Project title:	Sweetcorn: responses to Nitrogen and Phosphorus
Project number:	FV 409
Project leader:	Dr Richard M. Weightman, ADAS UK Ltd.
Report:	Annual report, December 2013
Previous report:	None
Key staff:	Angela Huckle (Contract manager and report author) Jonny Kerley (Assistant Research Manager) Tom Whiteside (Research Technician) Chris Dyer (Statistician)
Location of project:	Grower sites in Hants, Sussex and Isle of Wight
Industry Representative:	Mr Neil Cairns, Barfoots of Botley Ltd. West Sussex
Date project commenced:	1 April 2012
Date project completed (or expected completion date):	31 December 2014

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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GROWER SUMMARY

Headline

- Significant yield responses of marketable cobs to applied N were seen at three out of six sites, but there may be a significant risk of nitrate leaching over winter following harvest at the highest recommended N rate,

- There was no response of marketable cob yield to phosphate fertiliser at three sites with P indices of 3, and at most the increase in total crop uptake with applied P was only 10 kg P_2O_5/ha.

Background

Supersweet sweetcorn varieties, which are predominantly sold as fresh intact produce, i.e. whole cobs and cobettes, now account for the majority of the UK area of sweetcorn. These produce higher levels of sugar in the endosperm than traditional varieties, enabling a longer period of sweetness after picking and therefore better shelf life. The Assured Crop Produce protocol (2011) for sweetcorn advises that when choosing a variety the soil type, fertility, soil temperature characteristics, shelter and irrigation potential of the proposed site should be taken into consideration, as well as the requirements of the end customer.

Nitrogen (N) is the major plant nutrient and the maximum recommended rate for sweetcorn is 150 kg N/ha at N index 0 (DEFRA 2010). This advice appears to be inadequate for modern varieties since it is far lower than international guidelines such as IFA (1992), which recommend 220 kg N/ha. Fertiliser requirements for current UK cropping systems therefore need reviewing, addressing possible under-fertilising in early-sown crops and assessing the contribution that SMN measurements can make when determining crop N requirements, particularly for late-sown crops.

It is known that maize is sensitive to phosphorus deficiency (Archer, 1985) so it is appropriate to review P recommendations since demands of modern high yielding supersweet crops may well be higher than existing RB209 recommendations. Recent work has been undertaken in New Zealand on P nutrition of sweetcorn (Fletcher et al., 2006, 2008), but none in the UK. There have been problems with soil management practices (causing erosion) with forage maize, and since a large proportion of sweetcorn is grown on the south coast of England, agricultural practices in the south east and south west catchments are likely to come under scrutiny.

Summary

Six experiments were carried out at three early (E1-E3), and three late-sown (L1-L3) sites in 2013, on commercial premises in West Sussex, Hampshire and the Isle of Wight. Field experiments were carried out each examining the response to N or P fertiliser rates (six N response, and three separate P response experiments). The timing of fertiliser N treatment was also studied in the N response experiments, with fertiliser being applied as per the following treatments:

1, two-way: split 2/3 in seedbed at drilling, 1/3 at 45 days after drilling (current practice)*
2, three way split: 1/3 in seedbed at drilling, 1/3 at 45 days after drilling, 1/3 at flowering
3, two-way split: none at drilling, 1/2 at 45 days after drilling, 1/2 at flowering

*maximum applied in the seedbed was 100 kg N/ha (RB209 recommendations)

Phosphate was incorporated in the soil prior to drilling. N response experiments also evaluated the timing of N application. Measurements were made of soil mineral nitrogen (SMN) to 90 cm depth, and topsoil for phosphate (P), potassium (K), and magnesium (Mg) status prior to drilling. Fresh weight and dry weight yield, total cob and marketable cob yields and N and P offtakes were determined, as well as measurements of cob sweetness (via Brix).

Phosphate

There were no detected yield responses to applied phosphate, at any of the three sites, and no effects on other quality attributes such as sweetness. Prior to drilling, the experimental sites had soil P indices in the range 2 to 3 and a positive response may have been expected; maximum phosphate offtake was 60 kg P_2O_5/ha (range 20-60 kg P_2O_5/ha). The conclusion from this year of study is that there is no yield response of sweetcorn to phosphate fertiliser at soil index 3.

Nitrogen

At five out of six sites, there were significant increases in total N uptake ($P = 0.011$ to <0.001) by the sweetcorn crop, which were maximal at the highest rate applied, 320 kg N/ha. However out of 18 separate N rates x timing combinations studied, only six (at sites E1, E2 and L2) gave significant marketable cob yield responses to applied N (Figure 1). These results show that when harvesting an immature crop such as sweetcorn, getting more N into the plant does not necessarily deliver more marketable yield. Optimal N rates

are shown in Table 1 for treatment combinations which enabled curve fitting (using a crop value of 17p per marketable cob and 72 p/kg of N fertilizer).

An understanding of site yield potential is important to determine fertiliser requirements, and this is dependent on factors such as aspect, soil type and previous cropping history. For example, yield responses at the two late sites were quite different: L2 had a good response with max yield of 33,026 cobs/ha at 220 kg N/ha, with 75 kg N/ha available as SMN at drilling, while L3 showed no yield response with a lower yield between 25,000 and 28,000 cobs/ha, with 100 kg N/ha as SMN at drilling (Figure 1).

Soil mineral N to 90 cm depth prior to drilling was 54-60 kg N/ha at the early drilled sites and 70-100kg N/ha at the late drilled sites, i.e. 1-2 Soil Nitrogen Supply (SNS) indices higher at the late sites, suggesting that N recommendations should be lower for late sown crops (e.g. 20 kg N/ha lower moving from SNS index 0 to 1, or 1 to 2). As estimated from total crop N uptake measured in the zero N plots, and assuming the crop can recover all the N available in the soil immediately prior to drilling, it was seen that around 28 kg N/ha was mineralised (i.e. became available) between drilling and harvest in early sown crops and 8 kg N/ha in late sown crop. Although these figures are for a single season and a narrow range of soil types, these rates of mineralisation should be considered when estimating SNS and fertiliser strategies.

The maximum N offtake for sweetcorn across the six sites in 2013 was around 170 kg N/ha (range 70-170 kg N/ha), even at the highest N rate where 320 kg N/ha was applied. Combined with the fact that total N offtake in cobs is relatively low (80-100 kg N/ha if all cobs are removed from the field) this implies that even though the economically optimum N rates are higher than those recommended in RB209, it would be difficult to justify such higher N rates from an environmental point of view because of the risk of nitrate leaching over winter following harvest, particularly in those situations when unmarketable cobs are returned to the field. For example at site E2 where the harvest index and N offtake in cobs was calculated, the maximum offtake (all cobs) was 83 kg N/ha. However, considering that on average 75% of these cobs were marketable, then only 62 kg N/ha would have been removed from the field. This means that although the maximum N uptake for the whole sweetcorn crop was 160 kg N/ha, only 60 kg N/ha was removed from the field as marketable cobs. The 100 kg N/ha remaining in crop residues would be at risk of leaching over winter. Where unmarketable cobs are processed further e.g. through anaerobic digestion, and N returned as digestate to crops in the following growing season, a case can

be made that higher N rates could be sustained responsibly, but this will be very much site and business dependent.

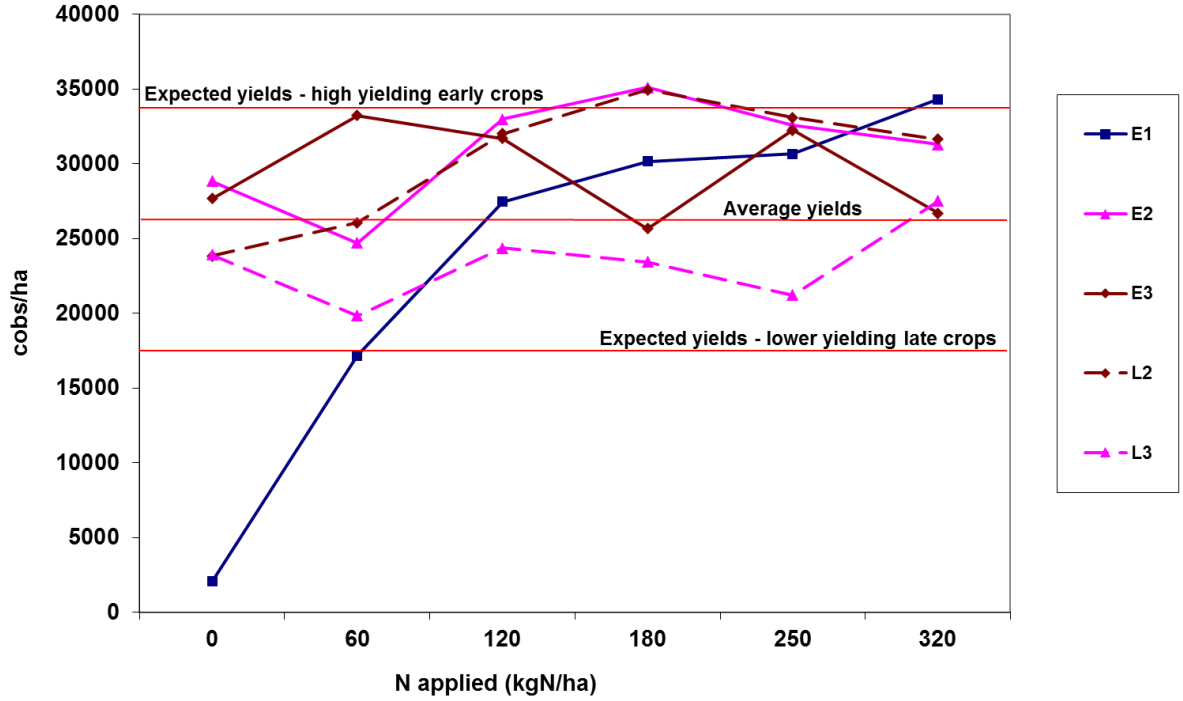


Figure 1. Effect of nitrogen application rates on numbers of marketable cobs from early and late drilled sweetcorn crops in Hants, Sussex and Isle of Wight, 2013 (means of the three N timings treatments in each experiment are shown).

Table 1. Economic optimum nitrogen application rates and timings (in bold) for the three sites with a significant response to marketable yield and where curve fitting could be carried out, Hants, Sussex and Isle of Wight, 2013

Site	N Timing treatment	SMN (Feb)	Available N at drilling	RB209 Rec. rate*	Economic Optimum (kg N/ha)	Cobs/ha at optimum
E1	All timing data combined	24	69	150	320	33,510
E1	**Seedbed + 45 days**	**24**	**69**	**150**	**196**	**38,257**
E1	3-way split	24	69	150	170	33,153
E1	No seedbed	24	69	150	320	36,142
E2	**Seedbed timings combined**	**37**	**82**	**150**	**157**	**33,752**
L2	**All timing data combined**	**29**	**103**	**100**	**227**	**33,026**

*Calculated from SNS Index prior to drilling

Nitrogen timing

In the two early crops which were picked at the correct crop ripeness (E1 and E2), there was a significant increase in cob weight (P = 0.05 and 0.09) when the nitrogen was applied in the seedbed with the remainder applied as a 2nd application 45 days later just before stem extension (N timing treatment 1). There was no significant effect of the timing of the application of the nitrogen on the later crops, which is probably due to the greater amount of available nitrogen at the time of drilling from mineralized soil residues, as indicated by the higher SMN at drilling.

Cob sweetness

There were no significant effects of any treatments on cob sweetness. All cobs measured had Brix values greater than 14ºBx. (Minimum sweetness required for the market is 10ºBx.)

Financial Benefits

The UK sweetcorn market is worth ca. £25.7M at retail level based on the annual volume of 18,000 tonnes/ha crop grown in 2013. This study suggests that for some late crops drilled without polythene covers in May and intended for harvest in September to October, it may be possible to apply less N fertiliser, when mineralisation from previous crop residues in a high SNS situation is expected. A soil mineral nitrogen (SMN) sample taken just prior to drilling could show that as much as 100 kg N/ha will already be available, allowing fertiliser inputs to be reduced according to the yield potential. If 85 kg N/ha as ammonium nitrate (current price of £250/t) could be saved, then the grower would benefit by £65/ha (ca. £60/ha taking into account the cost of SMN testing). If ca. 35% of crops in the UK are established as late crops, this is equivalent to around 780 ha of sweetcorn, and a potential saving overall of £45,000/annum from lower N inputs.

Action Points

- This single year of study indicate that RB209 recommendations are appropriate for sweetcorn production, both maximising cob yield and minimising the environmental impacts from excess fertiliser use.
- Providing most of the nitrogen early in growth appears to be the best strategy for early sown crops, but timing is less critical for late sown crops for yield optimization.
- Growers should take into account SMN to 90 cm depth prior to drilling, particularly for late sown crops, before deciding on the SNS index of a particular site,
- For late sown crops, consideration should be given to retesting for SMN prior to drilling, even if a soil sample was previously taken in winter/early spring.
- The results suggest that growers should not have any concerns about under- or over-fertilising ‘supersweet’ sweetcorn with respect to the effects of N on cob sweetness.
- While sweetcorn is known to be sensitive to P deficiency, there is little evidence that current best practice guidelines should be changed at present.

SCIENCE SECTION

Introduction

Supersweet sweetcorn varieties, which are predominantly sold as fresh intact produce, i.e. whole cobs and cobettes, now account for the majority of the UK area of sweetcorn. These produce higher levels of sugar in the endosperm than traditional varieties, enabling a longer period of sweetness after picking and therefore better shelf life. The Assured Crop Produce protocol (2011) for sweetcorn only advises that when choosing a variety the soil type, fertility, soil temperature characteristics, shelter and irrigation potential of the proposed site should be taken into consideration, as well as the requirements of the end customer.

Nitrogen (N) is the major plant nutrient and the maximum recommended rate for sweetcorn is 150 kg N/ha at N index 0 (DEFRA 2010). This advice appears to be inadequate for modern varieties since it is far lower than international guidelines such as IFA (1992), which recommends 220 kg N/ha. Fertiliser requirements for current UK cropping systems therefore need reviewing, addressing possible under-fertilising in early-sown crops and assessing the contribution that SMN measurements can make when determining crop N requirements, particularly for late-sown crops which may currently be over-fertilised.

There is somewhat conflicting advice on N timing: RB209 suggests that no more than 100 kg N/ha be applied in the seedbed and the remainder applied as a top dressing when the crop is fully established. The Assured Crop Produce protocol suggests that it is ‘prudent to apply low levels of N in the seedbed, with the balance being applied between the V4 and V6 stage’ and ‘all nutrients being applied before V8’. The IFA (1992) advice suggests that N should be given as a split application, one-quarter to one-half before or at planting, and the remainder in one or two applications up to approximately 40 days after germination. There is a need to test these different approaches in a UK field situation.

It is known that maize is sensitive to P deficiency (Archer, 1985) therefore it is appropriate to review P recommendations given potentially higher P requirement of modern high yielding crops. There has been recent work in New Zealand on P nutrition of sweetcorn (Fletcher et al., 2006, 2008), but none in the UK. There have been known problems of soil management (principally soil erosion, which is closely linked with P loss) with forage maize, and Defra-funded research is currently in progress on this topic. The European Water Framework Directive (WFD) came into force in December 2000 and became part of UK law in December 2003. It seeks to control the the quality of surface freshwater, ground waters,

estuaries and coastal waters out to one mile from low-water. Since a large proportion of the sweetcorn crop is grown on the south coast of England, agricultural practices in the south east and south west catchments are likely to come under increasing scrutiny. It is therefore necessary that sweetcorn growers should have strong evidence for P recommendations, should wider concerns regarding maize cultivation result in constraints on production, which may also impact on the sweetcorn crop.

The aim of the project is to improve the evidence base for recommendations for N and P applications and improve efficiency of production of sweetcorn.

Project Objectives: Field based experiments on grower holdings will be carried out to:

- Measure yield responses of sweetcorn to N and P fertiliser application in a commercial genotype;
- Evaluate N and P utilisation in relation to soil indices and soil mineral nitrogen; and
- Quantify N and P uptake to improve evidence for fertiliser recommendations.

Materials and methods

Site selection

Nine experiments were carried on grower holdings in Hampshire, Sussex and the Isle of Wight. These consisted of six N response trials (three early and three late drilled crops) and three P response trials. The aim was to select sites with low P and soil nitrogen supply (SNS) indices at which strong responses to applied N and P would be expected across all three holdings. However, the soil samples taken from the Isle of Wight in February showed a high P index and a late drilled trial in Hants was substituted for the original early site. Early trials were established in April under polythene which was subsequently removed approximately a month after drilling in accordance with commercial practice. The late trials were established as an uncovered crop in May. Site details are shown in Table 2. Variety choice was agreed in consultation with the host grower and reflected commercial practice, with the same maincrop variety grown across all sites except Hants E1.

Table 2. County, sowing and harvest dates, soil pH and nutrient indices and SNS index based on soil mineral nitrogen (SMN) to 90 cm depth measured at drilling, and soil type at the nine sites (E, early; L, late) in 2013.

County	Site	Sowing Date	Harvest date	Soil pH	SMN Index	Soil index (P, K, Mg)	Soil Type
Nitrogen response trials							
Hants	E1	22 April	13 Aug	7.1	0	4, 2+, 2	Sandy clay loam
W. Sussex	E2	23 April	20 Aug	7.6	0	2, 2-, 3	Clay loam
I. of Wight	E3	24 April	14 Aug	6.6	0	4, 2-, 1	Sandy clay
Hants	L1	14 May	18 Sept	6.7	1	3, 1, 2	Shallow sandy clay loam (high gravel content)
I. of Wight	L2	15 May	11 Sept	6.9	1	4, 3, 2	Sandy clay
W.Sussex	L3	23 May	19 Sept	7.2	2	3, 2+, 4	Sandy clay loam
Phosphorus response trials							
Hants	E1	22 April	13 Aug	6.9	0	3, 2-, 2	Sandy clay loam
W. Sussex	E2	23 April	20 Aug	7.3	0	3, 2-, 3	Clay loam
Hants	L1	14 May	18 Sept	6.0	1	3, 2-, 2	Shallow sandy clay loam (high gravel content)

Selected sites had no history of recent manure use or grass cropping in the previous year, and it was requested that no N or P based fertilisers were applied immediately prior to drilling the crop. All fertilisers required by the crop in addition to the treatments were applied by ADAS throughout the duration of the trial. The experimental areas were located within commercial crops and in an area of 100 m x 60 m (6000 m^2 total) for the N trials, and in an area of 60 m x 50 m (3000 m^2) for the P trials. Individual plots were marked out within these areas. Experimental plots were 12 m long x 6 rows (4.5 - 5 m drilling width dependent on site). Only the central two rows within the central 10 m of the treated area were assessed. Fertiliser treatments (see below for rates) were applied by hand at the specified timings. Seedbed treatments and base applications (e.g. P, K, Mg as required) were incorporated into beds using a compact tractor and rotavator prior to drilling to ensure that the phosphate fertiliser would be present in the rooting zone. Later applications at timing 2 and 3 were top dressed beside the rows by hand. After the seedbed applications, the beds were drilled by the grower using commercial farm equipment, and ADAS staff marked out the plots again with canes immediately after drilling. The early crops were also covered with polythene immediately after drilling. All crops were managed as per commercial practice; routine pesticide applications were applied and the crops were irrigated as necessary.

Nitrogen treatments

Six levels of N (0, 60, 120, 180, 250 and 320 kg/ha) x three timings were applied as shown in Table 3 in a fully factorial design such that individual responses to N and timing of application, as well as their interactions, could be examined. The timing treatments examined the differences between the benefits of N applied in the seedbed, or as a spread of treatments top dressed later as below;

1, two-way: split 2/3 in seedbed at drilling, 1/3 at 45 days after drilling (current practice)*
2, three way split: 1/3 in seedbed at drilling, 1/3 at 45 days after drilling, 1/3 at flowering
3, two-way split: none at drilling, 1/2 at 45 days after drilling, 1/2 at flowering

*Maximum applied in the seedbed was 100 kg N/ha - RB209 recommendations

Nitrogen was applied as ammonium nitrate (34.5% N) at all three timings, and seedbed applications of P, K and Mg were made as per RB209 recommendations to ensure that other nutrients were not limiting. The crop was monitored throughout the season for any non-nitrogen related nutrient deficiencies, but none were seen.

Table 3. A treatment list of the factorial design for all N x timing treatments for early and late sweetcorn trials in 2013.

Treat No	Rate	Timing	1st application (kg N/ha)	2nd application (kg N/ha)	3rd application (kg N/ha)	Total N (kg N/ha)
1	1	1	0	0	0	0
2	2	1	40	20	0	60
3	3	1	80	40	0	120
4	4	1	100	80	0	180
5	5	1	100	150	0	250
6	6	1	100	220	0	320
7	1	2	0	0	0	0
8	2	2	20	20	20	60
9	3	2	40	40	40	120
10	4	2	60	60	60	180
11	5	2	83	83	83	250
12	6	2	100	110	110	320
13	1	3	0	0	0	0
14	2	3	0	30	30	60
15	3	3	0	60	60	120
16	4	3	0	90	90	180
17	5	3	0	125	125	250
18	6	3	0	160	160	320

Phosphorus treatments

Six levels of P (0, 60, 120, 180, 250 and 320 kg/ha) were applied as shown in Table 4 in a fully randomised design. The phosphate was applied as triple superphosphate (TSP) (46% P_2O_5), and seedbed applications of N, K and Mg were made to RB209 recommendations to ensure that these nutrients were not limiting. The crop was monitored throughout the season for nutrient deficiencies, and an additional application of N was made at 45 days as the trials showed some senescence of lower leaves. No other deficiencies were seen.

Table 4. Phosphorus treatments for early and late sweetcorn trials in 2013.

Treatment	**1st application timing (kg P_2O_5/ha)**
1	0
2	60
3	120
4	180
5	240
6	320

Throughout the trial, any extreme weather conditions were recorded and the crop growth stage and any variation within the plots were recorded at each visit. Soil type, previous cropping and all pesticides and fertilisers and other treatments applied to the whole crop were recorded (details in the Results - individual site summaries).

Figure 2. Site E1 (early sweetcorn crop, Hampshire), showing the nitrogen and phosphorus response trials within the commercial crop marked by the non-drilled boundary, 2013.

Soil assessments

Initial soil sampling was carried out in early February. Sampling was carried out to 90 cm at 30 cm intervals for soil mineral nitrogen (SMN) and to 30 cm for P, K, Mg and Na. This was repeated in mid-April before treatments were applied to the early crops and in mid-May before treatments were applied to the late crops. A minimum of six cores from across each block at 0-90 cm depth at 30 cm intervals for SMN were taken, and to 30 cm for P, K, Mg and Na prior to fertiliser application and drilling. Soil samples for nitrate analysis were stored in an insulated box with ice packs immediately after sampling, stored in a cold store and sent to NRM for analysis the same or the following day or arranged for NRM collection direct from farm.

Crop assessments

Assessments were carried out at harvest from the nitrogen and phosphorus trials to determine nutrient uptake, cob sweetness, total yield and marketable yield. Plant population, lodging and leaning were also determined. Time of harvest for each trial was advised by the farm manager at each site, and on the day of harvest samples were taken from the central two rows. Fifteen plants from one row were cut to ground level and weighed to determine total above ground plant biomass, these plants were then shredded using a garden shredder, and a representative sub-sample was taken from this material for analysis of total N and dry matter for each plot (Figure 3). From the second row, 12 cobs were picked from each plot by ADAS staff and placed into labelled bags for determination of marketable yield counts, cob weight and sweetness by Brix by Barfoot's quality assessment (QA) staff. All samples were stored with ice packs during sampling, and then placed into an onsite cold store overnight before being dispatched directly from the farm to NRM or the packhouse for QA the following morning.

Design and statistical analysis

For the nitrogen response trials, a randomised factorial design was used was used with six levels of N and three levels of timing replicated in three blocks at each site. For the phosphorus trials a randomised design was used with six levels of phosphate replicated in four blocks at each site.

For the nitrogen response experiments; yield, cob sweetness, biomass and nutrient offtakes, statistical analysis was carried out by analysis of variance (ANOVA) with the treatment effects of N (df=4), timing (df=2) and their interactions (df=8) compared against the residual variation within treatments, between blocks (df=36).

For the phosphorus response experiments, yield, cob sweetness, biomass and nutrient offtakes, analysis was carried out by ANOVA with the treatment effects of P (df=5) compared against the residual variation within treatments, between blocks (df=15).

Figure 3. Equipment used for weighing and processing sweetcorn samples for biomass and N uptake, 2013.

Yield response curves and fitted functions (e.g. linear, quadratic or a linear plus exponential) between N applied and potential factors such as yield were fitted using *GenStat* (16th Edition). The economic optimum was determined, using the fitted response curve, by calculating the N rate at which there was no extra financial benefit from adding further N, therefore it gives the N rate which maximises profit. Economic optimum N (N_{opt}) was calculated for two early (E1 and E2) and one late site (L2) using an N price of 72 p/kg and a value of marketable cobs of 17p/cob.

Results

The nitrogen and phosphorus response experiments were carried out at six sites across Hampshire, west Sussex and the Isle of Wight in 2013. All of the phosphorous experiments were carried out on the mainland in Hampshire and W. Sussex as P indices on the Isle of

Wight were too high at Index 4. Details of responses at each of the individual sites is given in the following pages.

N responses – early sites

Site 13/E1, Hants

- Variety – Earlybird,
- Shallow sandy clay loam.
- Plant population at harvest – 56,133 plants/ha.
- Initial February SMN was low at 24 kg N/ha, rising to 46-67 kg N/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 22nd April.
- This made E1 an Index 0 -1 site with a recommended rate from RB209 of 150-100 kg N/ha. The 2012 crop was tenderstem broccoli.
- The site had a moderate to high initial P of 44-50 ppm (Index 3-4), and was a moderate to high yielding site with potential yields >30,000 cobs/ha.
- The crop showed a significant response (see appendix for data and analysis) to applied N fertiliser and curve fitting indicated a significant yield increase up to the highest N rate applied, in both numbers and weight of marketable cobs (Figures 4A and 4D), with a predicted economically optimum N rate of 320 kg N/ha when data was analysed across all timings. However, there would be a very high risk of leaching to the environment as only 40% of the available N from mineralised and applied sources was recovered by the crop at this level (see discussion section).
- N had significant effects on most factors including total weight of all cobs picked (P <0.001), and marketable weight of cobs (P=0.01); this was manifested as a large increase from 0-120 kg N/ha and a smaller increase from 120 - 320 kg N/ha (Figures 4C and 4D),
- Sweetness ranged from 14.4ºBx at zero N to 16.0ºBx at 180 kg N/ha but N effects were not statistically significant.
- There was a significant response to timing of the application of N (P = 0.01) at this site with higher yields produced at lower rates of nitrogen (120 kg N/ha) when part of the N is applied to the seedbed. When nitrogen was not applied in the seedbed it took a larger amount (320 kg N/ha) applied later to produce the equivalent yield,
- N uptake by the crop increased significantly with increasing N (P = 0.001) applied up to the highest N rate (320 kg N/ha). Maximum N uptake for this crop was 145 kg N/ha at the highest rate (Figure 4B).

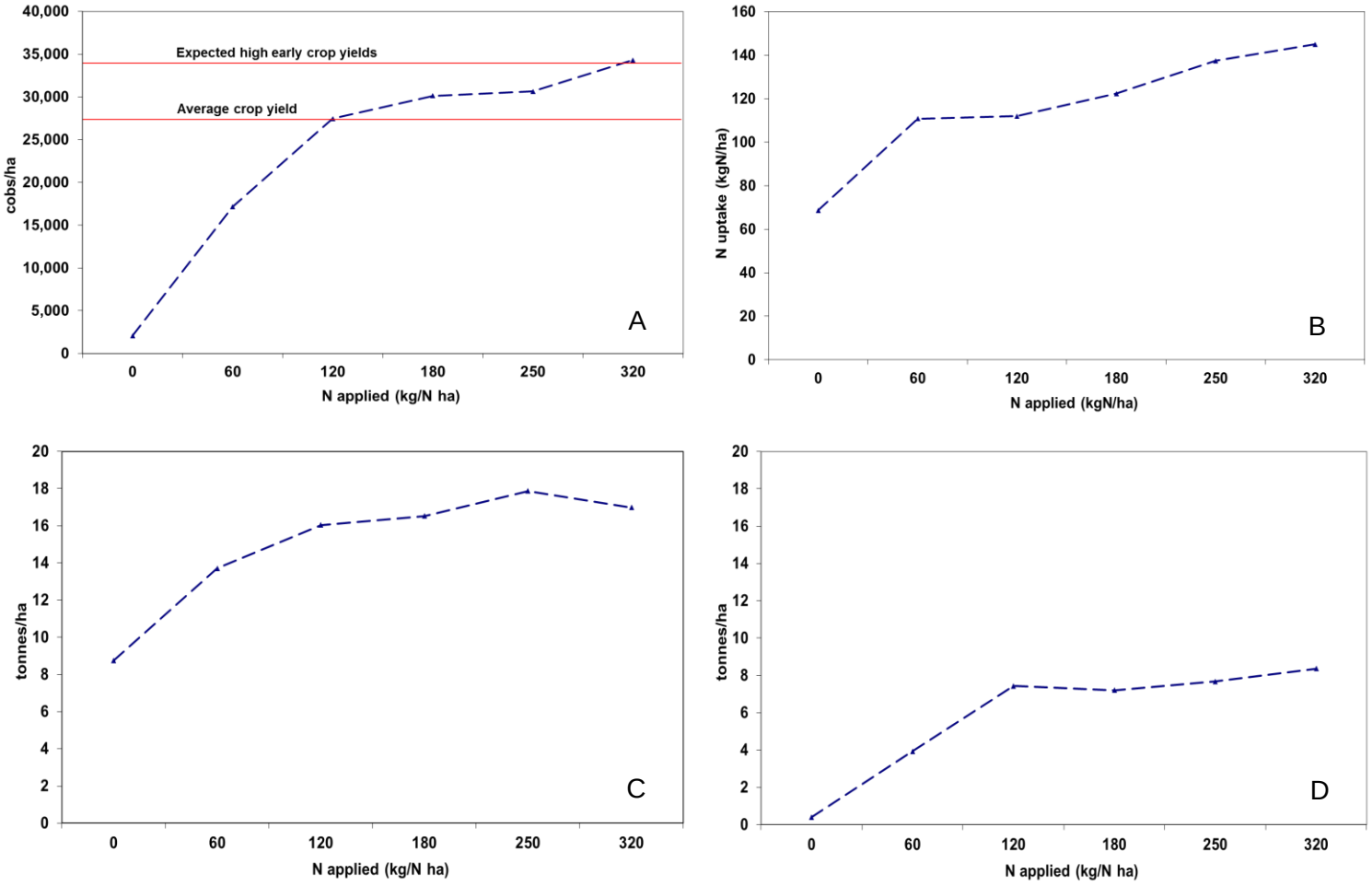


Figure 4. Effects of N rate on sweetcorn at site 13/E1 on A: Numbers of marketable cobs; B: N uptake; C: weight of total cobs (marketable plus non-marketable cobs) and D: weight of marketable cobs. Hants 2013.

Site 13/E2, W. Sussex

- Variety – 7403
- Soil type – clay loam.
- Plant population at harvest - 45,106 plants/ha.
- February SMN was low at 37 kg N/ha, and rose to 51-57 kg N/ha by drilling through mineralisation of N from organic matter as soils warmed prior to drilling on 23rd April,
- This made E2 an Index 0 site with a RB209 rate of 150 kg N/ha. Previous cropping was courgettes in 2012, grass in 2011.
- The site had a moderate initial P of 23-27 ppm (index 2-3), and was a moderate-high yielding site with potential yields >30,000 cobs/ha.

- The crop showed a significant yield response to applied N fertiliser (P = 0.022) with a peak at 180 kg N/ha, then yield of both numbers and weight of cobs decreased at higher applied rates (Figure 5A and 5D). It was possible to carry out curve fitting at this site to give a predicted economic optimum N of 157 kg N/ha,
- N had significant effects on most factors including total weight of all cobs picked (P = 0.006), and marketable weight of cobs (see appendix for full data sets and ANOVA); this was manifested as a significant increase from 0-180 kg N/ha, at higher rates of N the whole plant weight increases but cob weight and numbers decline.
- Total N uptake increased up to 250 kg N/ha applied but then declined at 320 kg N/ha (Figure 5B).
- There was a significant response to timing of the application of N at this site with higher yields produced at the mid-rate of nitrogen (180 kg N/ha) when part of the N is applied to the seedbed. When nitrogen was not applied in the seedbed, yield at lower rates of N were variable and at higher rates of N yields were lower.
- Sweetness did not respond to N applied at this site, varying from 16.3ºBx to 16.4ºBx.

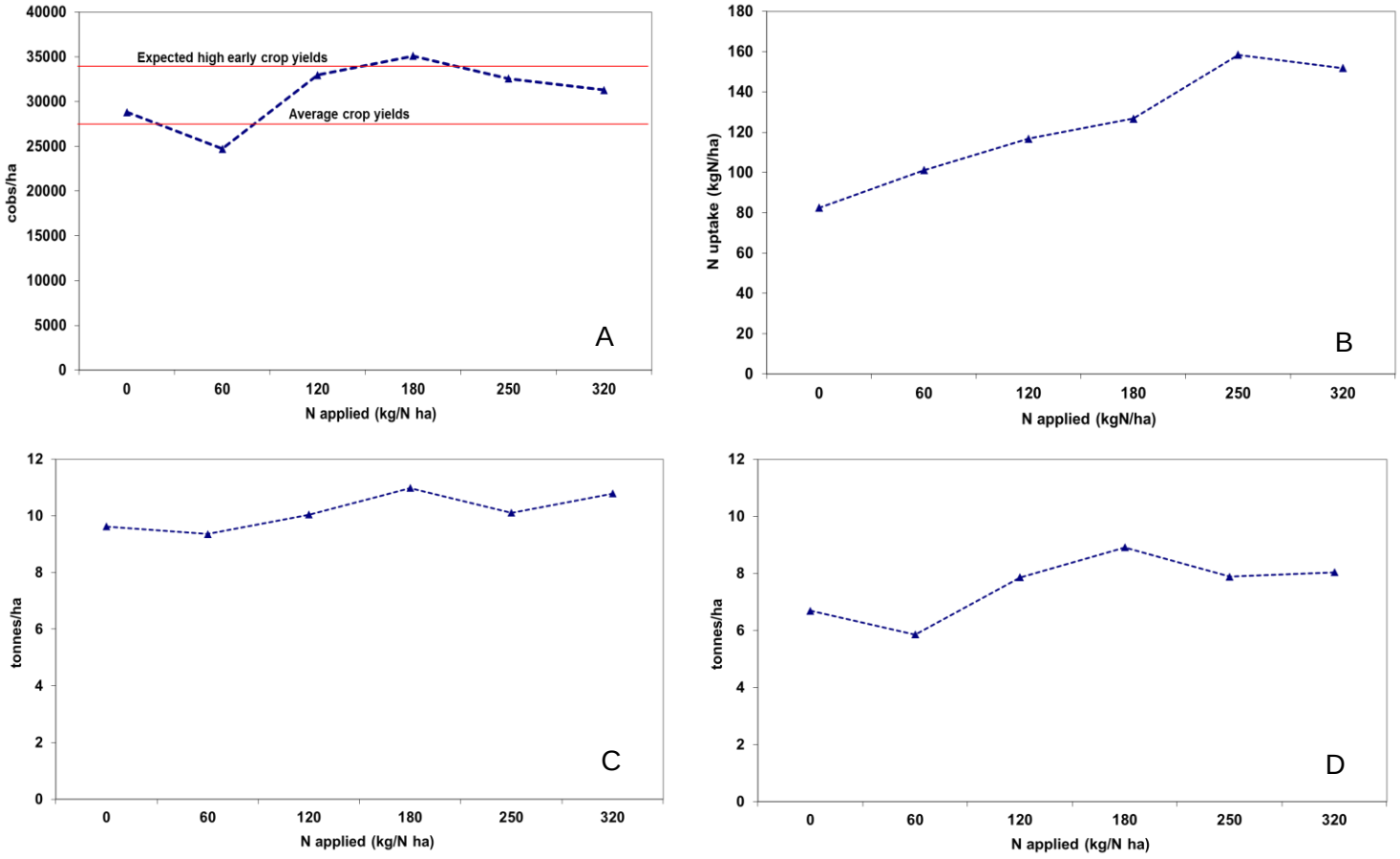


Figure 5. Effects of N rate on sweetcorn at site 13/E2 on A: Numbers of marketable cobs; B: N uptake; C: weight of total cobs (marketable and non-marketable cobs) and D: weight of marketable cobs. W. Sussex 2013.

Site 13/E3, Isle of Wight

- Variety – 7403
- Soil type – sandy clay
- Plant population at harvest - 54,360 plants/ha
- February SMN was low at 29 kg N/ha, and rose to 58-61 kg N/ha by drilling due to mineralisation of N from organic matter prior to drilling on 24th April,
- This made the E3 site an Index 0 site with a recommended rate from RB209 of 150 kg N/ha required and the previous cropping was wheat in 2012 (asparagus in 2011),
- The site had a moderate initial P of 59 - 64 ppm (P Index 4), and was a moderate-high yielding site with potential yields >30,000 cobs/ha.
- The crop showed no significant yield response to applied N fertiliser and had a variable trend. This could be due to harvesting the crop at least 4 days too early, and therefore some of the cobs that later would have been up to specification would have

been deemed non-marketable at this stage, affecting the figures for numbers and weight of marketable cobs (Figures 6A and 6D).

- N applied had significant effects on total N uptake (P <0.001) and total biomass (P = 0.002), at higher rates of N the biomass increasing strongly up to 180 kg N/ha and then at a lower rate of increase between 250 and 320 kg N/ha (Figure 6B). Total N uptake followed a similar pattern (see appendix for full data sets and ANOVA).
- There was no significant response to N applied with regards to the weight of all main cobs, but weight increased steadily from 9.38 tonnes/ha at zero N applied to 10.55 tonnes/ha at 320 kg N/ha (Figure 6C).
- Sweetness did not respond to N applied at this site, varying from 15.4ºBx to 16.1ºBx

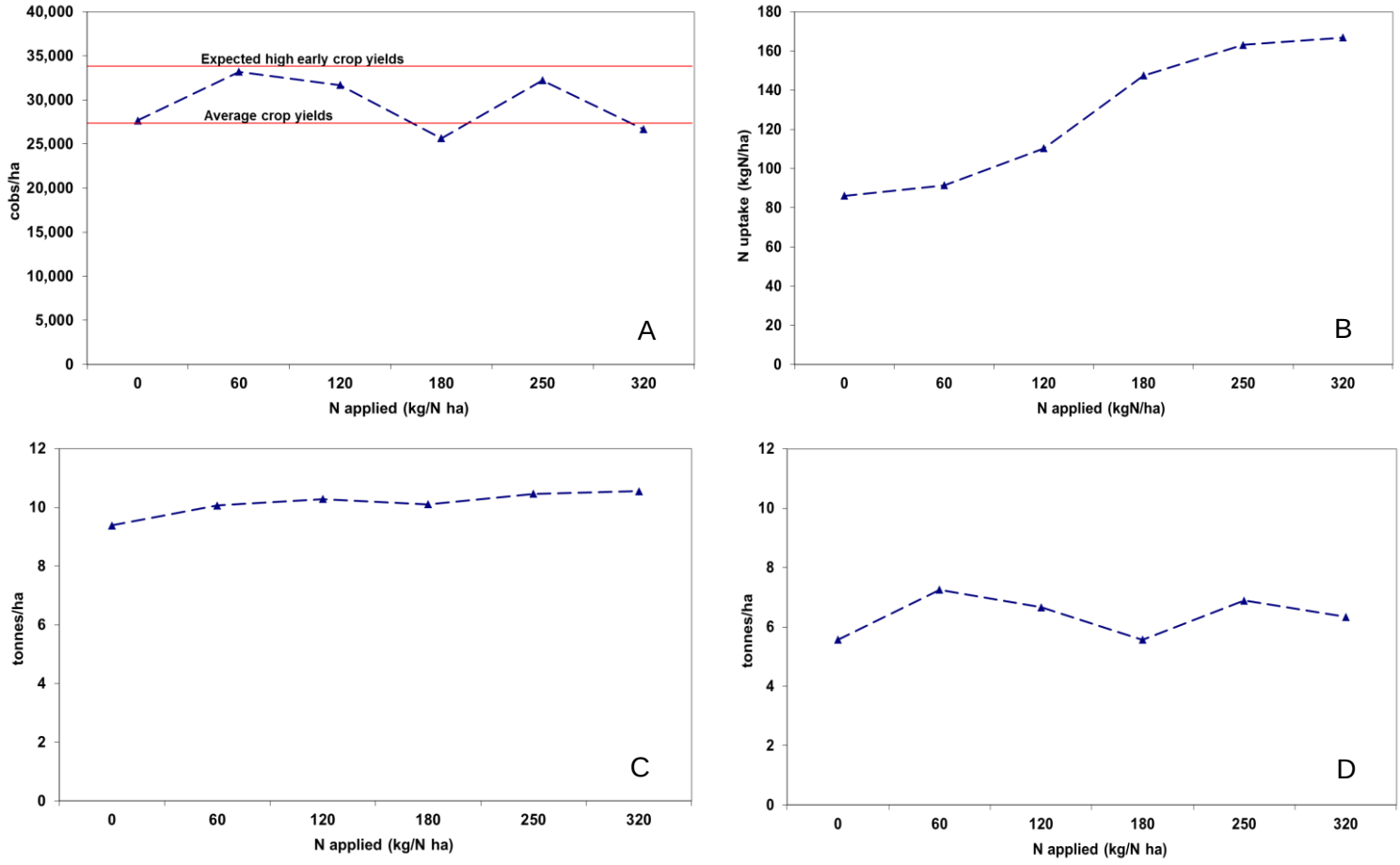


Figure 6. Effects of N rate on sweetcorn at site 13/E3 on A: Numbers of marketable cobs; B: N uptake; C: weight of total cobs (marketable and non-marketable cobs) and D: weight of marketable cobs. Isle of Wight, 2013.

N responses – late sites

Site 13/L1, Hants

- Variety – 7403
- Shallow sandy clay loam with a high gravel content,
- This was a low-moderate yielding crop compared to the other sites, as the site suffered from limited access to water in the dry summer when irrigation needs were high.
- Plant population at harvest was very variable at this site – plant population varied from 25,066 to 28,533 plants/ha.
- Initial SMN in February was low at 39 kg N/ha, and increased to 62 - 75 kg N/ha by drilling due to mineralisation of N prior to drilling on 14th May.
- This made L1 an Index 1 site with a recommended rate from RB209 of 100 kg N/ha required, and the previous crop was pumpkins in 2012, with sweetcorn grown in 2011.
- The site had a moderate initial P of 26-30 ppm (P Index 3).
- No quality or cob yield data were available for this site.
- The plants only reached a total biomass of approximately 20 tonnes/ha, whereas crops of this variety at all other trial sites reached 30 – 40 tonnes/ha (Figure 7B).
- The low plant biomass affected N uptake which showed no significant differences across plots and was much lower than all the other trial sites (Figure 7A).

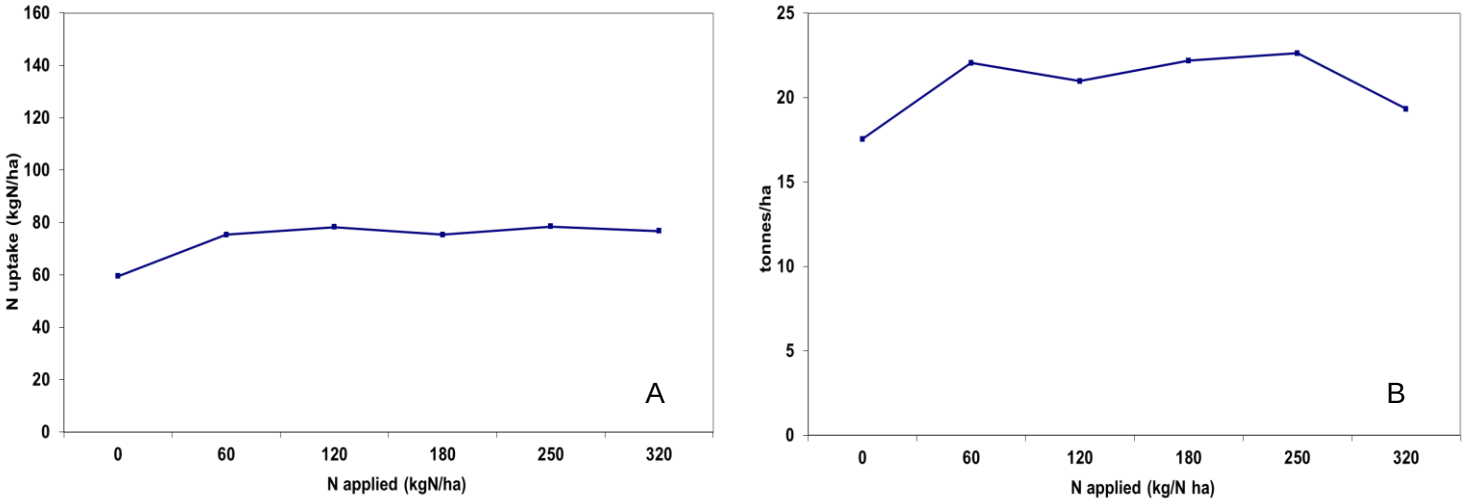


Figure 7. Effects of N rate on sweetcorn at site 13/L1 on A: N uptake; B: total plant weight. Hants 2013.

Site 13/L2, Isle of Wight

- Variety – 7403
- Soil type – sandy clay
- Plant population at harvest - 40,200 plants/ha
- Initial SMN in February was low at 29 kg N/ha, and rose to 67 - 87 kg N/ha by drilling due to mineralisation of N prior to drilling on 15th May.
- This made the L2 site an Index 1 site with a recommended rate from RB209 of 100 kg N/ha required and the previous cropping was wheat in 2012 (asparagus in 2011).
- The site had a high initial P of 69 - 71 ppm (P Index 4 - 5), and was a moderate-high yielding site with potential yields >30,000 cobs/ha.
- The crop showed an increasing trend for numbers of marketable cobs per hectare with a peak at 180 kg N/ha, after which the yield declined (Figure 8A), with a statistically significant yield response to applied N fertiliser (P = 0.021, also see appendix for full data sets and ANOVA). In addition, it was possible to carry out curve fitting on the trend to give a predicted economic optimum at 227 kg N/ha.
- N applied had significant effects on total N uptake (P = 0.011) and the weight of all main cobs (marketable and non-marketable) (P = 0.064). At increasing rates of applied N the weight of all cobs picked increases with a peak at 180 kg N/ha, and then the weight decreased between 180 and 320 kg N/ha (Figure 8C). However, total N uptake continued to increase up to 250 kg N/ha applied before decreasing slightly at the highest applied rate (Figure 8B).
- Sweetness did not respond to N applied at this site, varying from 17.1ºBx to 18.4ºBx.

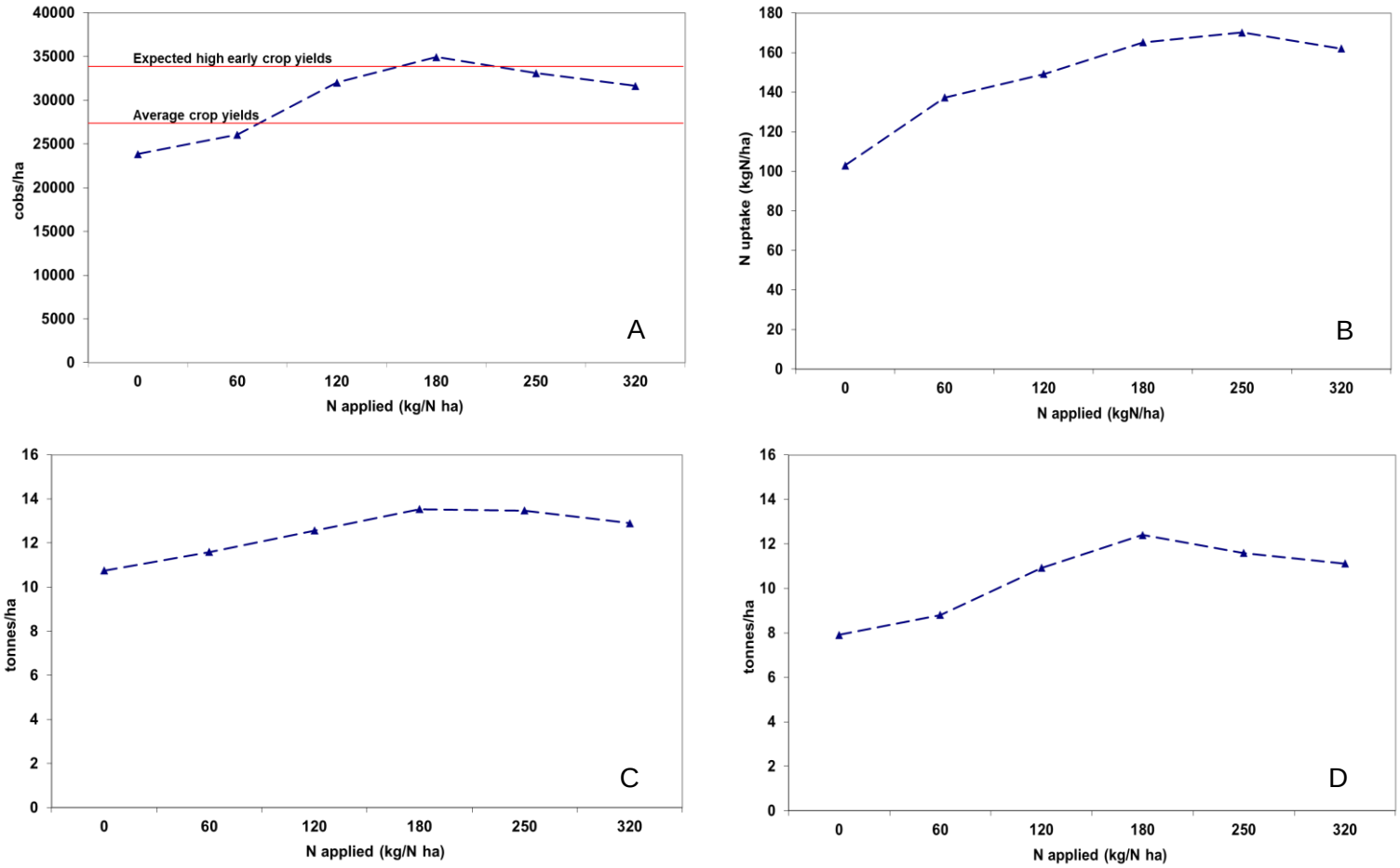


Figure 8. Effects of N rate on sweetcorn at site 13/L2 on A: Numbers of marketable cobs; B: N uptake; C: weight of total cobs (marketable and non-marketable cobs) and D: weight of marketable cobs. Isle of Wight, 2013.

Site 13/L3, W. Sussex

- Variety – 7403
- Soil type – sandy clay loam
- Plant population at harvest - 32,479 plants/ha
- Initial SMN in February was low at 52.9 kg N/ha, and rose to 90.2 – 108.7 kg N/ha by drilling due to mineralisation of N prior to drilling on 23rd May.
- This made the L3 site an Index 1 to 2 site with a recommended rate from RB209 of 50 - 100 kg N/ha required and the previous cropping was courgette in 2012 (grass in 2011).
- The site had a moderate initial P of 69 - 71 ppm (P Index 3), and was a low-moderate yielding site with potential yields of up to 27,000 cobs/ha.
- Only blocks one and two were used for statistical analysis as the third block was affected by wildlife damage, and crop maturity in this block was significantly different to the other two blocks.
- The crop showed no statistically significant yield response to applied N fertiliser for numbers of marketable cobs per hectare (Figure 9A, also see appendix for full data sets and ANOVA), and at this site it was difficult to visually distinguish the zero N plots from the plots where N fertiliser had been applied.
- Applied N had significant effects on total N uptake only (P = 0.003), there was no response in either the total weight of cobs picked, or marketable cobs (Figures 9B – 9D).
- Sweetness did not respond to N applied at this site, varying from 14.4ºBx to 15.6ºBx.

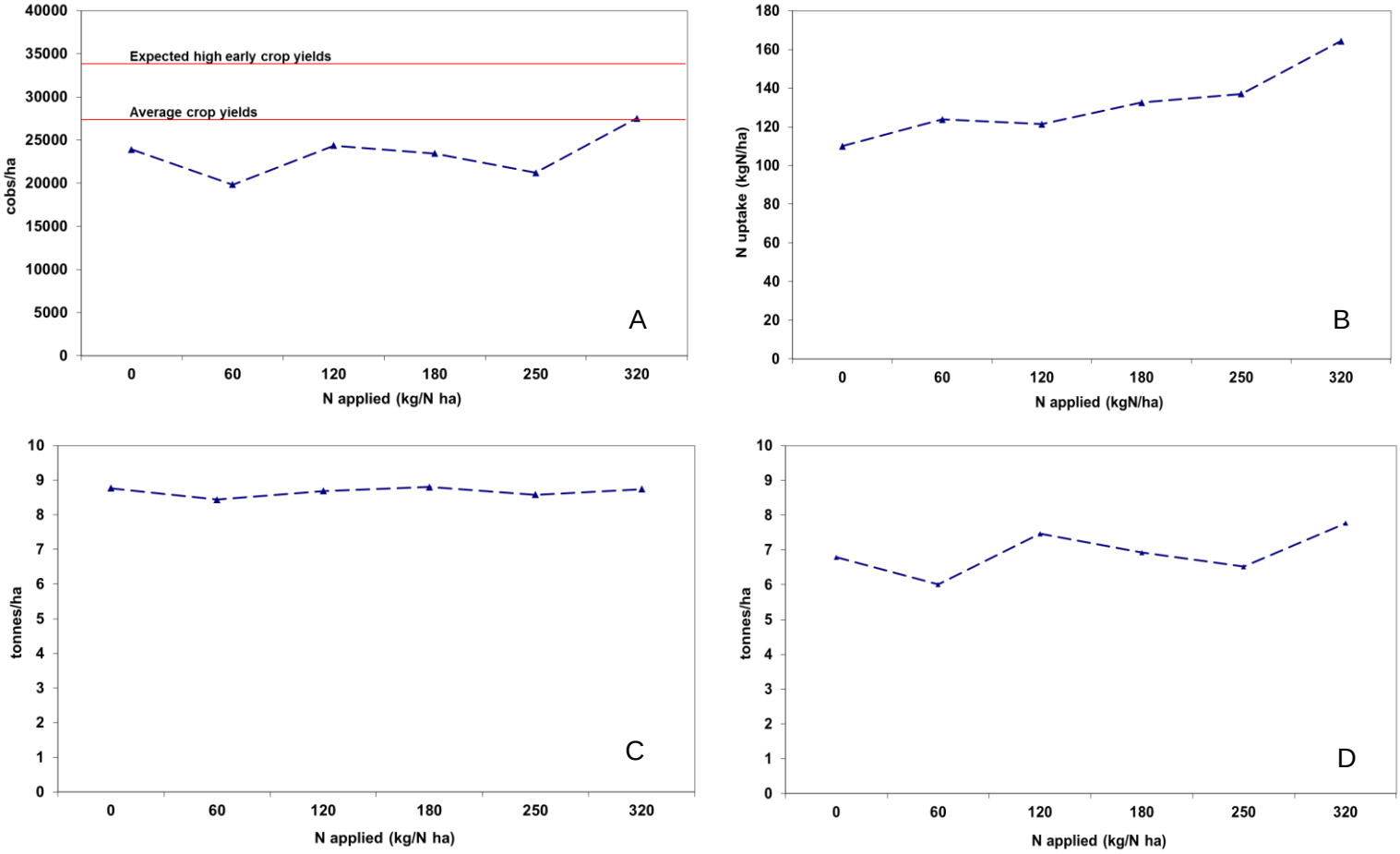
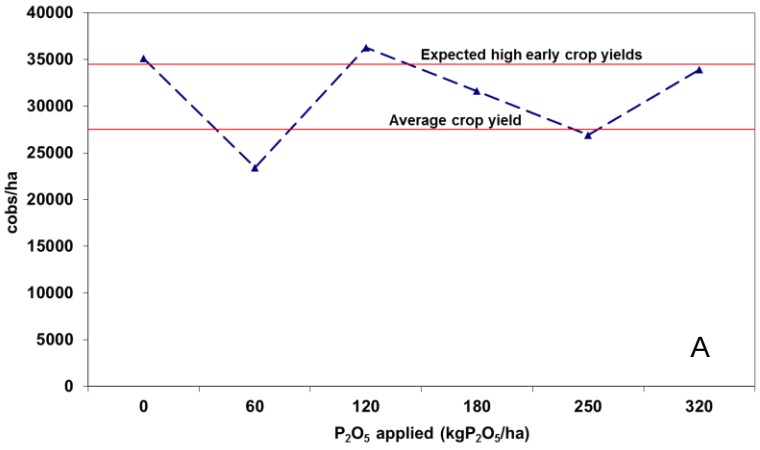


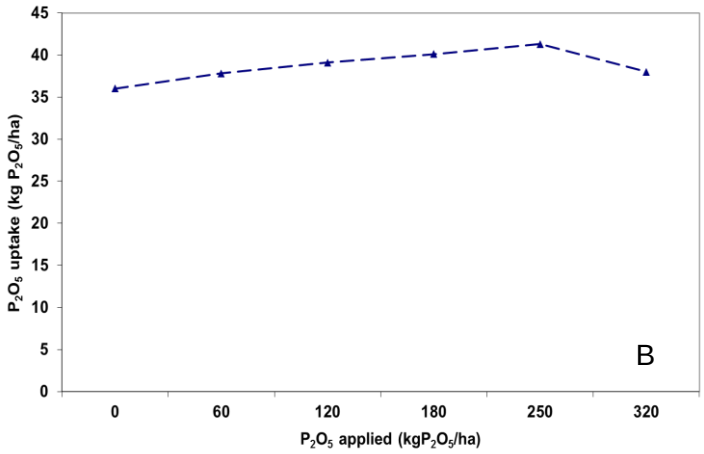
Figure 9. Effects of N rate on sweetcorn at site 13/L3 on A: Numbers of marketable cobs; B: N uptake; C: weight of total cobs (marketable and non-marketable cobs) and D: weight of marketable cobs. W. Sussex, 2013.

P responses

Site 13/E1, Hants

- Variety, soil type, plant population, previous cropping and SMN as for early nitrogen response site,
- The site had a moderate initial P of 40-42 ppm (P Index 3), and was a moderate-high yielding site with potential yields >30,000 cobs/ha,
- The crop showed no response to phosphate applied with regards to uptake of the nutrient (Figure 10B),
- The marketable yield of sweetcorn as weight or numbers of cobs did not show a response to phosphate (Figure 10A, also see appendix for full data sets and ANOVA),
- The total weight of cobs (marketable and non-marketable) showed a slight increase of 0.38 tonnes/ha between zero kg P_2O_5/ha and 120 kg P_2O_5/ha, and by a further 1.02 tonnes/ha between 120 kg P_2O_5/ha to 320 kg P_2O_5/ha but this was not significant (Figure 10C).





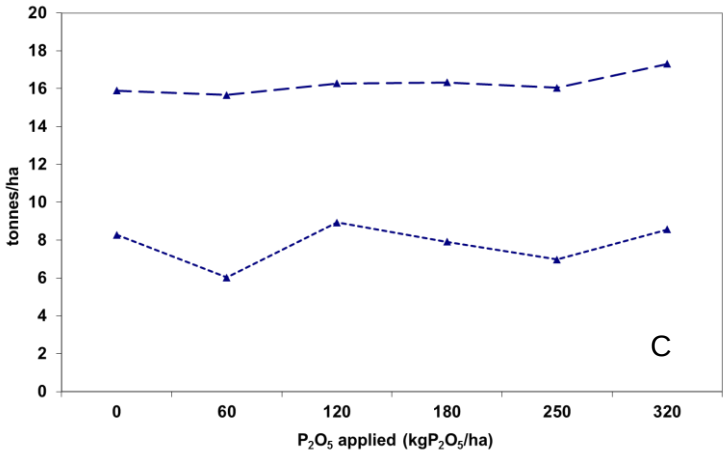
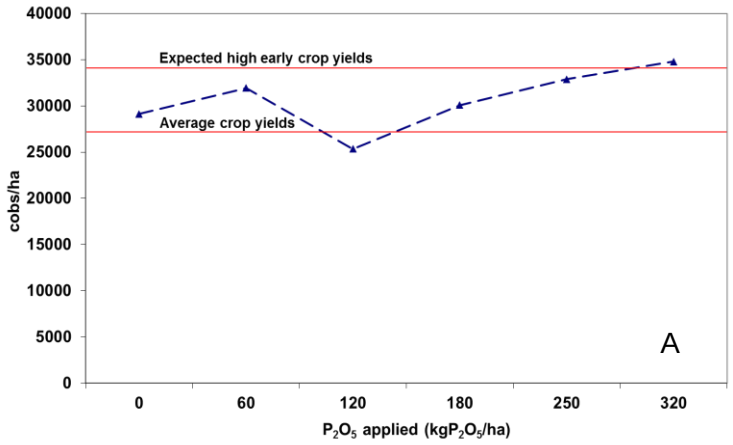
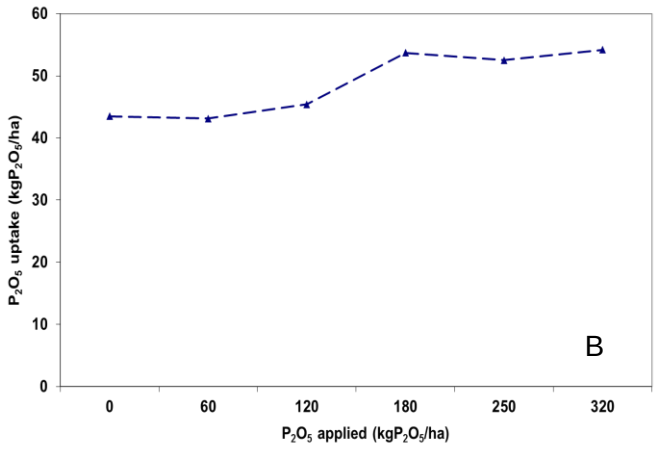


Figure 10. Effects of P_2O_5 rate on sweetcorn at site 13/E1 on A: Numbers of marketable cobs; B: P_2O_5 uptake; C: weight of total cobs shown by dashed line (marketable and non-marketable cobs) and weight of marketable cobs shown by dotted line. Hants 2013.

Site 13/E2, W. Sussex

- Variety, soil type, plant population, previous cropping and SMN as for early nitrogen response site,
- The site had a moderate initial P of 28-39 ppm (P Index 3), and was a moderate-high yielding site with potential yields >30,000 cobs/ha,
- The crop showed a significant response to phosphate applied with regards to uptake of the nutrient (P = 0.054), with an increase in uptake of 10 kg P_2O_5/ha between 120 to 180 kg P_2O_5/ha applied (Figure 11B, also see appendix for full data sets and ANOVA),
- The marketable yield of sweetcorn as weight or numbers of cobs did not show a response to phosphate (Figure 11A),
- The total weight of cobs (marketable and non-marketable) showed a slight increase by 0.9 tonnes/ha between zero and 120 kg P_2O_5/ha, and by a further 0.6 tonnes/ha from 120 to 320 kg P_2O_5/ha but this was not significant (Figure 11C).





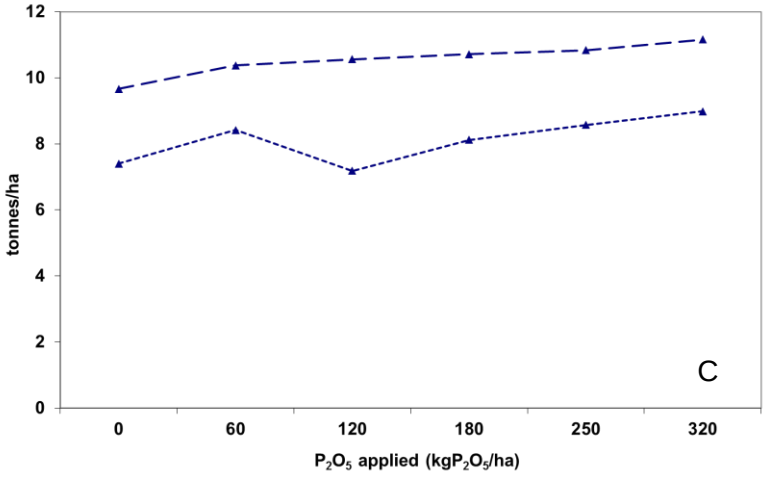


Figure 11. Effects of P_2O_5 rate on sweetcorn at site 13/E2 on A: Numbers of marketable cobs; B: P_2O_5 uptake; C: weight of total cobs shown by dashed line (marketable and non-marketable cobs) and weight of marketable cobs shown by dotted line. W. Sussex, 2013.

Site 13/L1, Hants

- Variety, soil type, plant population, previous cropping and SMN as for the late nitrogen response site,
- The site had a moderate initial P of 25-34 ppm (P Index 2-3),
- The crop at this site was a low-moderate yielding crop compared to the other sites for reasons as in the nitrogen trial results section, and the plants only reached a total biomass of approximately 20 tonnes/ha (Figure 12B). Whereas, crops of the variety 7403 at all other trial sites reached between 30 – 40 tonnes/ha of total biomass,
- The crop showed no significant response to phosphate applied with regards to uptake of the nutrient (Figure 12A, also see appendix for full data sets and ANOVA),
- There were no QA data available for this site.

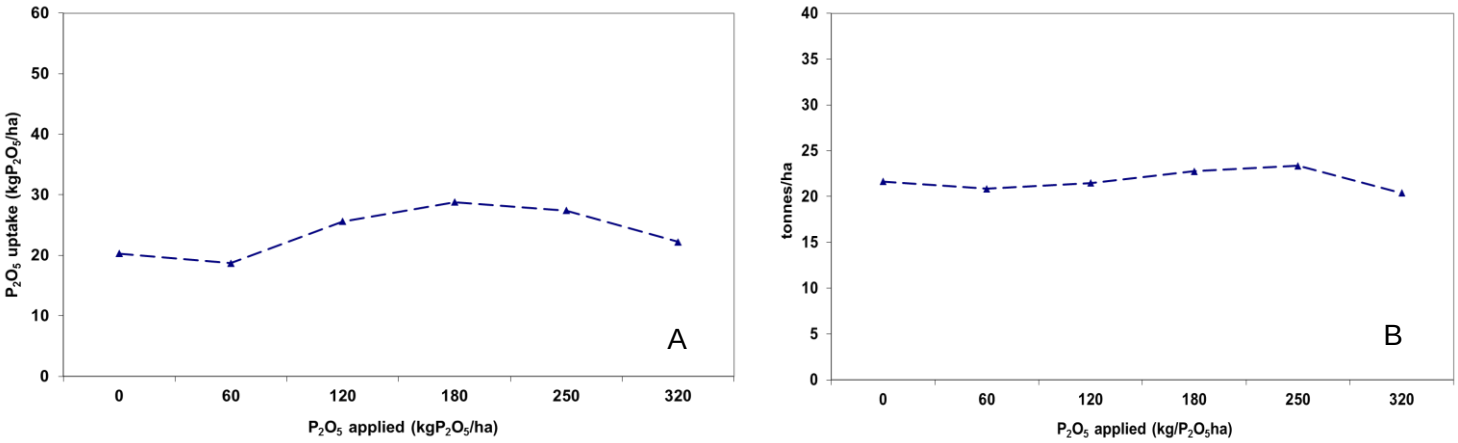


Figure 12. Effects of P_2O_5 rate on sweetcorn at site 13/E3 on A: P_2O_5 uptake; B: weight of above ground plant material, Hants, 2013.

Discussion

The aim of this project is to improve recommendations for N and P applications, and improve efficiency of production of sweetcorn using results gained from field based experiments on grower holdings over a period of two years. The specific objectives were to

- Evaluate N and P utilisation in relation to soil indices and soil mineral nitrogen,
- Measure yield responses of sweetcorn to N and P fertiliser application in a selected commercial genotype,
- Quantify N and P uptake to better guide fertiliser recommendations.

Progress against these objectives from the first year is discussed below.

N and P uptake and utilisation in relation to soil indices and soil mineral nitrogen

Nitrogen uptake and utilisation

There was a significant response to N applied, and crop N uptake increased steadily across all early and late sites with higher rates of nitrogen applied. The exception was the late-sown site L1 (low to moderate yield potential), resulting from a reduction in plant population and total biomass through water stress (see results section), and showed no N uptake response to applied nitrogen fertiliser (Figure 13). No marketable yield data were available for this site, so potential yield estimate is based on reduced crop biomass as the plants only reached a total biomass of approximately 20 tonnes/ha, representing around half of the biomass obtained from variety 7403 at all other trial sites.

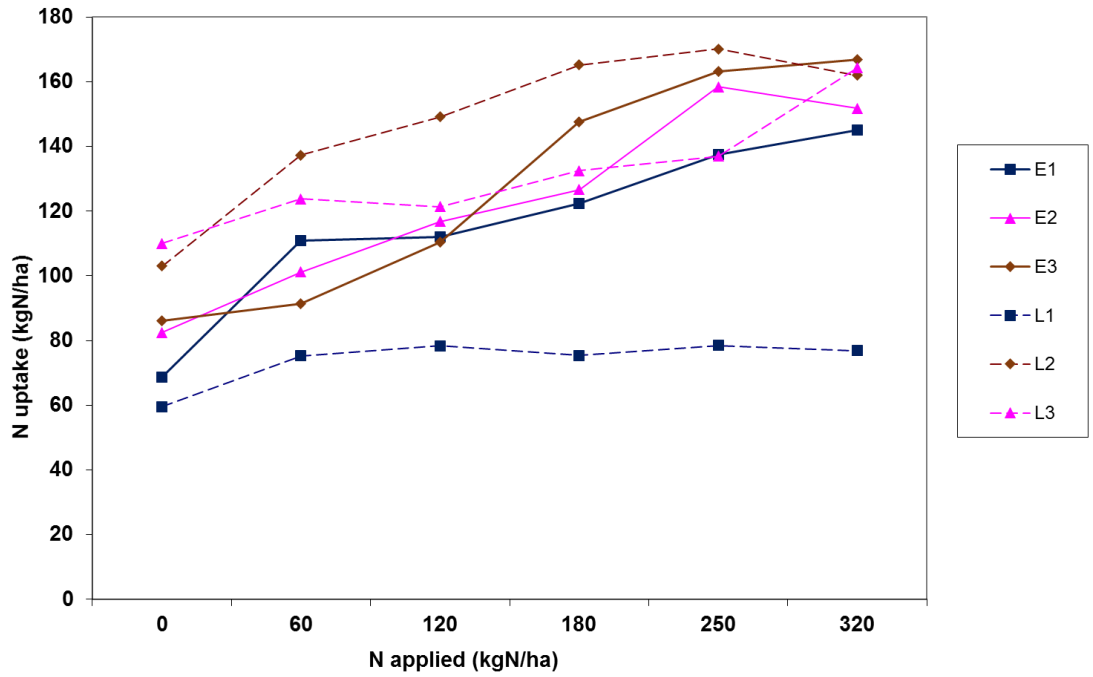


Figure 13. Effect of the application of increasing rates of nitrogen on N uptake, Hants, Sussex and Isle of Wight, 2013.

The maximum uptake from the trials in 2013 was 170 kg N/ha (Fig. 13), which gives a preliminary guide to crop requirements for sweetcorn. This figure is based on results from one year only, using mainly one variety so although this is a useful initial indication, values may vary in the second experimental season.

The soil nitrogen supply (SNS) that was available to the crop at drilling can be calculated from the amount of N uptake in the zero N plots (Table 5). In the table it can be seen that because the sweetcorn crops are drilled in spring after moist soils have warmed, extra nitrogen has become available from the mineralisation of previous crop residues since the initial soil samples taken in February. The polythene covered early crops on average recovered 75 kg N/ha from the soil where zero N was applied. This increased with late-sown crops, approximately 100 kg N/ha was available as SMN to 90 cm depth by the time these crops were drilled. Combining these figures with the crop requirement (170 kg N/ha) from the maximum N uptake, fertiliser needed to meet the needs of the early and late crops can be calculated: Assuming 60% recovery of available nitrogen applied as fertiliser to the crop, a total of 150 kg N/ha would be required to meet the demands of an early polythene covered crop drilled in April, and 100 kg N/ha would be required by a late-drilled (May) crop. It is also worth noting that much of the required nitrogen advised to be applied in the seedbed by RB209 (100 kg N/ha) was already available as SMN at the time of drilling of the late crops.

Table 5. Soil mineral nitrogen available at February soil sampling, at drilling and SNS without additional applied nitrogen in relation to current RB209 recommendations for six sweetcorn sites in 2013.

	Early sites			Late sites		
	E1	E2	E3	L1	L2	L3
SMN (kg N/ha) February	24	37	29	39	29	53
SMN at drilling (kg N/ha)	54	54	59	70	75	100
(Index)	(0)	(0)	(0)	(1)	(1)	(2)
Drilling date	22 April	23 April	24 April	14 May	15 May	23 May
RB209 rec. (kg N/ha)	150	150	150	100	100	50
Actual SNS (kg N/ha) estimated from N uptake at 0N applied	69	82	86	59	103	106

As for P at the early site E2, cobs, stems and leaves were analysed separately for N uptake to investigate nutrient partitioning between these two parts of the plant. N was fairly evenly distributed at harvest, with 53-55% of total N being partitioned to the cobs, which represent 51% to 53% of the total fresh weight of the plant. This is to be expected given that sweetcorn is picked at R2 (milk) while the plant is still actively photosynthesising, requiring much of the N to remain in the foliage.

Phosphorus uptake and utilisation

There was a significant response to P uptake at one site only, where the P index was a low 3, and where samples from the nearby N trial had a P index of 2, suggesting that P is only limiting at quite low levels, and even where responses are seen they are relatively small - 10 kg/ha increase in total phosphate uptake was observed when 180 kg P_2O_5 /ha was applied (Figure 14).

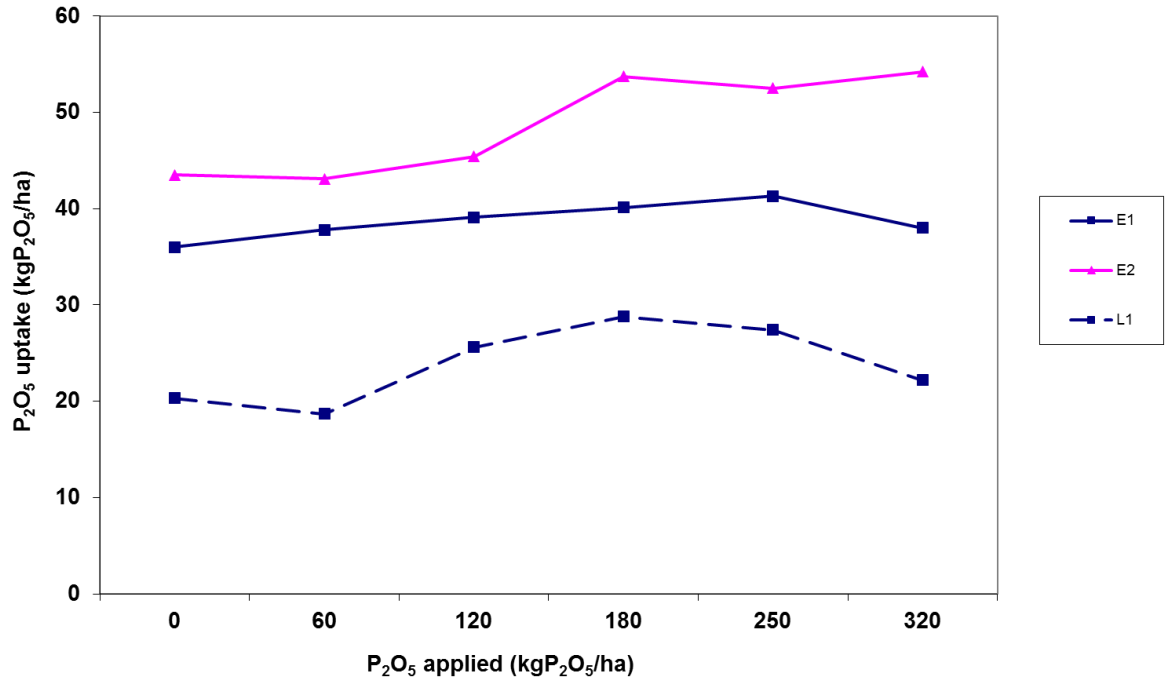


Figure 14. Effect of application rates of phosphate on uptake, Hants and Sussex, 2013.

At early-drilled site E2, cobs were separated from the plants and stems at harvest, and analysis of the uptake of total P to cobs, stems and leaves was measured to determine P harvest index. The P_2O_5 was preferentially taken up into the cobs, with 65-70% being partitioned to the cobs across all rates of applied P. Details of the division of the P_2O_5 between the parts of the plant are in Appendix 1.

Yield responses of sweetcorn to N and P fertiliser application

Marketable yield responses to applied N

Marketable yield responses (number of cobs/ha) to rates of applied nitrogen were seen at two of the early-drilled sites (E1 and E2) and one late-drilled site (L2). The lack of marketable yield response in numbers and weights of marketable cobs at the third early drilled site (E3) may have been caused by picking the crop too early, as some immature cobs failed to meet specifications, causing an anomalous data point at 180 kg N/ha (Figure 15). Late-sown trial L3 showed a small and variable response to N applied which could be due to a high available soil mineral nitrogen (SMN) at drilling (106 kg N/ha). During crop growth and harvest it was difficult to visually distinguish the zero N plots from applied N plots.

The trend at the early site E1 is different to the other sites; variety Earlybird was grown at this site, which produced smaller, less marketable cobs at lower N rates and was smaller in stature with fewer tillers than the maincrop variety 7403 grown elsewhere.

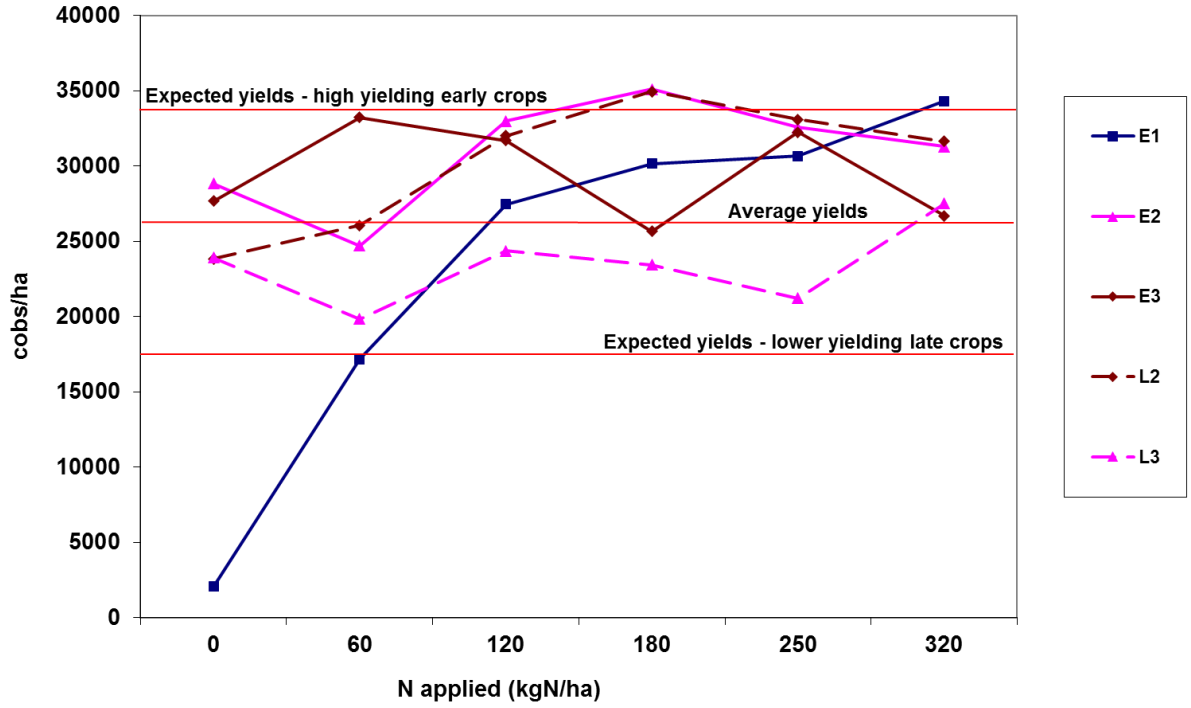


Figure 15. Effect of the application of increasing rates of nitrogen on the number of marketable cobs in early and late drilled sweetcorn crops, Hants, Sussex and Isle of Wight, 2013 (data shown are means of the three N timings treatments in each experiment).

From sites where a response to N applied was seen in marketable cob numbers, N response curves were fitted to show economic optimum N rates for each site. This was calculated at 17 pence/cob and 72 pence/kg of nitrogen. A summary of optimal rates and yields are given in Table 6. At the early site E1 and the late site L2, economically optimal N rates were much higher than current RB209 recommendations, which, contrastingly, were accurate for site E2. An understanding of the yield potential of each site is therefore clearly necessary to assess crop N requirements.

Table 6. Economic optimum nitrogen application rates and timings (in bold) for the three sites with a significant response to marketable yield and where curve fitting could be carried out, Hants, Sussex and Isle of Wight, 2013

Site	N timing treatment	SMN (Feb)	Available N at drilling (SNS) *	RB209 Rec. rate	Economic Optimum (kg N/ha)	Cobs/ha at optimum
E1	All timing data combined	24	69	150	320	33,510
E1	**Seedbed + 45 days**	**24**	**69**	**150**	**196**	**38,257**
E1	3-way split	24	69	150	170	33,153
E1	No seedbed	24	69	150	320	36,142
E2	**Seedbed timings combined**	**37**	**82**	**150**	**157**	**33,752**
L2	**All timing data combined**	**29**	**103**	**100**	**227**	**33,026**

*, Estimated from total N uptake in nil N plots

For the early drilled crop of sweetcorn at site E1 there was a weakly significant timing effect (prob = 0.08) between each of the treatment timings, with higher optimum yields produced at lower rates of nitrogen (196 kg N/ha) when part of the N was applied to the seedbed and then the remainder applied 45 days later just before stem extension. When nitrogen was not applied in the seedbed it took a larger amount (320 kg N/ha) applied as two later applications, associated with a lower yield (Figure 16). Using these results, for an extra 46 kg N/ha applied above current recommendations at a cost of the extra fertiliser needed of £33.12/ha this would produce an additional 1,015 cobs to give an extra benefit of £172.55/ha (N.B. this and the following calculations do not include the cost of spreading).

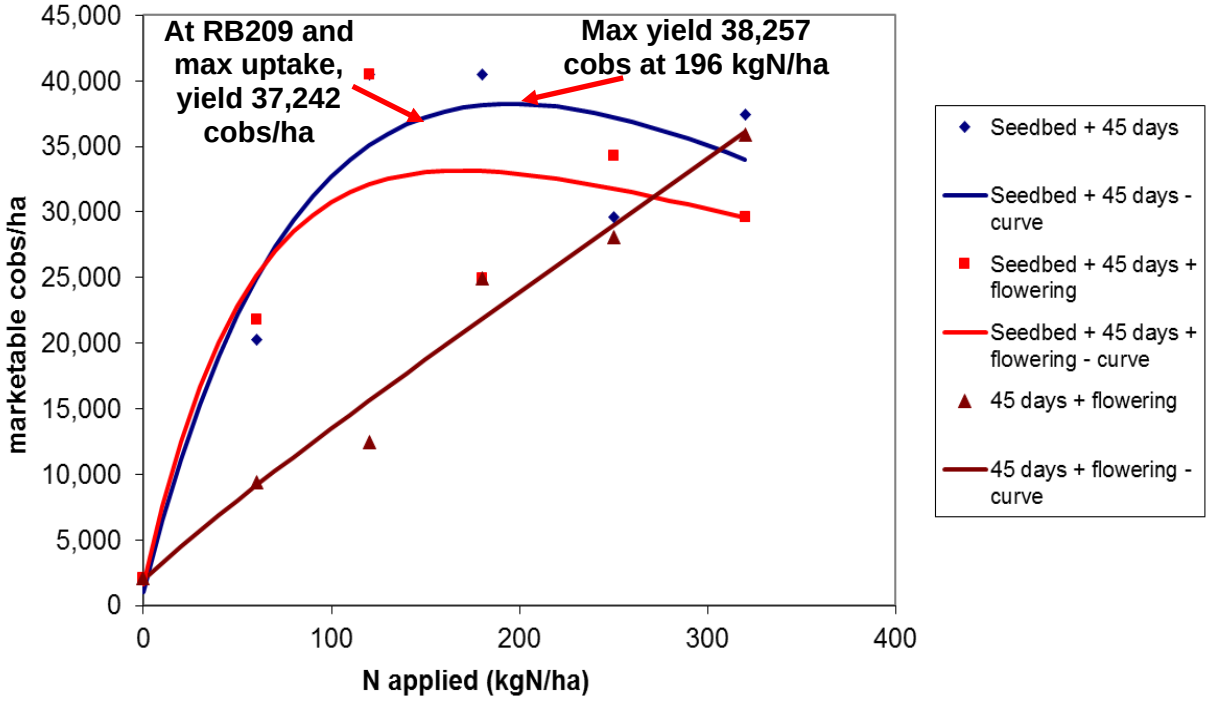


Figure 16. Economic optimum N curves for each of the separate nitrogen application timings for the early drilled crop, site E1 Hants, 2013.

At the late site L2 (Figure 17) there was no N timing effect so the economic optimum curve can be fitted through all the data to give a maximum yield of 33,026 cobs/ha at 227 kg N/ha applied using any of the timing regimes. Using the values that were used for the calculations this gives a benefit of £350/ha for an increase of 2,059 cobs/ha for an extra cost per ha for N of £91.44/ha at current costs. The N rate giving maximum yield potential of 227 kg N/ha for this site matches the current international recommended guidelines (220 kg N/ha: IFA, 1992)

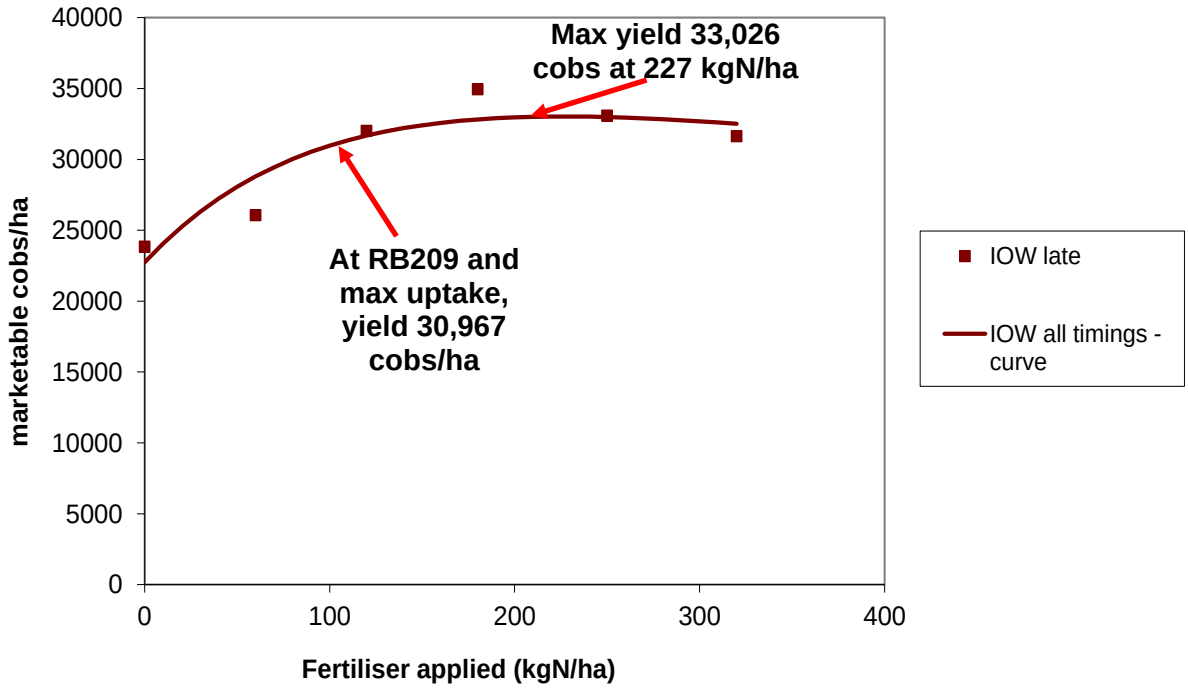


Figure 17. Economic optimum N curve for the late drilled crop, site L2 Isle of Wight, 2013.

At the early drilled site (E1) and the late drilled site (L2), at the recommended (economic optimum) N rate of 196 and 227 kg N/ha respectively to maximise yield, nitrogen would need to be supplied in excess of the trial crop requirements (145 and 170 kg N/ha total uptake respectively). It may be possible to apply this extra N as long as measures are taken to mitigate the environmental consequences of nitrate leaching over winter, such as removing crop residues for anaerobic digestion and undersowing cover crops in the autumn to capture remaining SMN. At a known high yielding site, more nitrogen may also be utilised by the crop, but this is advised only where high yields are consistently achieved.

Timing effects of nitrogen application on cob weight

In the two early crops which were picked at the correct crop ripeness (E1 and E3), there was a significant increase in total cob weight when the nitrogen was applied in the seedbed with the remainder applied as a 2nd application 45 days later just before stem extension (Table 7). There was no significant effect of the timing of the application of the nitrogen on the later drilled crops, which is probably due to the greater amount of available nitrogen at the time of drilling, as indicated by the higher SMN at that time. Given that early N treatments appeared to be the best option for maximising yield, in future years the timing treatments could be refined to explore applying more N in the seedbed, greater than the 100 kg N/ha limit currently recommended.

Table 7. Effect of N application timing on cob weight - Hants, Sussex & Isle of Wight, 2013.

		Weight of non-marketable and marketable cobs (t/ha)			
	*Nitrogen timing**	*T1 Early*	*T2 3 way split*	*T3 Late*	Proba-bility
Early crops	E1	16.93	16.14	15.53	0.099
	E2	10.45	10.6	9.81	0.054
	E3	10.96	10.06	9.78	NS
Late crops	L2	12.76	12.5	13.2	NS
	L3	8.72	8.58	8.61	NS
	Average early sites	12.78	12.27	11.71	-
	Average late sites	10.74	10.54	10.91	-
	Average all sites	11.96	11.57	11.38	-

* see Table 4 for details of N timing treatments

Phosphorus yield responses

There were no significant yield responses to P applied at the two early sites (data were unavailable for the late site), but total cob weight of both marketable and non-marketable sweetcorn increased slightly by 0.5 to 0.9 tonnes/ha when up to 120 kg P_2O_5/ha was applied, and increased by a further 0.6 to 1.03 tonnes/ha between 120 kg P_2O_5/ha and 320 kg P_2O_5/ha (Figure 18). Marketable yields were more variable with no significant trends.

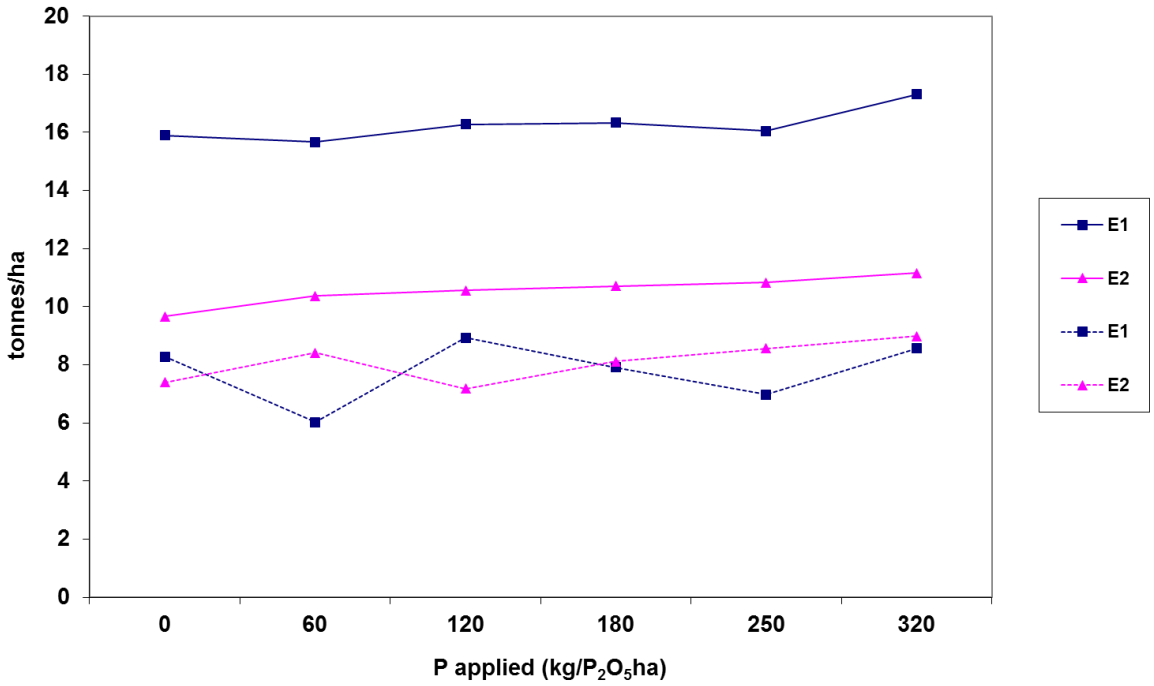


Figure 18. Effect of P_2O_5 application rates on weight of all cobs (unbroken line) and marketable cobs (dotted line), Hants and Sussex, 2013.

Both the sites where the trials were located had a P index of 3, which could have reduced the likelihood of a response to phosphate fertiliser

Effect of N and P application on cob sweetness (BRIX)

Cob sweetness was measured by Barfoots' quality assessment team using BRIX. The only significant effects on Brix values were in one early crop (E1) and two late crops (L2 and L3) comparing zero N (control plots) to all rates of N applied (Table 8). In E1, BRIX levels increased by 1ºBx when N was applied, but were reduced sigficantly by N application in late-sown crops. Importantly, all samples achieved a BRIX score greater than 10ºBx, which is the minimum specification required by the retail market.

Table 8. Effect of N on cob sweetness (BRIX) Hants, Sussex & Isle of Wight, 2013.

	BRIX value (°Bx)			
	Control (0N)	N applied*	P =	LSD
E1	14.40	15.62	0.005	0.832
E2	16.28	16.38	NS	
E3	15.36	15.81	NS	
L2	18.37	17.64	<0.001	0.353
L3	15.58	14.82	0.037	0.713

* values averaged across all rates, as there was no significant response to N rate

Crop leaning was only recorded at site L3 where SMN at drilling was highest but this was not significant (see appendix).

Conclusions

- Results from this first year of study suggest that current RB209 recommendations are appropriate for sweetcorn to maximise cob yield without causing environmental impacts from over-fertilising.
- Providing most of the nitrogen early in growth appears to be the best strategy for early sown crops, but timing is less critical for late sown crops for optimising cob yield.
- Growers should take into account SMN to 90 cm depth prior to drilling, particularly for late sown crops, before deciding on the SNS index of a particular site.
- For late sown crops, particular consideration should be given to retesting for SMN prior to drilling if a soil sample was previously taken in winter/early spring.
- Growers need not be concerned about under- or overfertilising supersweet varieties with respect to the effects of N on cob sweetness.
- While sweetcorn is known to be sensitive to P deficiency, there is little evidence that current best practice guidelines should be changed at present.
- In future experiments N timings could be refined to explore the possible benefits of applying more than 100 kg N/ha in the seedbed.

Knowledge and Technology Transfer

Project meeting – Barfoots of Botley, Romsey, 28th November 2013.

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Appendix – Complete data sets for each site

13/E1 early N – Hants

SMN February	23.8 kg N/ha	Previous crop (2012)	Tenderstem broccoli
SMN pre drilling	45.7 – 66.9 kg N/ha	Soil type	sandy clay loam over gravel
P pre drilling	(Index 3-4)		
pH	7 – 7.2		
Drilled 22 April	Harvest 13 August	Variety - Earlybird	Plant population = 42.1 plants/10m (56,133 plants/ha)

N rate (kg N/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**	**N timing**	**Seedbed + 45 day**	**Three equal apps**	**45 day + flowering**	**F Prob**	**LSD**
N Uptake (kg/ha)	68.7	110.8	112.0	122.4	137.4	145.0	0.001	18.12	N Uptake (kg/ha)	131.8	130.5	114.2	0.026	16.21
Fresh weight whole plant (t/ha)	21.5	33.6	33.8	35.6	37.2	38.3	NS	-	Fresh weight whole plant (t/ha)	36.5	36.9	33.6	0.091	1.8556
Total fresh weight 15 plants (kg)	5.7	8.9	9.1	9.5	9.9	10.2	NS	-	Total fresh weight 15 plants (kg)	9.7	9.8	8.9	0.091	0.496
Weight main cobs (t/ha)	8.7	13.7	16.1	16.5	17.8	16.9	<0.001	-	Weight main cobs (t/ha)	16.9	16.2	15.5	0.099	0.463
Weight all main cobs per 12 plants (kg)	1.8	2.9	3.4	3.5	3.8	3.6	<0.001	0.173	Weight all main cobs per 12 plants (kg)	3.6	3.5	3.3	0.099	0.496
Weight marketable cobs (kg)	0.1	0.8	1.6	1.5	1.6	1.8	0.01	0.266	Weight marketable cobs (kg)	1.7	1.5	1.2	0.024	0.238
% marketable cobs	3.7	30.6	55.6	53.7	54.6	61.1	0.009	17.03	% marketable cobs	60.0	53.9	39.4	0.010	15.23
Marketable cobs (numbers/ha)	2076	17176	27466	30143	30648	34297	0.009	9,559	Marketable cobs (numbers/ha)	33680	30256	22116	0.010	8,549
Marketable cobs (t/ha)	0.4	3.9	7.4	7.2	7.7	8.4	0.01	1.244	Marketable cobs (t/ha)	8.2	7.2	5.4	0.024	1.113
BRIX	14.4	15.18	15.56	16.01	15.89	15.48	NS	-	BRIX	15.77	15.39	15.71	NS	-

	(T1) Timing 1 Seedbed + 45 day						(T2) Timing 2 Three equal applications (Seedbed, 45 day and flowering)						(T3) Timing 3 At 45 post drilling and flowering						F Prob	LSD
N rate (kg N/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	68.7	115.9	127.2	126.4	148.2	141.6	68.7	137.4	118.9	122.8	126.4	147.0	68.7	79.0	89.9	117.9	137.7	146.3	0.088	25.63
Fresh weight whole plant (t/ha)	21.5	33.4	38.6	36.0	39.2	35.5	21.5	40.6	33.8	35.2	35.1	39.9	21.5	26.9	28.9	35.5	37.4	39.2	0.03	5.957
Total fresh weight 15 plants (kg)	5.7	8.9	10.3	9.6	10.5	9.5	5.7	10.8	9.1	9.4	9.4	10.7	5.7	7.2	7.7	9.5	9.9	10.5	0.03	1.592
Weight main cobs (t/ha)	8.7	14.7	17.5	17.5	19.4	15.5	8.7	14.7	16.2	15.8	16.7	17.4	8.7	11.6	14.4	16.1	17.5	18.1	0.084	1.142
Weight all main cobs per 12 plants (kg)	1.8	3.2	3.7	3.7	4.2	3.3	1.8	3.2	3.5	3.4	3.5	3.7	1.8	2.5	3.1	3.4	3.7	3.8	0.084	0.244
Weight marketable cobs (kg)	0.1	1.1	2.1	2.1	1.6	1.8	0.1	1.1	2.1	1.3	1.8	1.5	0.1	0.4	0.6	1.3	1.5	2.1	NS	-
% marketable cobs	3.7	36.1	72.2	72.2	52.8	66.7	3.7	38.9	72.2	44.4	61.1	52.8	3.7	16.7	22.2	44.4	50.0	63.9	NS	-
Marketable cobs (numbers/ha)	2076	20264	40528	40528	29638	37441	2076	21835	40528	24923	34297	29638	2076	9374	12462	24923	28066	35869	NS	-
Marketable cobs (t/ha)	0.4	4.7	10.1	9.7	7.7	8.7	0.4	4.9	9.5	5.7	8.6	7.1	0.4	2.1	2.7	6.2	6.8	9.4	NS	-
BRIX	14.4	15.47	16.10	15.43	16.33	15.50	14.4	14.70	15.30	15.90	15.73	15.33	14.4	15.37	15.27	16.70	15.60	15.60	NS	-

13/E2 early N – W. Sussex

SMN February	36.7 kg N/ha	Previous crop (2011/12)	Grass then courgettes
SMN pre drilling	51.3 - 57 kg N/ha	Soil type	Clay loam
P pre drilling	(Index 2-3)		
pH	6.8– 7.7		
Drilled 23 April	Harvest 20 August	Variety – 7403	Plant population = 33.83 plants/10m (45,106 plants/ha)

N rate (kg N/ha)	0	60	120	180	240	300	F Prob	LSD		N timing	Seedbed + 45 day	Three equal apps	45 day + flowering	F Prob	LSD
N Uptake total (kg/ha)	82.5	101.2	116.8	126.7	158.4	151.8	<0.001	21.08		N Uptake total (kg/ha)	137.9	136.7	118.4	0.035	18.85
N Uptake cobs (kg/ha)	43.7	54.8	65.0	68.9	81.9	83.2	<0.001	9.61		N Uptake cobs (kg/ha)	75.1	73.8	63.3	0.005	8.59
N Uptake stem/leaves (kg/ha)	38.9	46.5	51.8	57.8	76.5	68.6	<0.001	13.51		N Uptake stem/leaves (kg/ha)	62.8	62.9	55.0	NS	-
% proportion N uptake to cobs	53.4	53.7	55.5	54.4	52.7	54.9	NS	-		% proportion N uptake to cobs	54.5	54.6	53.6	NS	-
Total fresh weight whole plants (t/ha)	29.1	36.7	42.9	44.4	47.9	48.5	<0.001	4.643		Total fresh weight whole plants (t/ha)	44.7	46.2	41.5	0.04	4.179
Total fresh weight cobs (t/ha)	15.1	18.6	21.8	22.8	25.3	25.6	<0.001	2.538		Total fresh weight cobs (t/ha)	23.4	24.0	21.1	0.014	2.267
Total fresh weight stem/leaves (t/ha)	14.1	18.1	21.2	21.6	22.6	22.9	0.002	2.415		Total fresh weight stem/leaves (t/ha)	21.3	22.2	20.4	NS	
% cob total weight as a proportion of whole plant	51.6	50.8	50.6	51.3	53.1	52.9	0.048	2.061		% cob total weight as a proportion of whole plant	52.2	52.0	50.9	NS	
Weight all main cobs (t/ha)	9.6	9.4	10.1	10.9	10.1	10.8	0.006	0.891		Weight all main cobs (t/ha)	10.5	10.6	9.8	0.054	0.796

N rate (kg N/ha)	0	60	120	180	240	300	F Prob	LSD		N timing	Seedbed + 45 day	Three equal apps	45 day + flowering	F Prob	LSD
Weight marketable cobs (t/ha)	6.7	5.8	7.8	8.9	7.9	8.1	0.01	1.635		Weight marketable cobs (t/ha)	8.1	8.3	6.8	0.07	1.462
Marketable cobs (numbers/ha)	28823	24718	32972	35092	32567	31304	0.022	6229		Marketable cobs (numbers/ha)	32161	33333	28507	NS	
% marketable cobs	63.9	54.8	73.1	77.8	72.2	69.4	0.022	13.81		% marketable cobs	71.3	73.9	63.2	NS	
BRIX	16.28	16.39	16.38	16.33	16.42	16.4	NS			BRIX	16.29	16.35	16.52	NS	

	(T1) Timing 1 Seedbed + 45 day						(T2) Timing 2 Three equal applications (Seedbed, 45 day and flowering)						(T3) Timing 3 At 45 post drilling and flowering						F Prob	LSD
N rate (kg N/ha)	0	60	120	180	250	320	0	60	120	180	250	320	0	60	120	180	250	320		
N Uptake (kg/ha)	82.5	111.2	119.3	127.6	163.2	168.1	82.5	114.6	105.2	137.7	176.4	149.5	82.5	77.8	125.9	114.8	135.6	137.7	NS	-
N Uptake cobs (kg/ha)	43.7	61.5	65.6	68.2	87.7	92.4	43.7	64.9	59.2	75.7	89.0	80.1	43.7	37.8	70.1	62.8	68.8	77.0	NS	-
N Uptake stem/leaves (kg/ha)	38.9	49.7	53.7	59.4	75.5	75.7	38.9	49.7	45.9	62.0	87.4	69.4	38.9	40.0	55.8	52.0	66.7	60.7	NS	-
% proportion N uptake to cobs	53.4	54.9	54.9	53.4	54.5	54.9	53.4	56.6	55.9	54.9	51.5	54.1	53.4	49.5	55.7	55.0	52.3	55.7	NS	-
Fresh weight whole plant (t/ha)	29.1	37.5	41.4	43.8	49.7	50.9	29.1	42.2	42.1	47.2	51.2	48.1	29.1	30.5	45.5	42.3	42.7	46.5	NS	-
Total fresh weight cobs (t/ha)	15.1	19.0	21.6	22.5	26.6	27.2	15.1	21.9	21.5	24.4	26.7	25.4	15.1	15.0	22.3	21.5	22.6	24.3	NS	-
Total fresh weight stem/leaves (t/ha)	14.1	18.5	19.8	21.4	23.2	23.8	14.1	20.2	20.5	22.7	24.5	22.7	14.1	15.5	23.2	20.8	20.1	22.2	NS	-
% cob total weight as a proportion of whole plant	51.6	50.8	52.2	51.1	53.7	53.2	51.6	51.9	50.7	51.9	52.3	53.3	51.6	49.5	48.9	50.9	53.2	52.3	NS	-
Weight all main cobs (t/ha)	9.6	10.1	10.2	11.4	9.7	10.8	9.6	10.1	9.8	11.5	10.4	11.1	9.6	7.8	10.1	9.9	10.3	10.6	NS	-
% marketable cobs	63.9	70.4	75	80.6	69.4	61.1	63.9	69.4	66.7	80.6	75	77.8	63.9	24.6	77.8	72.2	72.2	69.4	0.036	19.54
Marketable cobs (numbers/ha)	28823	31755	33830	36355	31304	27560	28823	31304	30086	36355	33830	35092	28823	11096	35092	32567	32567	31304	0.036	
Marketable cobs (t/ha)	6.7	7.7	8.1	9.5	7.4	7.2	6.7	7.5	7.2	9.5	8.5	8.8	6.7	2.4	8.3	7.8	7.7	8.1	NS	-
BRIX	16.28	16.57	16.27	16.37	16.1	16.17	16.28	16.1	16.5	16.07	16.57	16.5	16.28	16.52	16.37	16.57	16.6	16.53	NS	-

13/E3 early N – IOW

SMN February	29.1 kg N/ha	Previous crop (2011/12)	Asparagus then wheat
SMN pre drilling	58 – 61.1 kg N/ha	Soil type	Sandy clay
P pre drilling	(Index 4)		
pH	6.1– 6.6		
Drilled 24 April	Harvest 14 August	Variety – 7403 Plant population = 45.3 plants/10m (54,360 plants/ha)	

Note: Harvested 4 days too early, which affected consistent cob maturity/fill and hence size. Marketability scores would be affected by cobs not being ready.

N rate (kg N/ha)	0	60	120	180	250	320	F Prob	LSD	N timing	Seedbed + 45 day	Three equal apps	45 day + flowering	F Prob	LSD
N Uptake (kg/ha)	86.1	91.4	110.4	147.5	163.1	166.9	<0.001	25.04	N Uptake (kg/ha)	145.3	131.9	130.4	NS	-
Fresh weight whole plant (t/ha)	31.2	38.9	41.8	50.9	52.3	50.8	0.002	7.567	Fresh weight whole plant (t/ha)	48.3	45.6	46.9	NS	-
Total fresh weight 15 plants (kg)	8.6	10.7	11.5	14.1	14.4	14.0	0.002	2.088	Total fresh weight 15 plants (kg)	13.3	12.6	12.9	NS	-
Weight main cobs (t/ha)	9.4	10.1	10.3	10.1	10.5	10.5	NS	-	Weight main cobs (t/ha)	10.9	10.1	9.8	NS	-
Weight all main cobs per 12 plants (kg)	2.1	2.2	2.3	2.3	2.3	2.3	NS	-	Weight all main cobs per 12 plants (kg)	2.4	2.2	2.2	NS	-
Weight marketable cobs (kg)	1.3	1.6	1.5	1.3	1.5	1.4	NS	-	Weight marketable cobs (kg)	1.7	1.4	1.2	NS	-
% marketable cobs	50.9	61.1	58.3	47.2	59.3	49.1	NS	-	% marketable cobs	65.0	52.8	47.2	NS	-
Marketable cobs (numbers/ha)	27669	33214	31692	25658	32235	26691	NS	-	Marketable cobs (numbers/ha)	35334	28702	25658	NS	-
Marketable cobs (t/ha)	5.6	7.3	6.6	5.6	6.9	6.4	NS	-	Marketable cobs (t/ha)	7.9	6.3	5.4	NS	-
BRIX	15.4	16.16	16.07	15.67	15.52	15.66	NS	-	BRIX	15.95	15.53	15.96	NS	-

	(T1) Timing 1 Seedbed + 45 day						(T2) Timing 2 Three equal applications (Seedbed, 45 day and flowering)						(T3) Timing 3 At 45 post drilling and flowering						F Prob	LSD
N rate (kg N/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	66.9	91.7	113.9	168.3	181.5	171.0	91.7	89.5	94.3	146.9	157.7	171.1	99.7	93.2	123.0	127.1	150.1	158.7	NS	-
Fresh weight whole plant (t/ha)	25.8	39.3	43.4	52.3	56.3	50.6	30.4	39.7	36.6	52.0	50.6	49.4	37.3	37.7	45.4	48.5	50.5	52.5	NS	-
Total fresh weight 15 plants (kg)	7.2	10.8	11.9	14.4	15.5	13.9	8.4	10.9	10.1	14.4	13.9	13.6	10.3	10.4	12.5	13.4	13.9	14.5	NS	-
Weight main cobs (t/ha)	9.1	10.8	11.1	10.6	10.8	11.5	9.8	11.1	9.8	9.8	9.8	9.6	9.2	8.2	9.9	9.8	10.5	10.5		
Weight all main cobs per 12 plants (kg)	2.1	2.4	2.4	2.4	2.4	2.5	2.2	2.4	2.2	2.2	2.2	2.2	2.1	1.8	2.2	2.2	2.3	2.3	NS	-
Weight marketable cobs (kg)	1.5	1.9	1.6	1.5	1.8	1.9	1.4	2.1	1.4	1.4	1.2	0.8	0.8	0.8	1.4	0.8	1.6	1.4	NS	-
% marketable cobs	61.1	72.2	63.9	55.6	69.4	63.9	58.3	77.8	52.8	52.8	47.2	33.3	33.3	33.3	58.3	33.3	61.1	50.0	NS	-
Marketable cobs (numbers/ha)	33214	39248	34736	30224	37726	34736	31692	42292	28702	28702	25658	18102	18102	18102	31692	18102	33214	27180		
Marketable cobs (t/ha)	6.6	8.8	7.4	6.7	8.3	8.8	6.4	9.4	6.2	6.5	5.4	3.9	3.7	3.6	6.4	3.6	7.1	6.3		
BRIX	15.3	17.10	16.27	15.47	15.33	15.57	14.53	16.20	15.43	15.33	15.27	15.43	16.20	15.17	16.50	16.20	15.97	15.97	NS	-

13/L1 late N – Hants

SMN February	38.9 kg N/ha	Previous cropping (2011/12)	Sweetcorn then pumpkins
SMN pre drilling	61.9 – 75.5 kg N/ha	Soil type	Shallow sandy clay loam over gravel
P pre drilling	(Index 3)		
pH	6.3– 6.9		
Drilled 14 May	Harvest 18 September	Variety – 7403	Plant population = variable

N rate (kg N/ha)	0	60	120	180	250	320	F Prob	LSD	N timing	Seedbed + 45 day	Three equal apps	45 day + flowering	F Prob	LSD
N Uptake (kg/ha) by ave pop'n	56.1	74.7	74.7	80.8	82.3	74.2	NS	-	N Uptake (kg/ha) by ave pop'n	81.5	77.7	72.8	NS	-
N Uptake (kg/ha) by row length sampled	59.5	75.3	78.3	75.4	78.5	76.8	NS	-	N Uptake (kg/ha) by row length sampled	84.4	75.3	70.8	NS	-
Fresh weight whole plant (t/ha)	17.5	22.1	20.9	22.2	22.6	19.3	NS	-	Fresh weight whole plant (t/ha)	22.2	21.1	21.1	NS	-
Total fresh weight 15 plants (kg)	9.7	12.2	11.6	12.3	12.5	10.7	NS	-	Total fresh weight 15 plants (kg)	12.3	11.7	11.7	NS	-
Plant population /10m	21.0	19.7	21.4	21.3	18.8	19.7	NS	-	Plant population /10m	19.4	20.0	21.3	NS	-

	(T1) Timing 1 Seedbed + 45 day						(T2) Timing 2 Three equal applications (Seedbed, 45 day and flowering)						(T3) Timing 3 At 45 post drilling and flowering						F Prob	LSD
N rate (kg N/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha) by ave pop'n	56.1	76.8	81.1	79.8	98.6	71.3	56.1	66.9	86.8	84.1	76.8	74.1	56.1	80.5	56.3	78.5	71.5	77.2	NS	-
N Uptake (kg/ha) by row length sampled	59.5	78.0	90.3	80.5	96.0	77.0	59.5	70.7	83.7	75.7	71.1	75.3	59.5	77.1	60.9	69.8	68.3	78.1	NS	-
Fresh weight whole plant (t/ha)	17.5	21.1	23.2	21.3	27.1	18.2	17.5	20.2	22.6	21.9	20.1	20.4	17.5	24.8	17.1	23.3	20.8	19.3	NS	-
Total fresh weight 15 plants (kg)	9.7	11.7	12.8	11.8	14.9	10.1	9.7	11.2	12.5	12.2	11.2	11.3	9.7	13.7	9.5	12.9	11.5	10.7	NS	-
Plant population	21.0	18.0	23.0	20.3	19.3	16.1	21.0	20.0	19.0	22.3	18.0	20.6	21.0	21.0	22.3	21.3	19.1	22.5	NS	-

13/L2 late N – IOW

SMN February	29.1 kg N/ha	Previous cropping (2011/12)	Asparagus then wheat
SMN pre drilling	67.5 – 87.3 kg N/ha	Soil type	Sandy clay
P pre drilling	(Index 4-5)		
pH	6.5– 6.9		
Drilled 15 May	Harvest 11 September	Variety – 7403	Plant population = 33.5 plants/10m (40,200 plants/ha)

N rate (kg N/ha)	0	60	120	180	250	320	F Prob	LSD	N timing	Seedbed + 45 day	Three equal apps	45 day + flowering	F Prob	LSD
N Uptake (kg/ha)	103.0	137.3	149.2	165.2	170.1	162.0	0.011	19.58	N Uptake (kg/ha)	158.0	162.6	149.7	NS	-
Fresh weight whole plant (t/ha)	32.7	37.6	40.0	43.3	42.0	40.0	NS	-	Fresh weight whole plant (t/ha)	41.0	41.4	39.3	NS	-
Total fresh weight 15 plants (kg)	12.2	14.0	14.9	16.1	15.7	14.9	NS	-	Total fresh weight 15 plants (kg)	15.3	15.4	14.7	NS	-
Weight main cobs (t/ha)	10.8	11.6	12.6	13.5	13.5	12.9	0.064	-	Weight main cobs (t/ha)	12.8	12.5	13.2	NS	-
Weight all main cobs per 12 plants (kg)	3.2	3.5	3.8	4.0	4.0	3.9	0.064	0.435	Weight all main cobs per 12 plants (kg)	3.8	3.7	3.9	NS	-
Weight marketable cobs (kg)	2.4	2.6	3.3	3.7	3.5	3.3	NS	-	Weight marketable cobs (kg)	3.3	3.1	3.4	NS	-
% marketable cobs	59.3	64.8	79.6	86.9	82.3	78.7	NS	-	% marketable cobs	78.9	75.6	80.9	NS	-
Marketable cobs (numbers/ha)	23839	26050	31999	34934	33085	31637	NS	-	Marketable cobs (numbers/ha)	31718	30391	32522	NS	-
Marketable cobs (t/ha)	7.9	8.8	10.9	12.4	11.6	11.1	NS	-	Marketable cobs (t/ha)	11.2	10.3	11.4	NS	-
BRIX	18.37	17.94	17.5	17.53	17.68	17.57	NS	-	BRIX	17.47	17.67	17.77	NS	-

	(T1) Timing 1 Seedbed + 45 day						(T2) Timing 2 Three equal applications (Seedbed, 45 day and flowering)						(T3) Timing 3 At 45 post drilling and flowering						F Prob	LSD
N rate (kg N/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	103.0	128.4	169.3	162.1	166.4	164.0	103.0	144.0	146.2	180.7	178.8	163.3	103.0	139.6	132.2	152.9	165.0	158.7	NS	-
Fresh weight whole plant (t/ha)	32.7	37.0	44.8	42.8	39.2	41.1	32.7	38.0	38.7	47.0	42.9	40.3	32.7	37.7	36.5	39.9	44.0	38.5	NS	-
Total fresh weight 15 plants (kg)	12.2	13.8	16.7	16.0	14.6	15.3	12.2	14.2	14.4	17.5	16.0	15.0	12.2	14.1	13.6	14.9	16.4	14.4	NS	-
Weight main cobs (t/ha)	10.8	10.7	12.7	13.3	13.2	13.9	10.8	12.1	11.9	13.3	13.5	11.6	10.8	12.0	13.1	14.0	13.7	13.2	NS	-
Weight all main cobs per 12 plants (kg)	3.2	3.2	3.8	4.0	4.0	4.1	3.2	3.6	3.6	4.0	4.0	3.5	3.2	3.6	3.9	4.2	4.1	3.9	NS	-
Weight marketable cobs (kg)	2.4	2.4	3.5	3.7	3.3	3.8	2.4	2.6	2.8	3.7	3.6	2.6	2.4	2.7	3.5	3.8	3.4	3.5	NS	-
% marketable cobs	59.3	61.1	80.6	86.1	77.8	88.9	59.3	61.1	72.2	88.9	91.7	63.9	59.3	72.2	86.1	85.7	77.3	83.3	NS	-
Marketable cobs (numbers/ha)	23839	24562	32401	34612	31276	35738	23839	24562	29024	35738	36863	25688	23839	29024	34612	34451	31075	33487	NS	-
Marketable cobs (t/ha)	7.9	8.1	11.6	12.3	11.2	12.8	7.9	8.8	9.5	12.3	12.2	8.8	7.9	9.6	11.7	12.6	11.4	11.7	NS	-
BRIX	18.37	17.9	17.2	17.1	17.5	17.67	18.37	17.51	17.67	17.9	17.97	17.33	18.37	18.4	17.63	17.57	17.57	17.7	NS	-

13/L3 late N – W. Sussex, Block 1 and 2 only

SMN February	52.9 kg N/ha	Previous cropping (2011/12)	Grass then courgette
SMN pre drilling	90.2 – 108.7 kg N/ha	Soil type	Sandy clay loam
P pre drilling	(Index 3)		
pH	7.1 – 7.4		
Drilled 23 May	Harvest 19 September	Variety – 7403	Plant population = 24.4 plants/10m (32,479 plants/ha)

N rate (kg N/ha)	0	60	120	180	250	320	F Prob	LSD	N timing	Seedbed + 45 day	Three equal apps	45 day + flowering	F Prob	LSD
N Uptake (kg/ha)	110.0	123.8	121.4	132.5	137.0	164.3	0.003	18.11	N Uptake (kg/ha)	140.6	126.8	140.0	NS	-
Fresh weight whole plant (t/ha)	38.3	36.4	34.5	37.4	35.8	36.9	NS	-	Fresh weight whole plant (t/ha)	35.3	35.7	37.6	NS	-
Total fresh weight 15 plants (kg)	17.7	16.8	15.9	17.3	16.5	17.0	NS	-	Total fresh weight 15 plants (kg)	16.3	16.5	17.4	NS	-
Weight main cobs (t/ha)	8.8	8.4	8.7	8.8	8.6	8.7	NS	-	Weight main cobs (t/ha)	8.7	8.6	8.6	NS	-
Weight all main cobs per 12 plants (kg)	3.2	3.1	3.2	3.3	3.2	3.2	NS	-	Weight all main cobs per 12 plants (kg)	3.2	3.2	3.2	NS	-
Weight marketable cobs (kg)	2.5	2.2	2.8	2.6	2.4	2.9	NS	-	Weight marketable cobs (kg)	2.5	2.5	2.7	NS	-
% marketable cobs	73.6	61.1	75.0	72.2	65.3	84.7	NS	-	% marketable cobs	71.7	73.3	70.0	NS	-
Marketable cobs (numbers/ha)	23905	19845	24359	23450	21209	27510	NS	-	Marketable cobs (numbers/ha)	23287	23807	22735	NS	-
Marketable cobs (t/ha)	6.8	6.0	7.5	6.9	6.5	7.8	NS	-	Marketable cobs (t/ha)	6.9	6.7	7.2	NS	-
BRIX	15.58	14.61	14.72	15.00	14.40	15.37	NS	-	BRIX	14.89	14.69	14.88	NS	-
Leaning (%)	6.5	7.7	7.8	7.8	5.7	10.2	NS	-	Leaning (%)	8.7	6.4	8.4	NS	-

	(T1) Timing 1 Seedbed + 45 day						(T2) Timing 2 Three equal applications (Seedbed, 45 day and flowering)						(T3) Timing 3 At 45 post drilling and flowering						F Prob	LSD
N rate (kg N/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	110.1	127.0	129.6	121.8	139.6	184.9	110.1	111.1	118.2	136.1	136.4	132.4	110.1	133.2	116.5	139.6	135.0	175.5	NS	-
Fresh weight whole plant (t/ha)	38.3	36.4	32.3	34.8	36.7	36.3	38.3	37.5	35.8	37.9	31.5	35.9	38.3	35.3	35.3	39.6	39.3	38.3	NS	-
Total fresh weight 15 plants (kg)	17.7	16.8	14.9	16.1	16.9	16.8	17.7	17.3	16.6	17.5	14.5	16.6	17.7	16.3	16.3	18.3	18.2	17.7	NS	-
Weight main cobs (t/ha)	8.8	8.7	8.5	9.4	8.8	8.3	8.8	8.8	8.7	8.8	8.1	8.5	8.8	7.8	8.9	8.1	9.0	9.4	NS	-
Weight all main cobs per 12 plants (kg)	3.2	3.2	3.1	3.5	3.2	3.1	3.2	3.3	3.2	3.3	3.0	3.2	3.2	2.9	3.3	3.0	3.3	3.5	NS	-
Weight marketable cobs (kg)	2.5	2.1	2.2	3.2	2.7	2.5	2.5	2.8	2.8	2.4	1.6	2.9	2.5	1.8	3.3	2.1	2.9	3.3	NS	-
% marketable cobs	73.6	58.3	62.5	87.5	79.2	70.8	73.6	83.3	79.2	70.8	41.7	91.7	73.6	41.7	83.3	58.3	75.0	91.7	0.018	30.25
Marketable cobs (numbers /ha)	23905	18935	20299	28419	25723	22995	23905	27055	25723	22995	13544	29783	23905	13544	27055	18935	24359	29783	0.018	-
Marketable cobs (t/ha)	6.8	5.6	5.9	8.6	7.4	6.7	6.8	7.6	7.4	6.5	4.4	7.9	6.8	4.8	9.0	5.7	7.9	8.8	NS	-
BRIX	15.58	14.95	15.10	15.05	14.65	14.70	15.58	14.15	14.80	15.25	13.95	15.30	15.58	14.74	14.25	14.70	14.60	16.10	NS	-
Leaning (%)	6.5	5.5	9.5	8.5	7.0	13.0	6.5	6.0	4.5	8.5	5.0	8.0	6.5	11.5	9.5	6.5	5.0	9.5	NS	-

13/E1 early P – Hants

SMN February	23.8 kg N/ha	Previous crop (2012)	Tenderstem broccoli
SMN pre drilling	45.7 – 66.9 kg N/ha	Soil type	sandy clay loam over gravel
P pre drilling	(Index 3-4)		
pH	7 – 7.2		
Drilled 22 April	Harvest 13 August	Variety - Earlybird	Plant population = 42.1 plants/10m (56,133 plants/ha)

P rate (kg P2O5/ha)	0	60	120	180	240	300	F Prob	LSD
P2O5 Uptake (kg/ha)	36.0	37.8	39.1	40.1	41.3	38.0	NS	-
Fresh weight whole plant (t/ha)	32.7	33.8	33.9	35.2	36.2	33.9	NS	-
Total fresh weight 15 plants (kg)	8.7	9.0	9.1	9.4	9.7	9.1	NS	-
Weight main cobs (t/ha)	15.9	15.7	16.3	16.3	16.0	17.3	NS	-
Weight all main cobs per 12 plants (kg)	3.4	3.4	3.5	3.5	3.4	3.7	NS	-
Weight marketable cobs (kg)	1.8	1.3	1.9	1.7	1.5	1.8	NS	-
% marketable cobs as a proportion/12	62.5	41.7	64.6	56.3	47.9	60.4	NS	-
Marketable cobs (numbers/ha)	35083	23407	36262	31603	26888	33904	NS	-
Marketable cobs (t/ha)	8.3	6.0	8.9	7.9	7.0	8.6	NS	-
BRIX	15.73	16.08	15.98	16.60	16.12	16.10	NS	-

13/E2 early P – W. Sussex

SMN February	36.7 kg N/ha	Previous crop (2011/12)	Grass then courgettes
SMN pre drilling	51.3 - 57 kg N/ha	Soil type	Clay loam
P pre drilling	(Index 3)		
pH	6.8– 7.7		
Drilled 23 April	Harvest 20 August	Variety – 7403	Plant population = 33.83 plants/10m (45,106 plants/ha)

P rate (kg P_2O_5/ha)	**0**	**60**	**120**	**180**	**240**	**320**	**F Prob**	**LSD**
P_2O_5 Uptake total (kg/ha)	43.5	43.1	45.4	53.7	52.5	54.2	0.054	9.49
P_2O_5 Uptake cobs (kg/ha)	28.2	29.9	30.3	36.2	36.1	36.0	NS	
P_2O_5 Uptake stem/leaves (kg/ha)	15.3	13.1	15.2	17.5	16.4	18.2	NS	
% proportion P_2O_5 uptake to cobs	64.9	69.6	67.1	67.6	69.1	66.4	NS	
Total fresh weight whole plants (t/ha)	42.6	37.9	41.8	47.4	44.1	45.6	NS	
Total fresh weight cobs (t/ha)	22.1	20.9	21.8	25.7	24.0	24.2	NS	
Total fresh weight stem/leaves (t/ha)	20.5	17.0	20.0	21.6	20.2	21.4	NS	
% cob total weight as a proportion of whole plant	51.9	55.3	52.6	54.6	54.4	53.0	NS	
Weight all main cobs (t/ha)	9.7	10.4	10.6	10.7	10.8	11.2	NS	
Weight marketable cobs (t/ha)	7.4	8.4	7.2	8.1	8.6	9.0	NS	
Marketable cobs (numbers/ha)	29138	31935	25350	30086	32882	34777	NS	
% marketable cobs as a proportion/12	64.6	70.8	56.2	66.7	72.9	77.1	NS	
BRIX	16.43	16.55	17	16.7	16.67	16.77	NS	

13/L1 late P – Hants

SMN February	38.9 kg N/ha	Previous cropping (2011/12)	Sweetcorn then pumpkins
SMN pre drilling	61.9 – 75.5 kg N/ha	Soil type	Shallow sandy clay loam over gravel
P pre drilling	(Index 3)		
pH	6.3– 6.9		
Drilled 14 May	Harvest 18 September	Variety – 7403	Plant population = variable/average 27,066 plants/ha

P_2O_5 rate (kg N/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**
P_2O_5 Uptake (kg/ha) by ave pop'n	21.3	21.0	22.1	25.2	25.4	22.0	NS	-
P_2O_5 Uptake (kg/ha) by row length sampled	20.3	18.7	25.6	28.8	27.4	22.2	NS	-
Fresh weight whole plant (t/ha)	21.7	20.8	21.5	22.8	23.4	20.4	NS	-
Total fresh weight 15 plants (kg)	12.0	11.6	11.9	12.6	13.0	11.3	NS	-
Plant population /10m	22.7	18.7	16.6	13.3	17.3	18.5	0.008	4.196