Project title:	Identification of critical soil P in vining pea crops.
Project number:	FV 380
Project leader:	Nathan Morris, NIAB (NIAB TAG)
Report:	Annual report, October 2013
Previous report:	Annual report, October 2012
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Location of project:	East Anglia
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Date project commenced:	July 2010
Date project completed (or expected completion date):	Dec 2014

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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CONTENTS

GROWER SUMMARY

Headline

- This project has identified some clear yield responses to soil Olsen P levels.

Background

The recent increasing costs of Phosphate (P) fertiliser and concerns from the risk of diffuse pollution have re-opened the debate on the need to apply P, and whether or not a target P Index of 2 (Olsen P 16-25 mg/l) is appropriate for all soil types and crop conditions. It is intended that on completion, the project will deliver improved guidance to growers on target soil P indices suitable, in terms of plant nutrition, for both yield and quality for vining pea crops on a range of soil types, and new information on how soil type influences crop response to fresh P fertiliser.

Guidance to growers following results from this project should allow the use of P fertiliser to improve the economic efficiency in vining pea production. Specific targeted doses of P fertiliser should reduce the risk of undesirable P losses to water courses resulting in eutrophication and potentially help to meet future requirements of the Water Framework Directive.

Summary

Many vining pea growers are questioning whether or not a target soil Phosphate (P) Index of 2 (Olsen P range of 16-25 mg/l) is appropriate for all soil types and crop conditions. This target Index, based on critical soil P levels to achieve 95% of maximum crop yield, was established to achieve economic yields for all crops grown in any rotation and was based on the results of a limited number of field experiments.

This project aims to identify the levels of Phosphate required in vining pea production to help growers maximise yield and quality.

Critical P values can vary between soils, depending upon soil physical conditions (*e.g.* soil structure, moisture, bulk density, stone content and soil porosity) and between crops, depending on root growth and architecture and P uptake rate needed to achieve maximum yield. To date, however, sufficient data for making a scientifically robust change to the recommendations have not been available. This project aims to identify the levels of Phosphate required in vining pea production to help growers maximise yield and quality.

Results from Year 2 are in keeping with previous year's results (HDC FV 380 annual report; 2012) and suggest some clear effects on crop yield responses to soil Olsen P levels. The greater yield responses at Index 3 (26-45 mg/kg) or above at all sites are likely to have been influenced by factors such as soil structure, air temperature and rainfall during the season.

However, it is too early in the project to draw firm conclusions and to develop guidelines for the grower; therefore, further information will be reported at a later stage in the project.

Financial Benefits

Current field experiments are on-going; possible financial benefits from the project will be detailed in the final report.

Action Points

None at present.

SCIENCE SECTION

Introduction

The British Survey of Fertiliser Practice shows that there has been an overall decline in phosphate (P) use on crops from 56 kg/ha P_2O_5 in 1983-87 to 34 kg/ha in 2004-08. Over recent seasons the long term price trend for P fertiliser has continued to rise. While there have been some recent fluctuations in P cost, price shifts for the 15 months running up to April 2008 saw world di-ammonium phosphate price rise by around 400%. Where P is not applied, crop off take (e.g. 8-10 kg/ha P_2O_5 for vining pea crops) is leading to a gradual decline in soil P reserves. RB209 (edition 8) guidance on phosphate levels for vining pea crops suggests that P is required at more than maintenance where soil levels are less than Index 2. This can be expensive to the grower; for example at soil Index 1 or below, a dose of between 60 and 85 kg/ha of P_2O_5 is often suggested for vining pea crops, this dose could cost around £75/ha based on spring 2011 prices.

Many growers are questioning whether or not a target soil P Index of 2 (Olsen P range of 16-25 mg/l) is appropriate for all soil types and crop conditions. This target Index, based on critical soil P levels to achieve 95% of maximum crop yield, was established to achieve economic yields for all crops grown in any rotation and was based on the results of a limited number of field experiments. Although for a given Olsen P value the crop availability of P per unit volume of soil should be the same regardless of the crop and soil type (except perhaps on acid soils or for permanent grassland receiving water-insoluble P), critical P values can vary between soils, depending upon soil physical conditions (*e.g.* soil structure, moisture, bulk density, stone content and soil porosity) and between crops, depending on root growth and architecture and P uptake rate needed to achieve maximum yield. To date, however, sufficient data for making a scientifically robust change to the recommendations have not been available.

High soil P levels increase the risk of P transfer to surface waters leading to the undesirable effects of eutrophication; annual losses of P of as little as 2 kg/ha, whilst of no economic significance to the grower, can be associated with an increased eutrophication risk. In Ireland (Agri-Food and Biosciences Institute, 2002 and Environmental Protection Agency, 2011) phosphates have been found in high concentrations in surface waters; this has resulted in legislation being introduced under the Water Quality Standards for Phosphorus Regulations, 1998. Further monitoring of water quality under the Water Framework Directive (WFD) is likely to become of increasing importance within England and put further

pressure on growers to validate P fertiliser use.

The P levels suggested for vining pea production are based on long-standing data and perceptions that have not been validated in the context of modern production techniques / varieties, environmental influences and current costs. The objective of this project is to provide agronomic validation of P requirements, help growers to maximise yield and quality and also potentially offer useful savings.

Materials and methods

Site design and selection

Experimental design is based on a randomised block design involving seven treatments with two replicates (see Appendix A for trial plan), on relatively large plot areas, as plots will need to remain in place and be easily locatable for the following vining pea crop. Data will be analysed across seasons both within and across soil types to allow for cross-trial analysis.

The field experiments will focus specifically on vining pea crops; 3 experiments will be carried out on each of 3 soil types across a staggered 4 year trialling sequence (a total of 9 experiments) as detailed below.

Table 1. Proposed staggered experimental design.

	2010/11 (Year 1)	**2011/12 (Year 2)**	**2012/13 (Year 3)**	**2014 (Year 4)**
Experiment 1	Cereal	Vining peas	-	-
Experiment 2	-	Cereal	Vining peas	-
Experiment 3	-	-	Cereal	Vining peas

Soil types may include a loamy sand, sandy loam and silty clay loam. For each of the experimental locations, a series of sites destined for vining pea production (covering the desired set of soil types) will be sought. These sites will have a low inherent P index (with the majority at an Index 1 or lower) i.e. sites that would normally receive a substantial P dose ahead of a vining P crop. At each site a preceding crop (*e.g.* typically a cereal crop) will be established and managed by the host farmer. A trial area will be established within the cereal crop that will be used as a canvas on which to create a range of Olsen P levels, on large plot areas, ranging from 0 mg/kg to 24 mg/kg above the lowest value at each site. Information being made available through the existing HGCA RD-2008-3554 project (HGCA, 2009) will facilitate the attainment of this range of soil P levels by applying

appropriate amounts of triple superphosphate (TSP) fertiliser. At each site soil texture, stone content and soil organic matter will be determined to aid interpretation. The soil will also be analysed to ensure no other major nutrient deficiencies are present.

Soil sampling

Each of the 14 large plots are individually sampled, to the intended cultivation depth (15, 20 or 25 cm), using a gouge auger or similar. Sixteen cores per large plot area are sampled at random. From each plot the soil cores are bulked and mixed thoroughly, cutting any lumps into small pieces and removing any vegetation, other extraneous material and as many stones as possible. A sub-sample of c. 1 kg from each plot is sealed in a plastic bag, labelled with the project title, site name, plot/rep number, and sampling date and sent to NRM Laboratories for analyses.

Fertiliser application

Large plots receive one of five different P fertiliser doses that are established prior to the preceding crop of the field experiments, in order to raise soil Olsen P levels by different amounts to create a range of 'stabilised' P values prior to sowing the vining pea crop. Further large plots will receive one of two different P fertiliser doses prior to the vining pea crop, in order to raise soil Olsen P levels by different amounts and create a range of 'fresh' P values. Required doses of P fertiliser are calculated for specific treatments, as shown in Table 2, to take account of soil type, stone content and cultivation depth (this will take advantage of methods already being utilised in the analogous HGCA project; research at Rothamsted has shown how much fresh P fertiliser is needed to increase Olsen P by 1 mg/kg). Treatments are arranged in two replicates of seven treatments, as there will be two untreated treatments in each replicate. This will give 14 large plots in all.

Table 2: Treatment list.

Treatments	P status	Olsen P (mg/kg)
Treatment 1a	Untreated a	Untreated
Treatment 1b	Untreated b	Untreated
Treatment 2	Stabilised	3
Treatment 3	Stabilised	6
Treatment 4	Stabilised	9
Treatment 5	Fresh	3
Treatment 6	Fresh	9

For each experiment, P will either be applied ahead of the preceding (cereal) crop and

allowed to ‘stabilise’ for around 18 months or will be applied as a ‘fresh’ dose immediately ahead of the vining pea crop. To ensure that doses of P are sufficiently incorporated into the soil specific treatments for large doses will be applied prior to primary cultivations. The application of TSP fertiliser was applied to the 12m wide large plots using a 12m wide pneumatic spreader, calibrated to deliver the required dose, or using a purpose built plot spreader.

Site locations

Year 2

Three experimental sites were found in 2012/13 (year 2) on a range of soil types as described in Table 3. In order to further understand the effects that soil P can have on relative crop maturity a sequential harvest over a period of days (once vining peas reach approximately TR 85) was completed at each site.

Table 3: Site details for vining peas in 2012.

Location	**Soil type**	**Soil series**	**Cultivation and depth**	**Crop harvest 2012**
Docking, Norfolk	Sandy loam	Barrow	Plough (25cm)	Sugar beet
Kirby Cane, Suffolk	Clay loam	Beccles	Plough (25cm)	Winter wheat
Hallington, Lincs	Silty clay loam	Andover 1	Non-inversion (22cm)	Winter barley

The soil sampling was completed (as specified above) with each site attaining a range of Olsen P values as shown in Figure 1. The application of varying doses of TSP fertiliser has created a range of Olsen P levels, on large plot areas, expected to range from 0 mg/kg to 24 mg/kg above the lowest value at each site as shown in Figure 2.

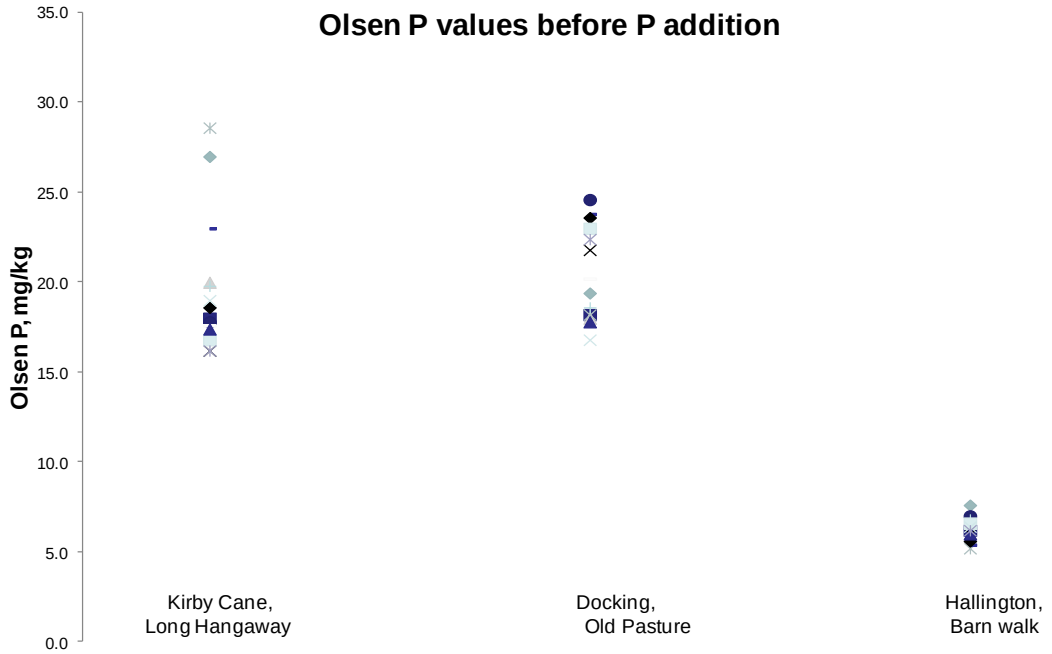

Figure 1: Olsen P values attained at each site in Year 2 (2011-13) prior to P fertiliser addition.

Note: Individual coloured points represented separate plots

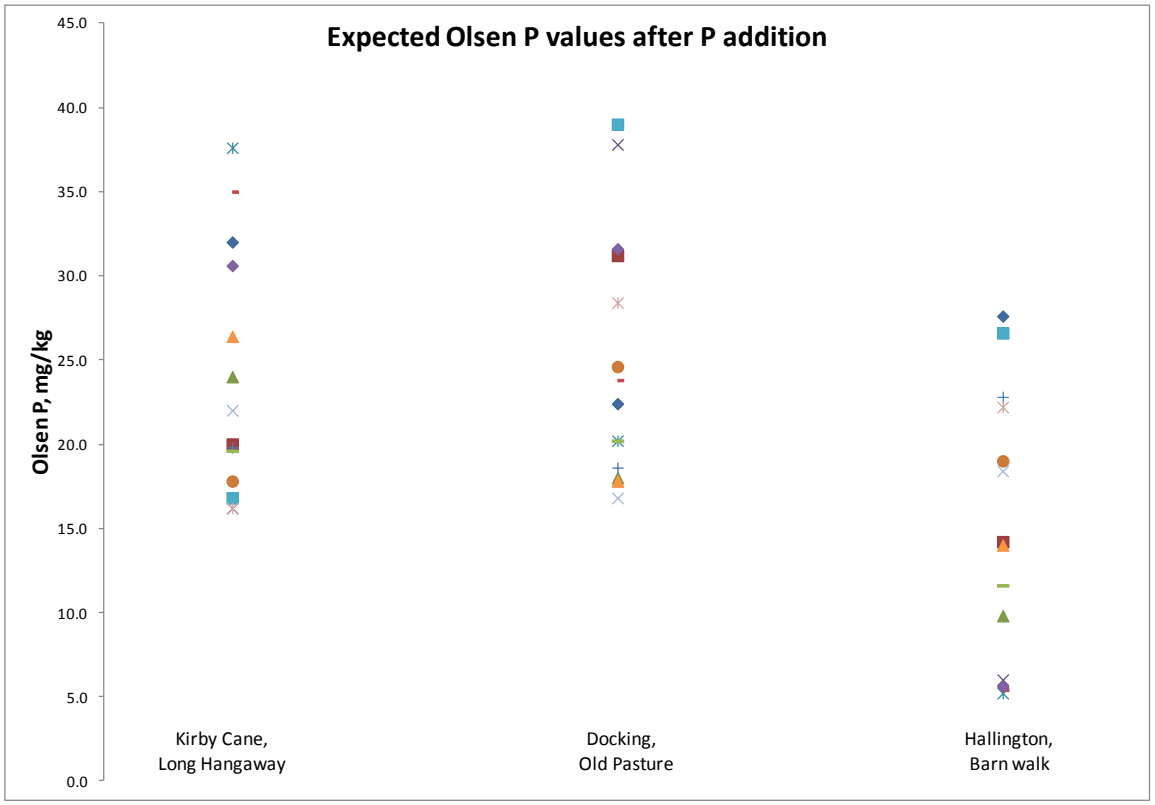

Figure 2: Expected Olsen P values attained at each site in Year 2 (2011-13) following P fertiliser addition.

Note: Individual coloured points represented separate plots

During the season specific observations in the vining pea crop relating to P nutritional status were assessed, with parameters including, crop vigour and an assessment for root nodulation and colour. The plots were used to determine the yield and quality response of the vining peas grown on 'stabilised' P index soils or in response to 'fresh' applied P; responses in these situations will be used to ascertain critical P levels. Soil P deficiency may alter crop maturity and therefore a sequential harvest lift occurred at these sites to assess for relative crop maturity. Following harvest specific sensory evaluation assessments may include both flavour and texture to ensure that quality specifications are met.

Year 3

A further two experimental locations for vining peas in 2014 (Year 3) have been completed as shown in Table 4. Currently these sites are in the preceding crop prior to vining peas with the 'stabilised' P doses applied to the plots and awaiting the application of 'fresh' doses immediately ahead of the vining pea crop.

Table 4: Provisional site details for vining peas in 2014.

Location	**Soil type**	**Soil series**	**Cultivation and depth**	**Crop harvest 2012**
Brocklesby, Lincs.	Sandy loam	Andover 1	Plough (25cm)	Winter wheat
Kirby Cane, Suffolk	Clay loam	Beccles	Plough (25cm)	Winter wheat

The soil sampling was completed (as specified above) with each site attaining a range of Olsen P values as shown in Figure 3. The application of varying doses of TSP fertiliser has created a range of Olsen P levels, on large plot areas, expected to range from 0 mg/kg to 24 mg/kg above the lowest value at each site as shown in Figure 4.

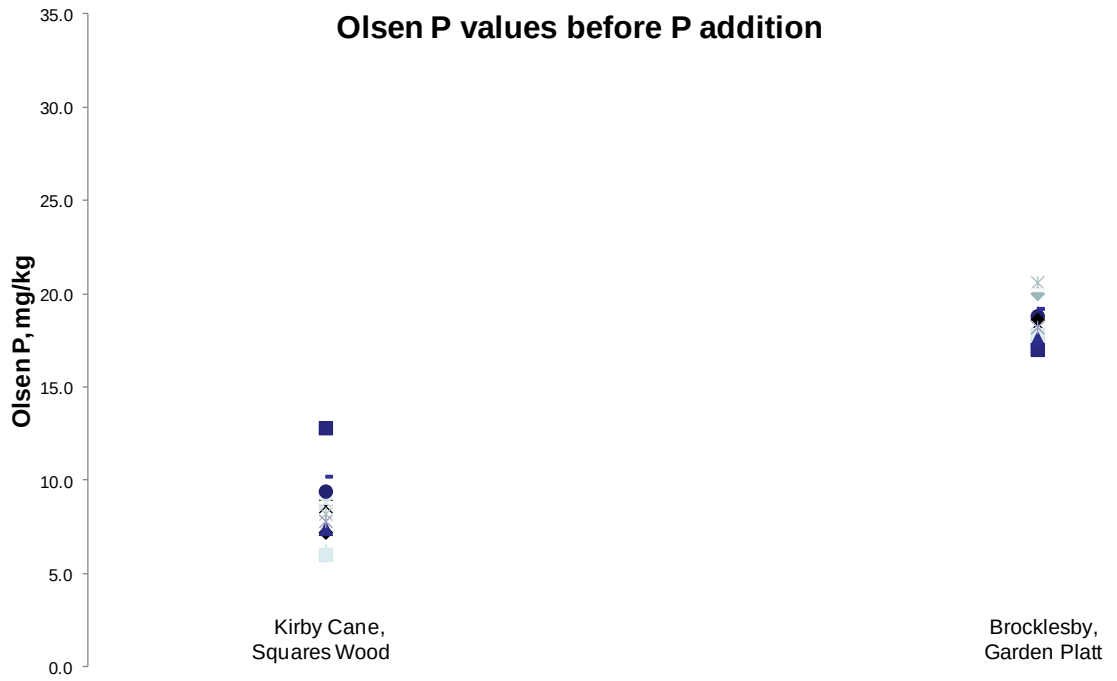

Figure 3: Olsen P values attained at each site in Year 3 (2012-14) prior to P fertiliser addition.

Note: Individual coloured points represented separate plots

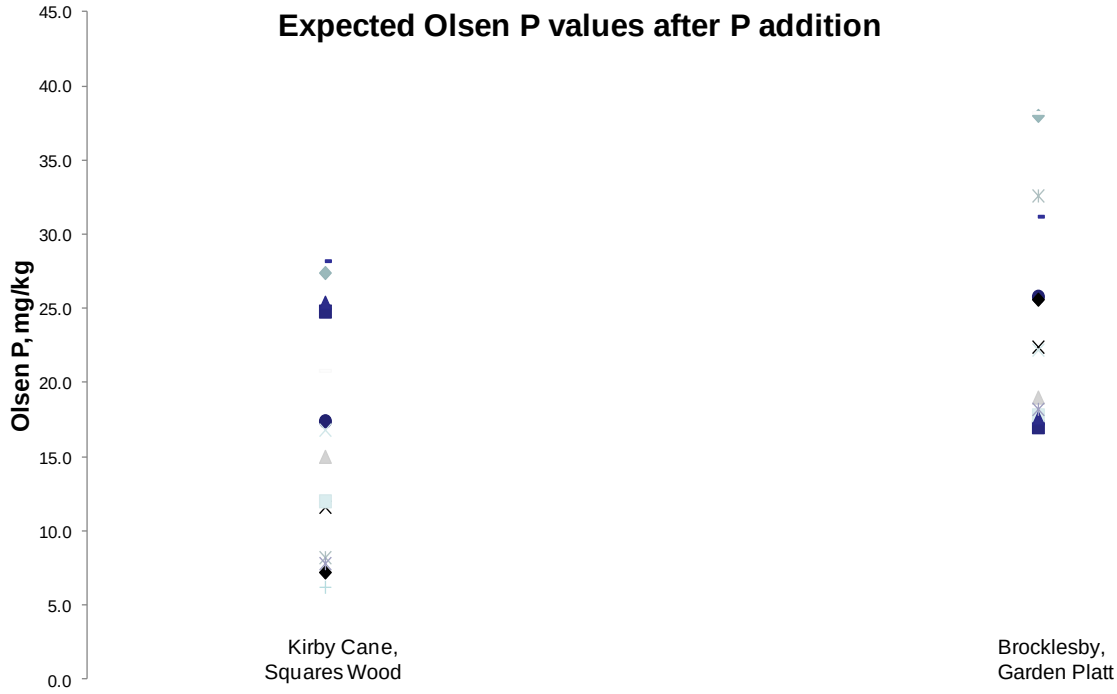

Figure 4: Expected Olsen P values attained at each site in Year 3 (2012-14) following P fertiliser addition.

Note: Individual coloured points represented separate plots

To enable further investigation of how soil P affects crop maturity a sequential harvest is planned at these sites to assess for relative crop maturity.

Future crop assessments

During the years in which cereal crops are grown, crops will not be harvested as part of the project. Vining peas will be grown following the preceding (cereal) crop. During the season specific observations in the vining pea crop relating to P nutritional status will be assessed, with parameters likely to include, crop height, crop vigour and an assessment for root nodulation and colour. The plots will then be used to determine the yield and quality response of the vining peas grown on 'stabilised' P index soils or in response to 'fresh' applied P; responses in these situations will be used to ascertain critical P levels. Soil P deficiency may alter crop maturity and therefore a sequential harvest will take place on all sites to assess for relative crop maturity. Following harvest specific sensory evaluation assessments may include both flavour and texture to ensure that quality specifications are met.

Results

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.

Year 2 (2011-13)

Preliminary results are reported for the three sites at Docking, Norfolk; Kirby Cane, Suffolk and Hallington, Lincolnshire were vining pea harvest was completed in summer 2013. A sequential harvest was carried out at all sites to enable further investigation of the affect soil Olsen P may have on relative crop maturity. Harvesting started when tenderometer readings (TR) reached 85 and then at regular intervals until maturity; this allowed for five sequential harvests at the Docking site, three sequential harvests at the Kirby Cane site and five sequential harvests at the Hallington site. Data analysis was completed on four harvest timings at the Docking site, three harvest timings at Kirby Cane and three harvest timings at the Hallington site to adjust vining pea yields to TR 100 from harvest timings between TR 95 to TR 120.

Expected and measured soil Olsen P

The application of TSP fertiliser was applied at timings prior to the preceding crop of the field experiments, in order to raise soil Olsen P levels by different amounts to create a range of 'stabilised' P values prior to sowing the vining pea crop. Further large plots received one of two different P fertiliser doses prior to the vining pea crop, in order to raise soil Olsen P levels by different amounts and create a range of 'fresh' P values. Specific fertiliser application timings are shown in Appendix B.

During the vining pea crop (spring 2013) the soil was sampled and analysed for Olsen P so that the expected soil Olsen P (assuming approximately 15% Olsen P is available from total fertiliser applied) can be compared to the measured soil Olsen P as indicated in Figure 5.

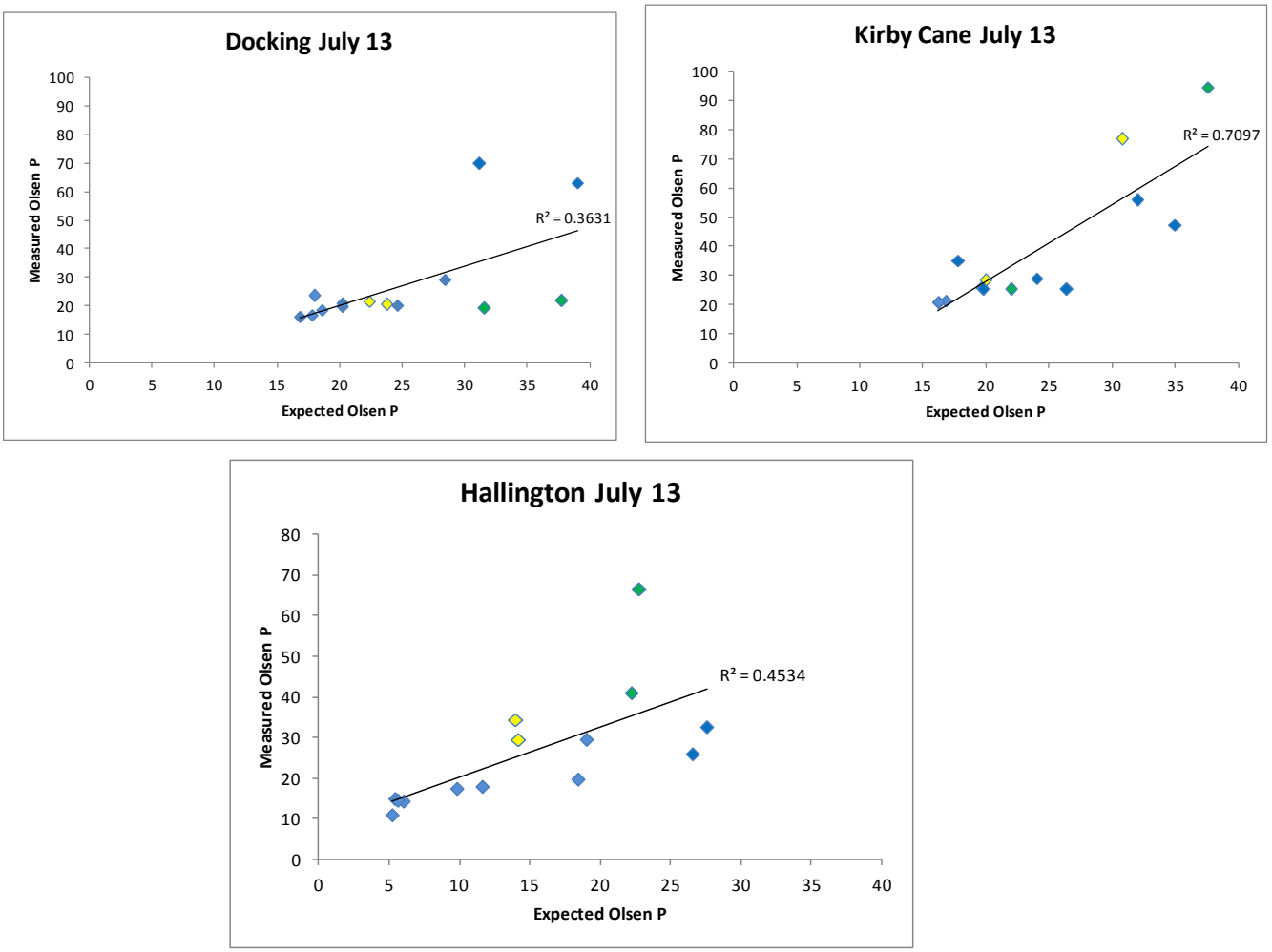

Figure 5: Expected and measured Olsen P values attained at each site in Year 2 (2011-13); soil sampling completed during July 2013.

Note: Blue coloured points represented 'stabilised' P doses; yellow coloured points represent low 'fresh' P and green coloured points represent high 'fresh' P doses.

At the Docking site the application of fertiliser as 'stabilised' doses resulted in no clear relationship between expected and measured values. However, the majority of plots had measured Olsen P levels above 16 mg/kg. The results for the 'fresh' doses indicated that measured values were, at the higher end, below that expected. The results at Kirby Cane also indicated that the application of fertiliser as 'stabilised' doses resulted in no clear relationship between expected and measured although the majority of 'stabilised' plots had measured Olsen P levels between 18 and 48 mg/kg. The results for the 'fresh' doses indicated that measured values were variable compared to that of expected. At both Docking and Kirby Cane the measured Olsen P was above 16 mg/kg (Index 2) and this highlights the difficulty in finding suitably low Olsen P levels (at or below an Index 1) on which to create a range of Olsen P levels as part of this study.

At Hallington the measured 'stabilised' doses showed a much closer trend to expected and resulted in Olsen P values of between 10 and 32 mg/kg. Whilst the 'fresh' doses at Hallington indicated that, at the higher end, measured values had yet to reach equilibrium.

Crop vigour and growth

Table 5 indicates the differences between crop vigour as categorised by the P Index. At Docking and Kirby Cane visual differences in crop vigour were less noticeable between P fertiliser treatments. The Olsen P levels at these two sites were between 17-28 kg/mg (Docking) and 17-40 mg/kg (Kirby Cane) and therefore differences in crop vigour are likely to be more marginal than where lower Olsen P values were achieved. At Hallington where a range of soil Olsen P levels (10-30 mg/kg) were achieved crops were stunted with thinner, paler leaves at and Index 1 (10-15 mg/kg) compared to a crop where an Index 3 (26-45 mg/kg) was maintained.

There was some suggestion that at Docking and Kirby Cane crop vigour was greatest at an Index 4 (46-70 mg/kg). However, it should be noted that at these sites the soil may have had poor structure and therefore must contain more Olsen P to achieve satisfactory crop performance. Other site (soil type and conditions) and weather conditions may have also interacted with soil Olsen P availability.

Table 5: Crop vigour at Docking, Kirby Cane and Hallington; 2013.

Site		**Docking, Norfolk**	**Kirby Cane, Suffolk**	**Hallington, Lincolnshire**
		GS 206 (Assessed 13/06/2013)	**GS 205-208 (Assessed 17/07/2013)**	**GS 202-205 (Assessed 18/07/2013)**
P Index	**Olsen P (mg/kg)**	**Crop vigour (1-5)**		
0	0-9	-	-	-
1	10-15	-	-	2
2	16-25	3	2	3
3	26-45	5	2	4
4	46-70	5	4	3

Crop vigour 1=weakest 5=most vigorous

Table 6 indicates that there was little suggestion that root nodulation was affected by the soil Olsen P. Generally, there was little difference between an Index 2 or 3 (16-25 mg/kg or 26-45 mg/kg) at any of the sites.

Table 6: Crop root nodulation at Docking, Kirby Cane and Hallington; 2013.

Site		Docking, Norfolk	Kirby Cane, Suffolk	Hallington, Lincolnshire
		GS 206 (Assessed 13/06/2013)	GS 205-208 (Assessed 17/07/2013)	GS 202-205 (Assessed 18/07/2013)
P Index	Olsen P (mg/kg)	Crop root nodulation (0-10)		
0	0-9	-	-	-
1	10-15	-	-	8
2	16-25	8	8	9
3	26-45	9	6	9
4	46-70	8	7	10

Root nodulation 0=fewest 10=greatest

Crop yield

Vining pea yield response to Olsen P for the Docking, Kirby Cane and Hallington sites are presented in Figures 6, 7 and 8 respectively. To relate yields harvested at different levels of maturity, yields were corrected to a common tenderometer reading (TR) of TR 100 (for further information on yield correction please refer to Appendix C). For ease of reporting the data for both 'fresh' and 'stabilised' doses has not been differentiated at this stage. Further details specific to 'fresh' and 'stabilised' doses will be detailed in the final report.

At Docking yields generally showed little yield response to soil Olsen P levels as shown in Figure 6. Yields tended to increase by 0.3 t/ha at Index 3 (26-45 mg/kg) compared to an Index 2 (16-15 mg/kg).

At Kirby Cane there was a positive yield response to soil Olsen P levels as shown in Figure 7. At an Index 2 or below (<26 mg/kg) yields were reduced by around 0.6 t/ha compared to an Index 3 (26-45 mg/kg) or above.

At Hallington there was a positive yield response to soil Olsen P levels as shown in Figure 8. At an Index 1 or below (<15 mg/kg) yields were reduced by as much as 2.25 t/ha compared to an Index 2 (16-25 mg/kg) or above. Yields at or below the lower half of Index 2 tended to be more variable compared to the upper end of Index 2 or above.

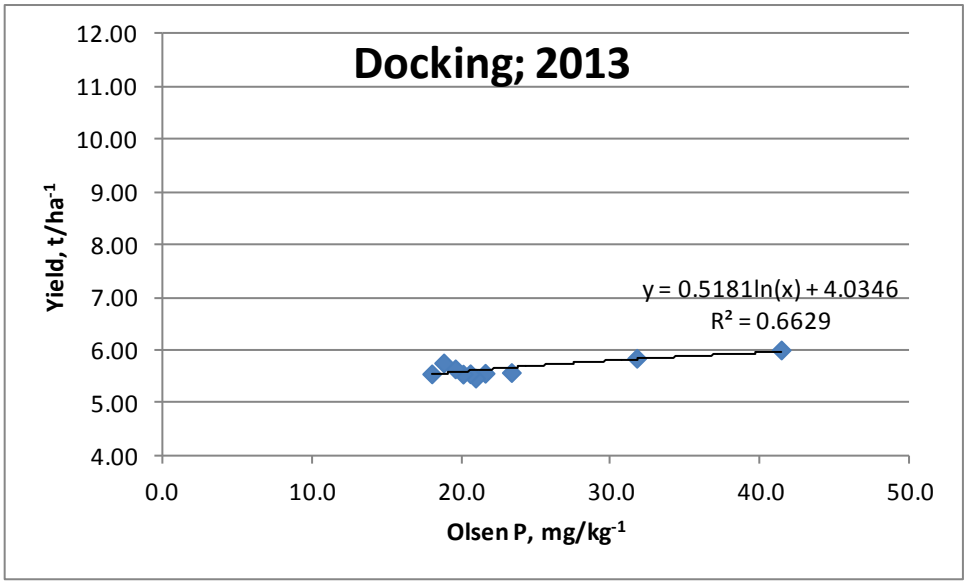

Figure 6: Regression of vining pea yield (t/ha adjusted to 100 TR) on Olsen P in soil at Docking in 2013. Data presented as a 5 sample moving average of the mean from 4 sequential harvests.

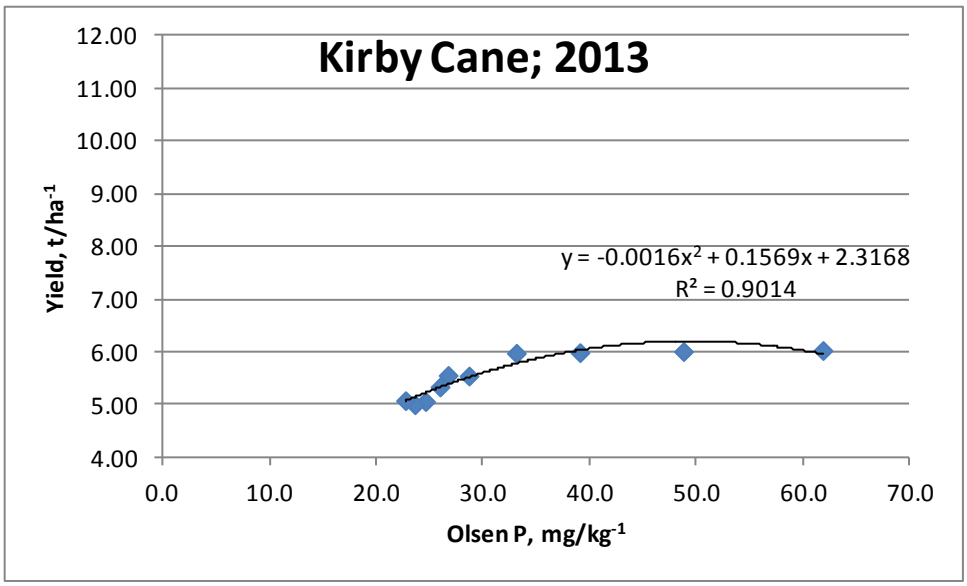

Figure 7: Regression of vining pea yield (t/ha adjusted to 100 TR) on Olsen P in soil at Kirby Cane in 2013. Data presented as a 5 sample moving average of the mean from 3 sequential harvests.

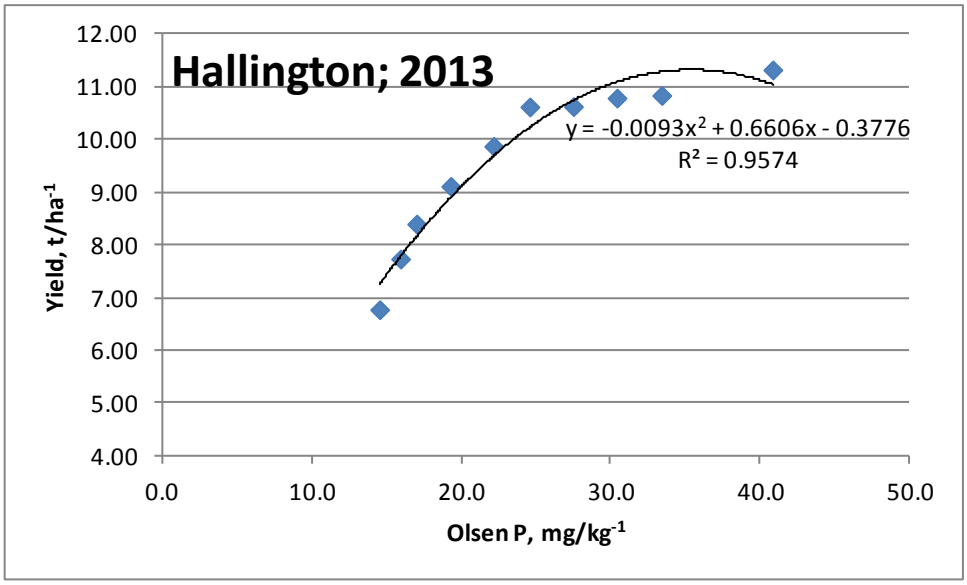

Figure 8: Regression of vining pea yield (t/ha adjusted to 100 TR) on Olsen P in soil at Hallington in 2013. Data presented as a 5 sample moving average of the mean from 3 sequential harvests.

A summary of the yield data is shown in Table 7. At Docking a maximum yield of 5.93 t/ha was attained when soil Olsen P was at Index 3 (26-45 mg/kg); however, it is likely that other factors such as the weather and soil type may have limited yield response. At an Index 3 (26-45 mg/kg) yield averaged 5.93 t/ha resulting in a yield increase of 0.34 t/ha above that of an Index 2 (16-25 mg/kg).

At Kirby Cane yields also indicated a trend for higher yields at higher Olsen P values with the maximum yield of 6.02 t/ha being achieved when soil Olsen P was maintained at an Index 4 (46-70 mg/kg). An Index 3 (26-45 mg/kg) resulted in an increase of 0.63 t/ha above that of an Index 2 (16-25 mg/kg).

At Hallington yield indicated the greatest yield response to soil Olsen P with the maximum yield of 10.89 t/ha being achieved when soil Olsen P was maintained at an Index 3 (26-45 mg/kg). An Index 3 (26-45 mg/kg) resulted in an increase of 3.64 t/ha above that of an Index 1 (10-16 mg/kg). At all sites yields tended to be the greatest at an Index 3 or above and this may have been affected by other factors such as air temperature, rainfall and soil structure condition that followed the prolonged wet autumn of 2012.

Table 7: Summary crop yield (t/ha) adjusted to TR 100; 2013.

Crop yield		t/ha		
P Index	**Olsen P (mg/kg)**	**Docking, Norfolk (sandy loam)**	**Kirby Cane, Suffolk (Clay loam)**	**Hallington, Lincs. (Silty clay loam)**
0	0-9	-	-	-
1	10-15	-	-	7.25
2	16-25	5.59	5.05	9.50
3	26-45	5.93	5.68	10.89
4	46-70	-	6.02	-

Crop maturity and quality

Crop maturity was assessed, at all harvest timings, by recording the TR values of all individual plots. At Hallington the effect of soil Olsen P on TR values, shown in Figure 9, was such that where Olsen P was below Index 1 (<15 mg/kg) the TR value was lower, on average, by 7 TR points compared to an upper Index 2 (20-25 mg-kg). This effect of Olsen P on crop maturity was marginal at Hallington and at both Docking and Kirby Cane the trend was observed to a lesser degree (data not shown). Further evaluation on crop quality including pea colour and a Brix test will be completed shortly and results will follow in the final report.

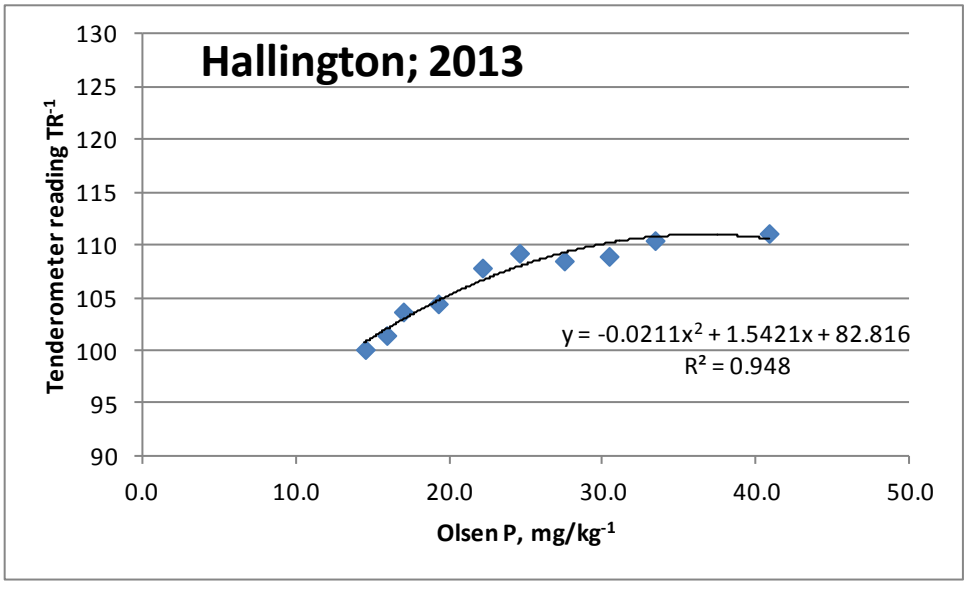

Figure 9: Regression of TR values on Olsen P in soil at Hallington in 2013. Data presented as a 5 sample moving average of the mean from 3 sequential harvests.

Discussion

Preliminary results from Year 2 clearly demonstrate increased yields with higher soil Olsen P values and follows a similar trend to that seen in year 1 (as reported in FV380 annual report 2012). The results suggest that yield can be increased by up to 3.64 t/ha where soil Olsen P is increased from an Index 1 (10-15 mg-kg) to an Index 3 (26-45 mg/kg).

The yield response to soil Olsen P levels, particularly at an Index 3 or 4 (46-70 mg/kg) are likely to have been influenced by weather conditions and soil type; this is particularly evident at the Kirby Cane site where it was noted during assessment for root nodulation that the soil (clay loam) was particularly dry and hard and this may have restricted root growth during the season thus limiting the crop uptake of soil P particularly at lower soil Olsen P levels. At Kirby Cane the heavy soil (clay loam) may have suffered from poor soil structure as a result of the prolonged rainfall in autumn 2012. To acquire nutrients and water the roots of annual arable crops have to explore the largest possible volume of soil in the shortest possible time, especially spring sown crops. When the volume of soil that can be explored by roots is restricted because of poor structure, especially when the soil is compacted, the opportunity for roots to take up nutrients and water is limited. Experiments at Rothamsted have indicated that soils that have a poor structure must contain more Olsen P to achieve satisfactory yields (HGCA, 2011).

Further factors such as air temperature during flowering and pod set may have also limited vining pea yields at Docking where the light soil (sandy loam) may have had insufficient soil moisture levels during these periods. Local weather station data indicates that the July monthly maximum air temperature reached 34.5^{o}C with the monthly rainfall totalling 21.8mm.

Crop vigour was notably reduced where soil Olsen P was below 15 mg/kg and results also suggest that crop maturity was more rapid (resulting in higher TR values at a specific harvest timing) where Olsen P was below Index 1 (<15 mg/kg). This would suggest that phosphate is affecting crop maturity and, where soil Olsen P is below the recommendation, yields maybe below the site potential.

Further discussion of results will be made available in the final report as the data presented is based on an investigation conducted over a one-year period. This project has a further season of field trials to complete, at which stage a full discussion and analysis across seasons both within and across soil types will be included in the final report.

Conclusions

Preliminary results from 2013 (Year 2 only) show that:

- The critical Olsen P varied from site to site in experiments, probably due to variations in soil physical conditions and seasonal affects e.g. rainfall;
- Crop vigour was reduced at or below an Index 1 (<15 mg/kg);
- Crop maturity was marginally affected by soil Olsen P. The higher Olsen P levels resulted in the higher TR readings and was opposite to the results in 2012;
- Results showed some clear yield responses to soil Olsen P levels;
- For Docking and Kirby Cane vining pea yields were reduced by 0.3 t/ha or more and were generally more variable at measured Olsen P below Index 3 (26-45 mg/kg).
- At Hallington, where yield response were greatest, vining pea yields were reduced by 2.25 t/ha or more and were generally more variable at measured Olsen P below Index 2 (16-25 mg/kg).
- The greater yield responses at Index 3 (26-45 mg/kg) or above at all sites are likely to have been influenced by factors such as soil structure, air temperature and rainfall during the season.

Further results detailing critical phosphate levels in vining peas will be available in late autumn 2014 after Year 3 (2012-14) is completed and a full report has been produced.

Knowledge and Technology Transfer

Recent knowledge transfer activities have included a series of articles in the following publications highlighting the results from Year 1 of this project:

- HDC Field Vegetable Review 2013
- PGRO Vegetable Magazine (Winter 2012)

A short presentation on the interim results from this project was presented at The Vegetable Agronomists Association meeting at PGRO, Thornhaugh, Peterborough on 15th January 2013.

A presentation on the interim results from this project is planned to be presented at The Vegetable Agronomists Association meeting at PGRO, Thornhaugh, Peterborough on 28th January 2014. Further articles in publications such as the NIAB Landmark magazine highlighting results from year 2 of this project are also planned.

References

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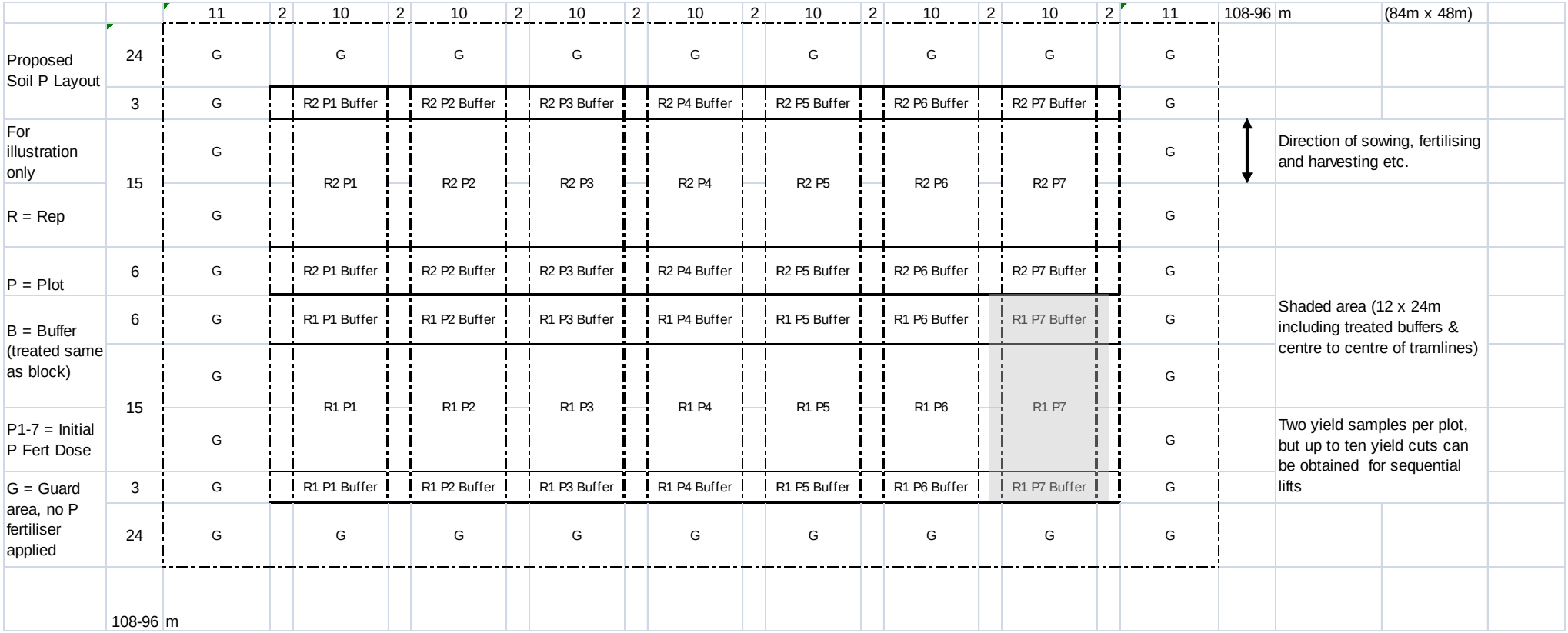
HGCA (2009). *On-going project* RD-2008-3554 Identification of critical soil phosphate (P) levels for cereal and oilseed rape crops on a range of soil types. AHDB, Warwickshire.

HGCA (2011). Response of cereals to soil and fertiliser phosphorus. Research Review No. 74. AHDB, Warwickshire.

Appendices

Appendix A – Trial plan



Appendix B – Site details

Year 2 – 2011-13

Site	County	GRIDREF	Soil series	Soil description	Primary cultivation depth (cm)	TSP application 'Stabilised' TSP application date	TSP application 'Fresh' TSP application date	Vining peas Date drilled	Variety
Docking	Norfolk	TF 799395	Barrow	Sandy loam	25	24/10/2011	14/12/2012	28/03/2013	Hesbana
Kirby Cane	Suffolk	TM 361968	Beccles	Clay loam	25	15/09/2011	11/02/2013	03/05/2013	Boogie
Hallington	Lincs	TA 141103	Andover 1	Silty clay loam	25	07/09/2011	01/03/2013	18/05/2013	Oasis

Appendix C – Harvest data

Yield data has been calculated by:

- Assimilating all the harvest data from each harvest timing between TR 95-TR 170.
- Adjusting all yields to a TR (tenderometer reading) of 100 derived from data published by Pumphrey *et al*. (1975).
- Results have been sorted in descending order for measured Olsen P values
- The measured Olsen P and yield data has then been averaged using a 5 point moving average.

Docking - Adjusted yield (corrected TR 100) for each harvest timing

Descending Olsen P (mg/kg)	**Plot**	Harvest 2 (08/07/2013)		Harvest 3 (09/07/2013)		Harvest 4 (10/07/2013)		Harvest 5 (12/07/2013)		Average	**Olsen P (mg/kg) 5 point moving average**	**Yield (t/ha) 5 point moving average**
		Adj. yield t/ha	TR	Adj. yield t/ha	TR	Adj. yield t/ha	TR	Adj. yield t/ha	TR	Adj. yield t/ha		
69.8	2	5.61	98.0	6.31	100.0	6.86	104.0	7.46	115.5	6.56		
63.0	11	6.80	95.0	4.93	101.0	6.52	105.5	7.65	118.0	6.48		
29.2	14	4.17	95.5	3.44	103.0	6.44	106.5	6.70	124.0	5.19	41.4	6.01
23.4	3	3.49	97.0	6.25	102.0	6.28	104.0	9.85	118.0	6.46	31.7	5.85
21.6	4	5.39	95.0	3.91	101.0	3.13	102.5	8.94	117.0	5.34	23.3	5.58
21.4	1	4.94	96.5	4.16	99.0	6.42	103.0	7.59	118.0	5.78	21.6	5.57
21.0	5	5.04	98.0	3.00	104.0	3.57	106.0	8.87	121.5	5.12	20.9	5.47
20.4	8	5.09	95.0	3.96	102.0	2.93	104.0	8.50	119.5	5.12	20.6	5.56
20.2	6	4.87	97.0	4.96	103.0	5.68	105.5	8.50	126.0	6.00	20.1	5.55
19.8	9	5.73	95.0	3.36	99.5	6.77	104.0	7.15	116.5	5.75	19.6	5.65
19.0	10	4.54	94.5	3.79	100.0	5.89	102.0	8.76	114.5	5.74	18.8	5.76
18.4	7	5.41	97.0	4.14	103.0	5.97	103.0	6.96	120.5	5.62	18.0	5.55
16.5	12	4.62	96.0	5.70	100.0	2.32	105.0	10.08	119.0	5.68		
16.2	13	5.00	96.5	2.96	104.5	6.29	106.0	5.63	124.5	4.97		

Kirby Cane - Adjusted yield (corrected TR 100) for each harvest timing

Descending Olsen P (mg/kg)	**Plot**	Harvest 1 (25/07/2013)		Harvest 2 (26/07/2013)		Harvest 3 (27/07/2013)		Average	**Olsen P (mg/kg) 5 point moving average**	**Yield (t/ha) 5 point moving average**
		Adj. yield t/ha	TR	Adj. yield t/ha	TR	Adj. yield t/ha	TR	Adj. yield t/ha		
94.4	5	3.75	107.0	6.92	116.0	5.85	126	5.51		
76.8	10	5.23	96.0	7.86	109.5	5.81	119.5	6.30		
55.8	1	6.79	98.5	.	.	5.19	129.5	5.99	61.9	6.03
47.4	8	5.97	97.0	7.91	109.5	6.32	123.5	6.73	48.8	6.01
35.0	6	5.04	96.0	6.00	108.5	5.80	122.0	5.61	39.1	5.99
29.0	3	5.94	95.0	4.62	113.5	5.66	123.0	5.41	33.1	5.98
28.2	2	5.70	95.5	7.38	106.5	5.52	115.0	6.20	28.7	5.54
26.0	9	6.42	95.5	6.67	107.0	4.69	122.0	5.93	26.7	5.56
25.2	7	4.65	95.0	.	.	4.50	119.0	4.58	26.0	5.34
25.2	12	5.29	95.0	6.91	106.0	4.82	119.0	5.67	24.6	5.06
25.2	13	4.36	91.0	3.95	108.0	4.63	119.0	4.31	23.6	5.00
21.4	11	4.90	91.5	4.34	107.5	5.19	114.5	4.81	22.7	5.08
21.0	14	4.54	93.0	6.58	106.5	5.77	125.5	5.63		
20.8	4	6.21	101.0	3.90	104.5	4.76	120.0	4.96		

Hallington - Adjusted yield (corrected TR 100) for each harvest timing

Descending Olsen P (mg/kg)	**Plot**	Harvest 3 (09/08/2013)		Harvest 4 (12/08/2013)		Harvest 5 (13/08/2013)		Average	**Olsen P (mg/kg) 5 point moving average**	**Yield (t/ha) 5 point moving average**
		Adj. yield t/ha	TR	Adj. yield t/ha	TR	Adj. yield t/ha	TR	Adj. yield t/ha		
66.6	7	8.27	95.5	14.19	124.0	15.53	135.5	12.66		
41.0	14	8.95	94.5	10.14	120.5	15.30	132.0	11.47		
34.4	12	7.46	95.5	11.93	115.0	12.64	124.5	10.68	40.8	11.32
32.6	1	6.45	89.5	12.10	107.0	13.73	113.0	10.76	33.4	10.84
29.6	6	5.72	91.5	12.58	117.0	14.83	111.5	11.04	30.4	10.79
29.4	2	7.05	97.5	11.39	124.0	12.27	123.5	10.24	27.5	10.63
26.0	11	6.78	86.5	12.12	111.0	14.76	127.0	11.22	24.6	10.62
19.8	13	6.89	91.5	9.51	115.0	13.22	122.0	9.87	22.1	9.87
18.0	9	6.47	88.5	10.94	109.0	14.77	123.0	10.73	19.3	9.11
17.5	3	4.94	86.0	7.15	103.0	9.81	110.0	7.30	17.0	8.40
15.0	8	5.07	88.5	6.35	97.5	7.92	108.0	6.45	15.9	7.73
14.6	10	4.75	90.0	8.54	108.0	9.64	115.0	7.64	14.5	6.77
14.4	4	4.48	87.0	6.87	99.0	8.32	109.0	6.56		
11.0	5	4.48	89.5	5.76	103.5	7.51	107.5	5.92		