (including slugs, asparagus beetle, purple spot (*Stemphylium*), *Fusarium* and *Phytophthora*); a full assessment was carried out monthly between June and September.

Rooting measurements

Soil cores were taken from all treatments at the end of the season (January 2015) to assess root biomass. Soil cores (60 mm diameter) were taken to a depth of 90 cm from each plot at 0.15 and 0.30 m from the centre of each row using the HydraCare pneumatic soil corer. The cores were divided into 15 cm sections prior to root washing to separate the asparagus roots from other weed roots and debris. The asparagus roots were scanned and assessed using the WinRHIZO programme which measures the volume, density, length and width of the roots (Figure 4). Analysis of root samples taken in January 2015 is currently on-going.

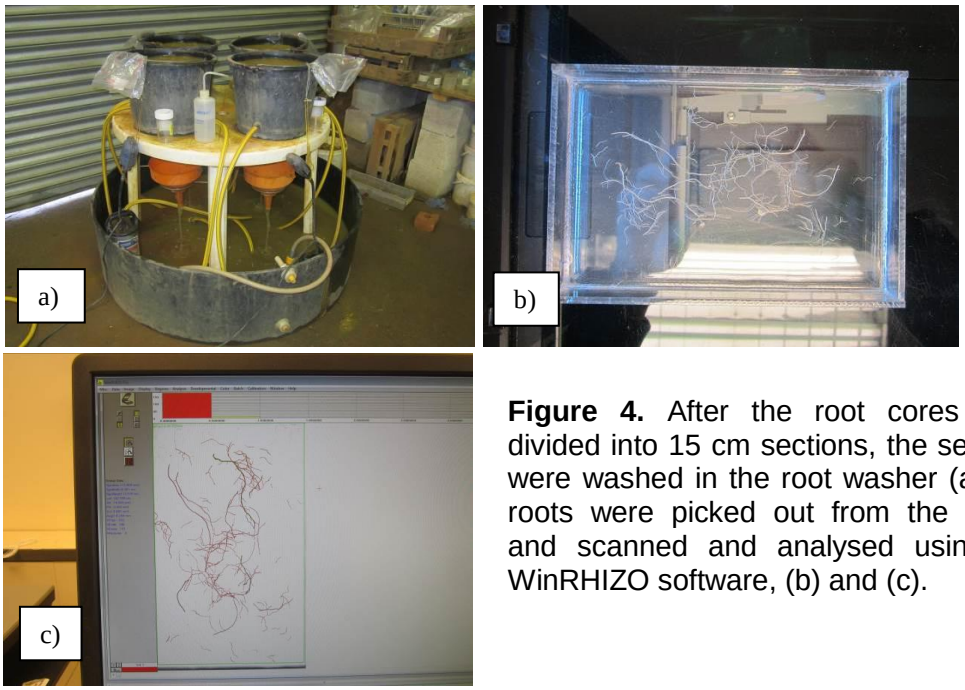

Figure 4. After the root cores were divided into 15 cm sections, the sections were washed in the root washer (a), the roots were picked out from the debris and scanned and analysed using the WinRHIZO software, (b) and (c).

Soil mineral nitrogen sampling (N response trial only)

Additional SMN samples were taken to 90 cm (in 30 cm sections; 0-30 cm, 30-60 cm and 60-90 cm) from all treatments on the N response trial at the end of the season in November 2014.

Results

Nitrogen response trial

Crop measurements and fern tissue analysis

- There was no significant effect of N fertiliser rates on the crop growth in the first establishment year (*P*>0.05; Table 5). The crop was planted in May 2014 when conditions were colder and wetter than normal, and the crop was initially slow growing (T.V.Casey, pers comm.),
- There was no significant effect (*P*>0.05) of N treatments on the fern tissue analysis (N, P, K, Mg, Cu, S, Ca, B, Fe, Mn and Zn) (Appendix 1). Concentrations measured were within the ranges reported by Drost (2013).

Table 5. Crop assessments made in August and October 2014 (treatment means)

	August 2014			**October 2014**		
N Treatment (kg N/ha)	**Crop Height (cm)**	**Number of stems per crown**	**Stem thickness (mm)**	**Crop Height (cm)**	**Number of stems per crown**	**Stem thickness (mm)**
0	72.9	3.1	4.8	70.5	3.1	4.8
50	72.1	3.8	4.9	79.2	3.8	4.9
100	70.5	3.5	5.3	79.7	3.5	5.3
150	71.3	3.6	5.0	81.9	3.6	5.0
200	69.3	3.5	5.0	72.3	3.5	5.0
250	71.5	3.5	4.8	69.6	3.5	4.8
Statistics						
***P* Value**	0.98	0.7	0.60	0.10	0.7	0.60
SED	4.59	0.45	0.32	5.02	0.45	0.32

Canopy size (spectral reflectance)

- There was no significant effect (*P*>0.05) of N fertiliser rates on crop canopy cover measured by the CropScan; NDVI was a mean of 0.43 (range 0.40 to 0.45),
- The NDVI ranges from -1 to 1; the common range for green vegetation is 0.2 to 0.8. Results reported here are for reflectance measured at the commonly used 670, 780 nm wavelengths (Rouse *et al*., 1973).

Disease and pest measurements

- Incidence of pests and disease were scored as an average percentage severity/damage of the affected plant,
- The level of pest and disease in the crop in 2014 was at a low level overall (Table 6), and there was no significant effect (*P*>0.05) of N treatment on the degree of disease and pest detected,
- Purple spot (*Stemphylium*) was the main disease observed in the crop through the season. During the final few months of year 1 there was some crop damage from deer and subsequent crop measurements were targeted to avoid affected areas. The main insect pest observed was asparagus beetle (*Crioceris asparagi*), though numbers were relatively low, due to agronomic control measures taken by the grower.

Table 6. Percentage disease severity and pest damage of the asparagus crop measured in August and October 2014.

	August		**October**	
N Treatment (kg N/ha)	**Disease per plot % (Aug)**	**Pest per plot % (Aug)**	**Disease per plot % (Oct)**	**Pest per plot % (Oct)**
0	0.62	2.46	4.35	6.87
50	0.05	1.60	4.23	5.72
100	0.28	1.69	4.35	5.62
150	0.43	3.77	4.43	5.32
200	1.39	2.17	7.25	3.90
250	0.43	2.83	5.95	3.85
Statistics				
***P* Value**	0.32	0.53	0.36	0.29
SED	0.570	1.230	1.600	1.40

Soil mineral nitrogen sampling

Soil mineral N sampling from the N response experiment in November 2014 showed a statistically significant linear increase in SMN with increasing fertiliser N rates (Figure 5).

Soil mineral N on the zero N control treatment in November 2014 was 165 kg/ha N, increasing to 247 kg N/ha on the 150 kg N/ha fertiliser N rate (i.e. RB209 recommended rate) and to 344 kg N/ha on the highest fertiliser N rate of 250 kg N/ha; indicating that the majority of fertiliser N applied was not taken up by the crop and remained within the soil at the end of the growing season and at risk of loss via nitrate leaching.

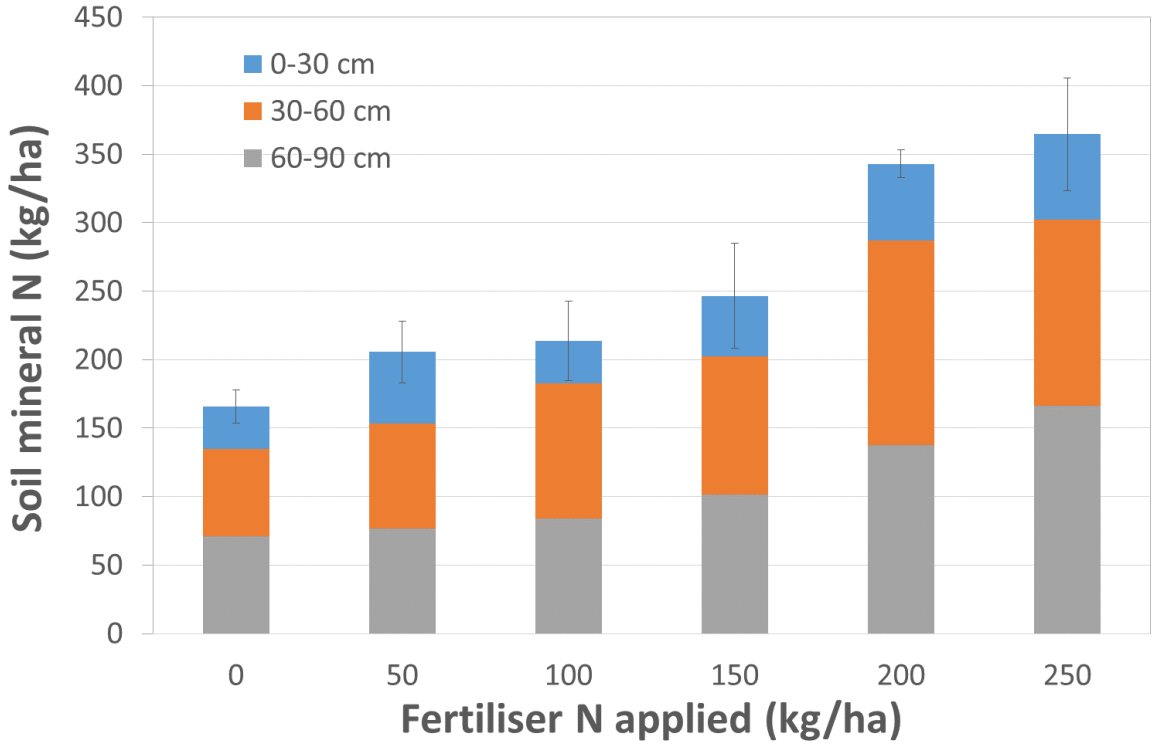

Figure 5. Soil mineral nitrogen (November 2014)

Phosphorus placement trial

Crop measurements and fern tissue analysis

- There was no significant effect of P treatments on crop growth in the first establishment year (P>0.05; Table 7). As noted for the N response trial, the crop was planted in May 2014 when conditions were colder and wetter than normal, and the crop was initially slow growing (T.V.Casey, pers comm.).
- There was no significant effect (P>0.05) of P treatments on the fern tissue analysis (N, P, K, Mg, Cu, S, Ca, B, Fe, Mn and Zn) (Appendix 1). Concentrations measured were within the range reported by Drost (2013).

Table 7. Crop measurements for August and October 2014

	August			October		
Treatment	**Crop Height (cm)**	**Number of stems per crown**	**Stem thickness (mm)**	**Crop Height (cm)**	**Number of stems per crown**	**Stem thickness (mm)**
1	69.90	3.42	5.16	69.90	4.18	4.03
2	66.70	3.42	4.88	67.70	4.22	4.10
3	71.00	3.10	5.18	74.70	4.03	4.30
4	64.80	3.17	5.17	74.30	4.10	4.40
Statistics						
***P* Value**	0.446	0.892	0.857	0.387	0.933	0.424
SED	4.02	0.524	0.41	4.43	0.314	0.23

Canopy size (spectral reflectance)

- There was no significant effect (*P*>0.05) of P treatment on crop canopy cover measured by the CropScan; NDVI was similar to that measured in the N trial at a mean of 0.44 (range 0.40 to 0.50).

Disease and pest measurements

- Incidence of pests and disease were scored as for the N trial, as an average percentage severity/damage of the affected plant. The P placement trial was affected by the same pests/diseases as the N response trial.
- The level of pest and disease in the crop in 2014 was at an overall low levels across both the N and P experiments (Table 8), and there was no significant effect (*P*>0.05) of P treatment on the degree of disease and pest detected.

Table 8. Percentage disease severity and pest damage of the asparagus crop measured in August and October 2014

Treatment	**Disease % per plot (Aug)**	**Pest % per plot (Sep)**	**Disease % per plot (Oct)**	**Pest % per plot (Oct)**
1	0.45	0.33	6.17	4.47
2	0.32	0.99	9.90	4.23
3	1.97	1.23	5.85	3.92
4	0.24	0.93	4.87	3.43
Statistics				
***P* Value**	0.102	0.376	0.287	0.934
SED	0.645	0.486	2.47	1.702

Discussion and Conclusions

Establishment of asparagus spans a 3 year period, which allows for the consolidation of the root stocks in soil and accumulation of carbohydrates to produce spears in subsequent years. Two field experiments were set up in 2014 at a single site in Lincolnshire to investigate the optimum rate of N and the effect of P placement at establishment for maximum yield from new asparagus plantations. Fertiliser N and P treatments were successfully applied enabling assessment of the impact of nutrition at establishment on crop growth (including root biomass) and yields in years 2 and 3 (and potentially over a longer time scale).

The crop, pest and disease assessments from the first year of the experiments showed no significant statistical differences between treatments. There were no visual symptoms of nutrient deficiency and fern tissue analysis showed macro and micro nutrient concentrations to be within the range reported in HDC factsheet 14/13 'Asparagus nutrient management' (Drost, 2013). Root cores were taken in January 2015 to assess root biomass; laboratory analysis is on-going and the results will be presented in the annual report for year 2 of the project. The crop, soil and root assessments taken in this establishment year have provided comprehensive baseline information for comparison with crop responses in subsequent years.

Soil mineral N sampling from the N response experiment in November 2014 showed a statistically significant linear increase in SMN with increasing fertiliser N rates, indicating that the majority of fertiliser N applied was not taken up by the crop and remained within the soil at the end of the growing season and at risk of loss via nitrate leaching. If the additional fertiliser N applied was not taken up by the crop in the 2014 establishment year, it is unlikely to further increase yields as it is likely to be lost from the soil via leaching over 2014/15 winter. In contrast, P is relatively immobile in the soil and Drost (2008) suggests that a single application of P to a young asparagus crop at planting has little effect in the first 2 years of establishment and more of a response in the subsequent years of growth.

Knowledge and Technology Transfer

Project meetings with the host grower and his agronomist;

- Initial project meeting (April 2014)
- First year review project meeting (February 2015)

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Appendix 1

Table A1. Nitrogen response trial tissue fern analysis (August 2014) and comparison with values reported by Drost (2013)

N Treatment (kg N/ha)	Total N	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B
	% dry weight						mg/kg dry weight				
0	3.0	0.19	3.13	0.88	0.14	0.30	28.6	3.9	17.7	292	26.9
50	2.6	0.22	3.47	0.77	0.14	0.28	28.5	4.2	19.1	258	25.6
100	2.9	0.21	3.21	0.69	0.12	0.28	23.5	3.6	16.3	254	22.5
150	2.9	0.20	3.17	0.94	0.16	0.30	32.0	3.6	17.1	273	32.3
200	2.8	0.18	3.34	0.77	0.13	0.30	25.1	3.8	14.8	283	22.0
250	3.0	0.20	3.52	0.73	0.13	0.32	24.8	3.4	16.4	268	24.1
MEAN	**2.8**	**0.20**	**3.31**	**0.40**	**0.14**	**0.30**	**27.06**	**3.68**	**16.9**	**271**	**25.6**
Statistics											
***P* Value**	0.812	0.749	0.800	0.144	0.407	0.945	0.107	0.322	0.332	0.979	0.173
SED	0.33	0.030	0.334	0.127	0.017	0.044	3.07	0.39	1.86	53.9	4.03
LSD	0.70	0.064	0.7014	0.266	0.036	0.093	6.45	0.82	3.91	113.3	8.47
Range of fern tissue analysis reported by Drost (2013)											
Range	2.1 -5.5	0.18 -0.50	1.50-4.50	0.40 - 1.50	0.14 -0.50	0.30 -0.45	10 - 200	5.0 - 25	20 - 100	40 - 300	25.0 - 150

Table A2. Phosphorus placement trial tissue fern analysis (August 2014) and comparison with values reported by Drost (2013)

P Placement Treatment	Total N	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B
	% dry weight						mg/kg dry weight				
1	2.7	0.15	2.70	0.93	0.12	0.23	29.3	3.8	14.6	225	28.3
2	2.7	0.16	2.92	0.85	0.12	0.26	25.9	3.5	14.3	211	22.3
3	3.0	0.18	3.06	0.87	0.12	0.29	28.7	3.7	15.7	232	26.6
4	3.0	0.17	3.06	1.00	0.14	0.28	29.3	3.3	14.5	198	26.7
MEAN	**2.9**	**0.17**	**2.94**	**0.91**	**0.12**	**0.26**	**28.3**	**3.6**	**14.8**	**216**	**26.0**
Statistics											
***P* Value**	0.608	0.286	0.253	0.161	0.092	0.110	0.749	0.666	0.594	0.864	0.628
SED	0.29	0.014	0.186	0.065	0.011	0.024	3.64	0.43	1.11	43.5	4.65
LSD	0.68	0.032	0.429	0.150	0.025	0.056	8.40	0.99	2.56	100.3	10.72
Range of fern tissue analysis reported by Drost (2013)											
Range	2.1 -5.5	0.18 -0.50	1.50-4.50	0.40 - 1.50	0.14 -0.50	0.30 -0.45	10 - 200	5.0 - 25	20 - 100	40 - 300	25.0 -150