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Project leader:	Dr Richard M. Weightman, ADAS UK Ltd.
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Location of project:	Grower sites in Hants, Sussex and Isle of Wight
Industry Representative:	Mr Neil Cairns, Barfoots of Botley Ltd. West Sussex
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Date project completed:	31 December 2014

DISCLAIMER

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

Headlines

- Using the nitrogen (N) recommendations given in the current RB209 is the most appropriate strategy for sweetcorn fertilisation for just over half of the UK's crops, to maximise cob yield and minimise the environmental impact from over-fertilisation.
- However, economically optimal yield responses to N of up to 1,400 marketable cobs/ha were observed when N was applied at rates above those recommended in RB209 at five out of eleven sites, and where SNS indices were 0 to 1.
- There were no significant responses of marketable cob yields to phosphate fertiliser at four sites with P indices of 2-3, but it is good practice to maintain the P Index at 3 in vegetable rotations and thus replace the expected phosphate off take (up to c. 50 kgP_2O_5/ha at the Index 2-3 sites used in these experiments).

Background

'Supersweet' sweetcorn, which is predominantly sold as fresh intact produce ranging from whole cobs to cobettes, now accounts for the majority of the UK area of sweetcorn. It differs from older varieties of the more traditional normal endosperm sweetcorn in its characteristic length of sweetness after picking, with the newer varieties remaining sweeter for longer. The crop specific protocol for sweetcorn (Assured Crop Produce, 2014) advises that when selecting a sweetcorn variety the soil type, fertility, soil temperature characteristics, shelter and irrigation potential of the proposed site should be taken into consideration; the requirements of the end customer must also be considered. However there is little more detailed guidance to the grower. Nitrogen (N) is the major plant nutrient and the recommended N rate for sweetcorn in the Fertiliser Manual (RB209, 8th Edition; Defra 2010) is 150 kgN/ha at N index 0. Not only has this been suggested to be out of date for modern high yielding varieties, but it is also lower than recommended internationally for maximum yield of sweetcorn (220 kgN/ha; IFA,1992). Current guidelines on appropriate levels of N fertiliser for sweetcorn in the fertiliser recommendations may therefore need to be reviewed, because a number of growers may be inadvertently under-fertilising their early-sown sweetcorn crops. Conversely, there is a need to understand whether SMN measurements can usefully be taken into account when estimating crop N fertiliser requirement, particularly for the late-sown sweetcorn crops, where crops may currently be over-fertilised.

It is known that maize is sensitive to P deficiency (Archer, 1985) so it is timely to review P recommendations for sweetcorn production because P requirement of modern high yielding 'supersweet' crops may well be higher compared with existing recommendations in RB209. 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 problems) with forage maize, and 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. Therefore it is timely to review the optimum P rates recommended for modern sweetcorn types.

Summary

A series of eleven field trials were carried out at three early (13/E1-E3), and three late-sown (13/L1-L3) sites in 2013, and three early (14/E1-E3) and two late-sown (14/L1 and L3) sites in 2014. The trials were sited within commercial crops on grower sites in West Sussex, Hampshire and the Isle of Wight. Only two late drilled N response trials were carried through to harvest in 2014 due to excessive crow damage at the site on the Isle of Wight. Field experiments were carried out each year examining the response to six N or P fertiliser rates (eleven N response, and six separate P response experiments). Timing of fertiliser N treatment was also studied in the N response experiments, with fertiliser applied using the following three approaches:

1. Two-way: split 2/3 in seedbed at drilling, 1/3 at growth stage V4-V6 (= current practice)*,
2. Three way split: 1/3 in seedbed at drilling, 1/3 at growth stage V4-V6, 1/3 at flowering,
3. Two-way split: none at drilling, 1/2 at growth stage V4-V6, 1/2 at flowering.

*The maximum applied in the seedbed was 100 kgN/ha to follow current RB209 recommendations.

Phosphate was incorporated into the soil prior to drilling. 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. In the nitrogen trials, P, K, and Mg were applied to current RB209 recommendations to ensure that N was the only limiting nutrient, and in the phosphate trials N, K, and Mg were applied to ensure phosphate was the only limiting nutrient. 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 significant detectable yield responses to applied phosphate, at any of the six 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 would not have been expected. There was an indication of a yield response up to 180 kg P_2O_5/ha applied at one site in 2014 with a soil P index of 2, but this was not significant. The maximum phosphate offtake was 60 kg P_2O_5/ha (range 20-60 kgP_2O_5/ha). The conclusion from the parameters measured in this study is that there is no yield response of sweetcorn to broadcast phosphate fertilisers at soil index 3, but it is good practice to maintain soil P indices and thus replace the expected phosphate off take. Other perceived agronomic benefits of phosphate, for example higher crop growth rate particularly early in the season when the crop struggles to compete against weeds, also need to be considered.

Nitrogen

At nine out of eleven 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 N rate applied (320 kgN/ha). However out of 33 separate N rate x timing combinations studied, only 14 (at sites 13/E1, 13/E2, 13/L2, 14/E2, 14/E3 and 14/L3) gave significant marketable cob yield responses to applied N. For those treatment combinations where it was possible to carry out curve fitting to determine N optima, then using a crop output value of 17 p/marketable cob and 96 p/kg of N fertiliser, the N optima were 196, 157, 227, 250, 232 and 227 kgN/ha compared to RB209 recommendations of 150, 150, 100, 150, 150 and 150 respectively (**Figure 1a and b**).Using the curve fitting approach, five out of 11 crops required a higher rate of N than RB209 recommendations to achieve economically optimal yields. Based on this, the requirements for current sweetcorn varieties may be higher in some situations, and there is scope to fine tune the current recommendations for these circumstances. Table 1 compares the difference in yield (%) between the current RB209 recommendation, the economic optimum and increasing the recommendations by an additional 70 kgN/ha for Index 0 sites, and an additional 50 kgN/ha for the Index 1 site for the N responsive crops in the project. The figures for 'fine tuning' have been calculated by taking the approximate average economic N optimum of all the sites at each Index (0 and 1) for both responsive and non-responsive sites (at non-responsive sites, RB209 is taken to be the optimum). The additional 70 kgN/ha would also bring the recommendations up to the internationally recommended amount of 220 kgN/ha.

The results show that at sites where a strong yield response is expected, applying N at rates above those currently recommended in RB209 can be justified to achieve optimum yields. However, it is also necessary to identify the situations in which the extra required N could be justified, to avoid unnecessary wastage of fertiliser which would result in reduced profit margins, and increased environmental risk from diffuse pollution, if the crop requirement were to be lower than expected. At a known high yielding site, more N may be utilised by the crop and a higher application justified, but this can only be advised where high yields are consistently achieved. Situations where a strong response is likely are at early, low SNS index sites drilled with the variety Earlybird. Later drilled sites and newer varieties such as 7403 and 1138 also respond to extra applied N but it is harder to predict the strength of these responses and thus a knowledge of agronomic parameters such as site history, aspect and soil type that may inform yield potential should be considered before increasing N above RB209. For example, yield responses at the two late sites in 2013 were quite different: 13/L2 had a good response with max yield of 33,026 cobs/ha at 220 kgN/ha applied, with 75 kgN/ha available as SMN at drilling, while 13/L3 showed no yield response with a lower yield between 25,000 and 28,000 cobs/ha, with 100 kgN/ha as SMN at drilling (Figure 1a).

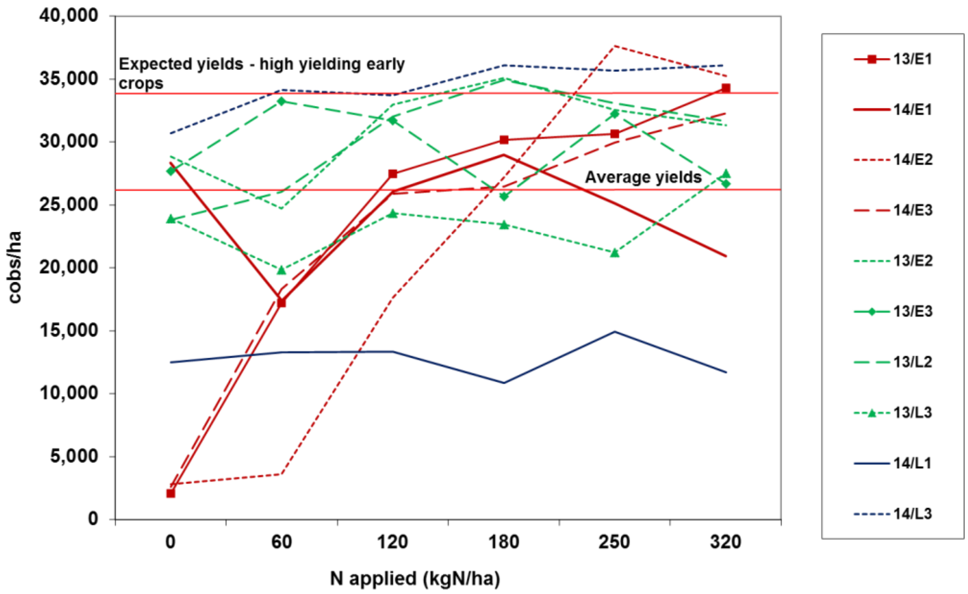

Figure 1a. Effect of the application of increasing rates of nitrogen on the number of marketable cobs in early and late drilled sweetcorn crops, Hants (solid line), Sussex (dotted line) and Isle of Wight (dashed line), 2013/14 (data shown are means of the three N timings treatments in each experiment).

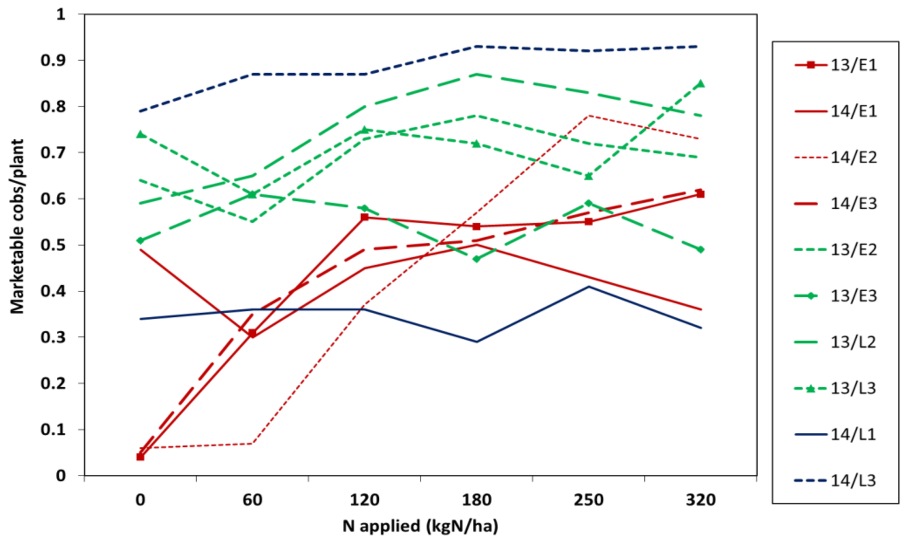

Figure 1b. Effect of the application of increasing rates of nitrogen on marketable cobs per plant (yield potential) in early and late drilled sweetcorn crops, Hants (solid line), Sussex (dotted line) and Isle of Wight (dashed line), 2013/14 (data shown are means of the three N timings treatments in each experiment).
Variety key: Red/brown = Earlybird, Green = 7403, Blue = 1138.

Table 1. Potential yield increase (%) from applying nitrogen at the actual economic optimum and using an increase of 70 kgN/ha or 50 kgN/ha to fine tune the recommendations at N responsive sites, compared to current practice, Hants, Sussex and IOW, 2013/14

				Marketable cobs/ha			% yield increase	
Site	**Index by SMN at drilling**	**RB209 rec. by SMN (kgN/ha)**	**Economic optimum N from trial (kgN/ha)**	**RB209**	**RB209 + 70 or 50 kgN/ha**	**Economic optimum**	**RB209 + 70 or 50 kgN/ha**	**Economic optimum**
13/E1	0 (54)	150	200	37,242	38,039	38,257	2.09	2.66
13/E2	0 (54)	150	157	33,748	33,364	33,752	-1.99	1.18
13/L2	1 (75)	100	230	30,967	32,408	33,026	4.45	6.24
14/E2	0 (46)	150	250	21,215	29,102	32,332	27.10	34.40
14/E3	0 (43)	150	230	27,511	29,707	29,745	7.39	7.50
14/L3	0 (56)	150	230	35,909	36,367	36,369	1.26	1.26
Average early crops /6 (All years)	-	-	-	-	-	-	5.76	7.62
Late crops /4 (All years)	-	-	-	-	-	-	1.43	1.90
Average 2013 /5	-	-	-	-	-	-	0.91	2.01
Average 2014 /5	-	-	-	-	-	-	7.15	8.64
Overall average /10							3.59 -4.03	4.76 – 5.32

Soil mineral N (to 90 cm depth) prior to drilling was 43-59 kgN/ha at the five out of six of the early drilled sites with one site at 138 kgN/ha, and 56 to 100kgN/ha at the late drilled sites. The late sites being generally 1-2 SNS indices higher than the early sites, suggesting that recommended N rates should be lower for the late sown crops (e.g. 20 kgN/ha lower moving from SNS index 0 to 1, or 1 to 2, according to RB209). As estimated from total crop N uptake measured from the predicted N uptake calculations, and assuming the crop can recover all the N available in the soil immediately prior to drilling, it can be seen that on average another -38 kgN/ha in early sown crops and 39 kgN/ha in late sown crops became available (i.e. mineralised) between drilling and harvest. Although these figures are for a narrow range of soil types, these rates of mineralisation should be considered when estimating SNS, and hence fertiliser strategies in the spring.

The maximum N offtake for sweetcorn, across the eleven sites for 2013 and 2014 was around 213 kgN/ha (range 70-213 kgN/ha), even at the highest N rate where 320 kgN/ha was applied. Combined with the fact that total N offtake in cobs is relatively low (80-100 kgN/ha if all the cobs were removed from the field) then the risk of overwinter leaching needs to be considered. The application of fertiliser N above current recommended rates leads to an approximate increase in 60 kgN/ha remaining in crop residues and soil after harvest. If mechanised harvesting is used a lot of crop residue is left behind but as carbon:nitrogen (C:N) ratios are high (>20:1) for the remaining plant tissues, breakdown is likely to be slow, and leaching risk from these residues is lower than from fertiliser N left in soil. Typical C:N values are 66:1 for stems of corn, 98:1 for cobs and 35:1 for leaves, which is why maize cobs and stems are still frequently seen in the field the following year. The whole plant has an overall average C:N value of 69:1 and thus residues will tend to immobilise nitrogen overwinter especially as soil microbial activity slows in cool conditions. However, this reduction in soil microbial activity means that the greatest risk of leaching is from remaining SMN, and applying 70 kgN/ha above recommendations for optimum yield increases the SMN remaining after harvest by on average 50 kgN/ha to approximately 132 kgN/ha. This increase in SMN from applying extra N to achieve higher yields can be mitigated against by using non-legume overwinter cover crops to capture the remaining N. Overwinter cover crops such as grasses, cereals, radish and non-legume mixes can typically capture approximately 50 kgN/ha, and once ploughed in, in spring will release this N for use by the following crop. Crop residues could also be removed to be used for silage or anaerobic digestion where facilities exist.

Nitrogen timing

In the two early crops in 2013 which were picked at the correct crop ripeness (13/E1 and 13/E2), there was a weakly 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 at growth stage V5 (approx. 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 mineralised soil residues, as indicated by the higher SMN at drilling. In 2014 there were no strong significant responses in cob weight to timing of N application.

Cob sweetness

There were no significant effects of any treatments on cob sweetness. All cobs measured had Brix values greater than 13 ^{0}Bx, whereas the minimum sweetness required for the market is a Brix value of 10 ^{0}Bx. Hence there were no problems with this quality character.

Financial Benefits

The UK sweetcorn market is worth ca. £27.4M at retail level based on the annual volume of 19,200 tonnes crop grown in 2014. Based on experimental results, the study shows that for 45% of crops the economic optimum was higher than current recommendations in RB209. If SMN sampling is used to guide SNS Index and current recommendations are increased by c. 70 kgN/ha for Index 0 sites and c. 50 kgN/ha for Index 1 sites where a strong response is expected, then yield could be expected to increase by up to 4.03% on average to give £118/ha increased margin over costs for these crops. The proportion of crops that responded is equivalent to 1,010 ha of sweetcorn, to give £118,955/annum benefit across the industry after the extra N costs are taken into account (calculated on increase on an average yielding crop of 27,000 cobs/ha). The study also suggests that for some late crops drilled in May without polythene covers 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 can indicate as much as 100 kgN/ha will already be available to the crop at this time, allowing for fertiliser inputs to be reduced according to the sweetcorn crop's yield potential. If 85 kgN/ha as calcium ammonium nitrate (current price of £245/t) could be saved, then the grower would benefit by £80/ha (ca. £75/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 £58,000/annum from lower N inputs on these late crops.

Action Points

- Results from this study suggest that for just over half of the UK's crops, using the current recommendations given in RB209 is the most appropriate strategy in sweetcorn, to both maximise cob yield, while minimising the environmental impacts from over-fertilising.
- However, for 45% of crops in the study where a strong response to N fertiliser was seen at SNS Index 0 – 1 sites, rates of between 200 – 250 kgN/ha were necessary to achieve economically optimal yields, and recommendations could be increased for these crops above those stated in the RB209.
- At present such higher recommendations should only be used where there is evidence of a history of high yields, and/or the advice of a FACTS qualified advisor is used.
- There was a difference in the strength of yield response between early (Earlybird) and main crop (7403 and 1138) varieties which could be used to guide N recommendations, but further work would be needed to increase the dataset and confirm trends and N requirements as main crop varieties are sown later and therefore any responses are confounded with higher starting SMN.
- Providing most of the nitrogen early in growth to ensure it is available prior to the sweetcorn's maximum period of demand for vegetative growth (V6 – R1) appears to be the best strategy with respect matching crop uptake to optimise cob yields.
- Growers should consider measuring SMN to 90 cm depth prior to drilling before deciding on the SNS index of a site, particularly for late sown crops and medium soils where consistently predicting the correct SNS index using the field assessment method (FAM) can be difficult.
- With respect to the effects of N on cob sweetness, the results suggest that growers should not have any concerns about under or over fertilising the 'supersweet' varieties, as Brix values were always above the marketing standard, and the greater effect of N is on yield.
- While sweetcorn is known to be sensitive to P deficiency, there is little evidence that current best practice guidelines should be changed at present.

- At nil N the average phosphate offtake was 45 kgP_2O_5/ha, therefore to maintain soil P indices it is considered good practice to replace the phosphate that will be taken off by the crop.

Science Section

Introduction

The ‘supersweet’ sweetcorn type now accounts for the majority of the UK area of sweetcorn. It differs from the more traditional normal endosperm sweetcorn in its characteristic sweetness after picking. The crop specific protocol for sweetcorn (Assured Crop Produce, 2014) advises that when choosing a sweetcorn 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. However there is little more detailed guidance to the grower. Nitrogen (N) is the major plant nutrient and the maximum recommended N rate for sweetcorn in the Fertiliser Manual (Defra 2010; RB209, 8th Edition) is 150 kgN/ha at N index 0. Not only has this been suggested to be out of date for modern high yielding varieties, but it is also lower than recommended internationally for maximum yield of sweetcorn (220 kgN/ha; IFA,1992). Therefore current guidelines on appropriate levels of N fertiliser for sweetcorn in the fertiliser recommendations may be need to be reviewed. Hence many growers may be under-fertilising their early-sown sweetcorn crops. Conversely, there is a need to understand whether SMN measurements can usefully be taken into account when estimating crop N fertiliser requirement, particularly for the late-sown sweetcorn crops, where crops may currently be over-fertilised.

There is somewhat conflicting advice on N timing: The Fertiliser Manual suggests that no more than 100 kgN/ha be applied in the seedbed and the remainder applied as a top dressing when the crop is fully established. The Crop-specific 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. These different approaches need to be tested in a UK field situation.

It is known that maize is sensitive to P deficiency (Archer, 1985) therefore it is sensible to review P recommendations for sweetcorn given the possibly greater 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 problems) with forage maize, and Defra - funded work is currently taking place on this topic. Phosphorus loss tends to be closely related to soil erosion. The European Water Framework Directive (WFD) came into force in December 2000 and became part of UK law in December 2003. Its aim is to plan and deliver a better water environment, focusing on ecology (chemical and biological status). The WFD aims to protect and enhance 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 sensible therefore that sweetcorn growers should also have robust evidence for P recommendations, should any of the wider concerns regarding maize results in constraints on production, which also impact on the sweetcorn crop.

The aim of the project is to improve 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 selected commercial genotype,
- Evaluate N and P utilisation in relation to soil indices and soil mineral nitrogen,
- Quantify N and P uptake to better guide fertiliser recommendations.

Materials and methods

Site selection

2013

Nine experiments were carried out on grower holdings in Hampshire, Sussex and the Isle of Wight in 2013; consisting 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 SNS indices (at which strong responses to applied N and P would be expected) across all three holdings. But, the soil samples taken from the Isle of Wight in February gave a high P result of Index 4 and a late drilled trial in Hants with P indices at the lower end of index 3 was substituted for the original early site. The 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 main crop variety, 7403 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	SNS 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	Silty clay
Isle of Wight	E3	24 April	14 Aug	6.6	0	4, 2-, 1	Sandy silt loam
Hants	L1	14 May	18 Sept	6.7	1	3, 1, 2	Loamy sand (high gravel content)
Isle of Wight	L2	15 May	11 Sept	6.9	1	4, 3, 2	Sandy silt loam
W.Sussex	L3	23 May	19 Sept	7.2	2	3, 2+, 4	Silty 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	Silty clay
Hants	L1	14 May	18 Sept	6.0	1	3, 2-, 2	Loamy sand (high gravel content)

2014

Eight experiments were carried out on grower holdings in Hampshire, Sussex and the Isle of Wight; consisting of five N response trials; three early and two late drilled crops (one late crop lost due to crow damage) and three P response trials. Only two late drilled N response trials were carried through to harvest in 2014 due to excessive crow damage at the site on the Isle of Wight. The aim was to select sites with low P and SNS indices (at which strong responses to applied N and P would be expected) across all three holdings. But, the soil samples taken from the early Hants site in March gave a high P result of index 5 and a late drilled trial in Hants at P index 2 was substituted for the original early site. The 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 late May/early June. Site details are shown in Table 3. Variety choice was agreed in consultation with the host grower and reflected commercial practice, with Earlybird grown at all early drilled sites, and 1138 grown at all late drilled sites.

Table 3. 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 2014.

County	Site	Sowing Date	Harvest Date	Soil pH	SNS Index	Soil index (P, K, Mg)	Soil Type
Nitrogen response trials							
Hants	E1	10 April	30 July	6.5	4	5, 3 , 4	Sandy clay loam (high gravel content)
W.Sussex	E2	17 April	31 July	6.5	0	2, 1 , 2	Silty clay loam
Isle of Wight	E3	10 April	5 Aug	6.7	0	4, 2+, 2	Sandy loam
Hants	L1	20 May	16 Sept	6.6	3	2, 1 , 2	Sandy loam (high gravel content)
Isle of Wight	L2	21 May	N/A*	6.7	0	4, 2+, 2	Sandy loam
W.Sussex	L3	1 June	19 Sept	7.2	0	3, 2-, 3	Silty clay loam
Phosphorus response trials							
W.Sussex	E2	17 April	1 Aug	6.7	0	2, 1 , 2	Silty clay loam
Isle of Wight	E3	10 April	6 Aug	6.4	0	4, 2+, 2	Sandy loam
Hants	L1	20 May	17 Sept	6.6	3	2, 1 , 2	Sandy loam (high gravel content)

* Trial abandoned due to poor establishment due to crow damage

Both years

Selected sites had no history of recent manure use (none applied within the previous 5 years) 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 at RB209 recommended rates 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 and an experimental plot was 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 by ADAS staff. The 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 of nitrogen 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, e.g. 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 timing applications were applied as shown in Table 4 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 growth stage V4-V6 (= current practice)*

2, three way split: 1/3 in seedbed at drilling, 1/3 at growth stage V4-V6, 1/3 at flowering

3, two-way split: none at drilling, 1/2 at growth stage V4-V6, 1/2 at flowering

*The maximum applied in the seedbed was 100 kgN/ha to follow current 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 4. A treatment list of the factorial design for all N x timing treatments for early and late sweetcorn trials in 2013.

Treat No	Rate treat	Timing treat	1st application (kgN/ha)	2nd application (kgN/ha)	3rd application (kgN/ha)	Total N applied (kgN/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 5 in a fully randomised design. The phosphate was applied using triple superphosphate (TSP) (46% P_2O_5), and seedbed applications of N, 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 nutrient deficiencies, and an additional application of nitrogen of 40 kg N/ha was made at 45 days as the trials showed some senescence of lower leaves. No other deficiencies were seen.

Table 5. A treatment list of the phosphorus treatments for early and late sweetcorn trials in 2013.

Treatment Code	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 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 in 2013, and in early March in 2014 once the proposed sites had been identified by the host growers. Sampling was carried out by ADAS to 90 cm, at 30 cm intervals for soil mineral nitrogen (SMN), and to 15 cm for P, K, Mg and Na. This was repeated in early 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 15 cm depth for P, K, Mg and Na prior to fertiliser application and drilling. Soil samples for nitrate analysis were stored in a cool 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 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 primary cobs were picked from each plot by ADAS staff in 2013, and 20 primary cobs were picked in 2014 and placed into labelled bags for determination of marketable yield counts, cob weight and sweetness by Brix by Barfoot's quality assessment (QA) staff. One cob was picked per plant, therefore the cob assessments are based on the primary cobs only. In reality some secondary cobs would be marketable, but it would have been prohibitively time consuming to pick both and the QA assessment of the primary cobs was deemed representative of yield responses. The sample size was increased in 2014 as one N site was abandoned and extra time was gained to allow a larger sample to be picked to reduce sample variability. 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.

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

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).

Yield response curves to applied N were fitted using *GenStat* (16th Edition). In all but one case (site 14/E2), linear plus exponential functions were fitted to the data. The economic optimum was determined in each case, using the fitted response curve, by calculating the N rate at which there was no extra financial benefit from adding further N, therefore giving the N rate which maximised profit. Economic optimum N (Nopt) was calculated for two early (E1 and E2) and one late site (L2) using an N price of 96 p/kg and a value of marketable cobs of 17p/cob (2014 prices).

Results - 2013

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 are given in the following pages, and in addition further summaries of the data sets from the ANOVA outputs are available in the Appendix.

N responses – early sites

Site 13/E1, Hants

- Variety – Earlybird,
- Shallow sandy clay loam,
- Plant population at harvest – 56,133 plants/ha,
- Initial SMN in February was low at 24 kgN/ha, and rose to 46 - 67 kgN/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 kgN/ha required depending on where you place the index boundary, and the previous crop was tenderstem broccoli in 2012 (sweetcorn in 2011),
- The site had a moderate to high initial P of 44-50 ppm (P Index 3-4), and was a moderate-high yielding site with maximum yields >30,000 cobs/ha,
- The crop showed a significant response to applied N fertiliser and curve fitting indicated a significant yield increase up to the highest N rate applied, in both numbers of marketable cobs and weight of marketable cobs (Figures 4A and 4E), with a predicted economically optimum N rate of 320 kgN/ha when data were pooled and analysed across all timings. However, there would be a very high risk of leaching to the environment at such an N rate as only 40% of the N was recovered from SMN and applied N by the crop at this level (see discussion section),
- N had significant effects on most variables including cobs per plant ($p<0.01$), total weight of all cobs picked ($p<0.001$), and marketable weight of cobs ($p<0.05$); this was manifested as a significant increase from 0-120 kgN/ha and a small increase from 120 - 320 kgN/ha (Figures 4B, 4D and 4E),
- Sweetness increased with kgN/ha applied from 14.4 ^{0}Bx at no N applied, peaking at 16.0 ^{0}Bx at 180 kgN/ha but this was not 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 kgN/ha) when part of the N is applied to the seedbed. When N was not applied in the seedbed it took a larger amount (320 kgN/ha) applied later to produce an equivalent yield,
- N uptake by the crop increased significantly with increasing N ($P = 0.001$) applied up to the highest N rate (320 kgN/ha). Maximum N uptake for this crop was 145 kgN/ha at the highest rate (Figure 4C).

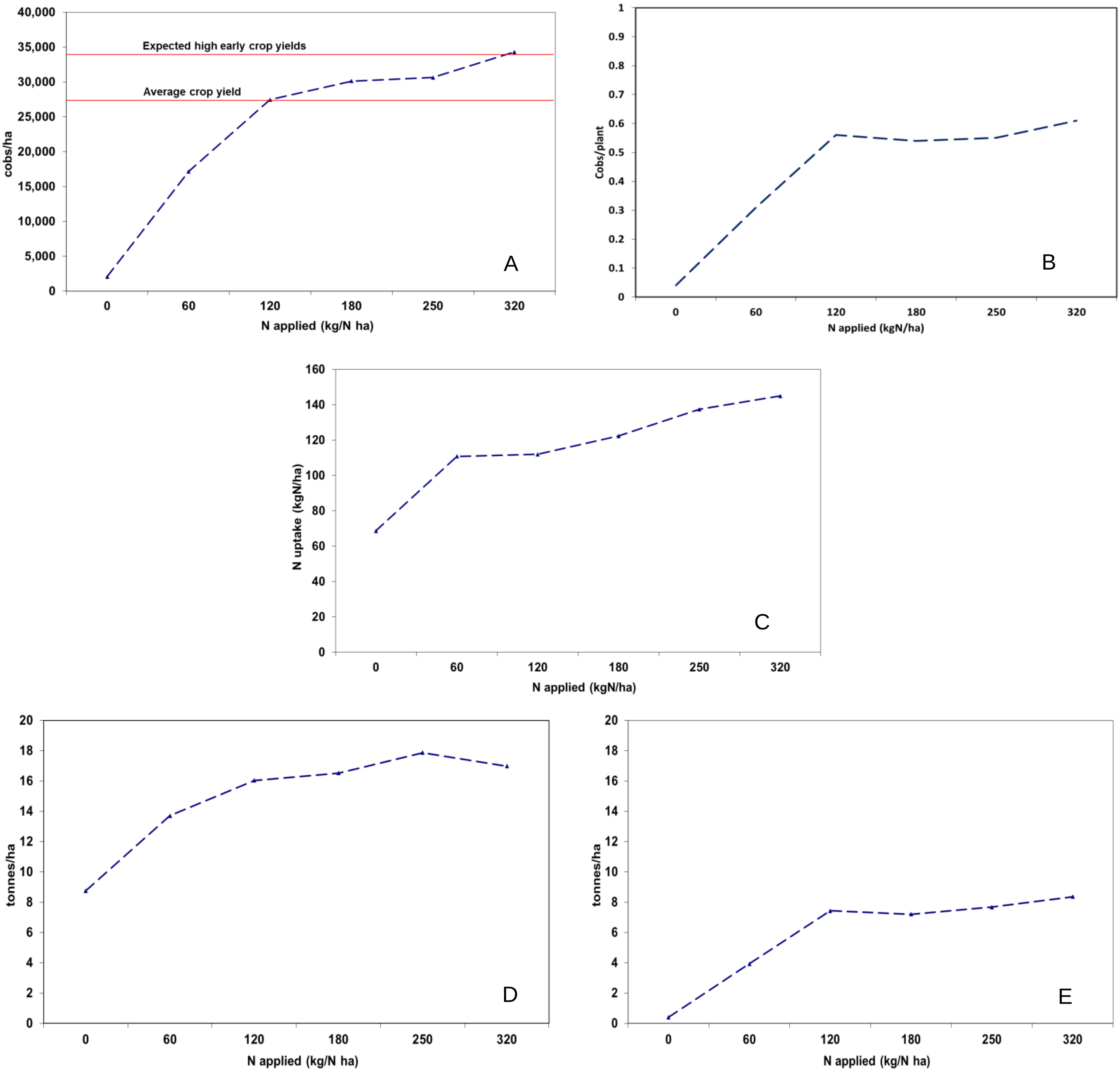

Figure 4. Effects of N rate on sweetcorn at site 13/E1 on A: Numbers of marketable cobs; B cobs per plant; C: N uptake; D: weight of total cobs (marketable plus non-marketable cobs) and E: weight of marketable cobs. Hants 2013 (data shown are means of the three N timings treatments in each experiment).

Site 13/E2, W. Sussex

- Variety – 7403
- Soil type – silty clay
- Plant population at harvest - 45,106 plants/ha
- Initial SMN in February was low at 37 kgN/ha, and rose to 51 - 57 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 23rd April,
- This made E2 an Index 0 site with a recommended rate from RB209 of 150 kgN/ha required and the previous cropping was courgettes in 2012 (1 year grass ley in 2011),
- The site had a moderate initial P of 23 - 27 ppm (P Index 2-3), and was a moderate-high yielding site with maximum yields >30,000 cobs/ha,
- The crop showed a significant yield response to applied N fertiliser (P = 0.022) with a peak at 180 kgN/ha, then yield of both numbers and weight of cobs decreased at higher applied rates (Figure 5A and 5E). It was possible to carry out curve fitting at this site to give a predicted economic optimum N of 157 kgN/ha,
- N had significant effects on most variables including cobs per plant (P=0.022), total weight of all cobs picked (P = 0.006), and marketable weight of cobs; this was manifested as a significant increase from 0-180 kgN/ha, at higher rates of N the whole plant weight increases but cob weight and numbers decline,
- Total N uptake increased up to 250 kgN/ha applied but then declined at 320 kgN/ha (Figure 5C),
- 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 kgN/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 16.3 ^{0}Bx to 16.4 ^{0}Bx.

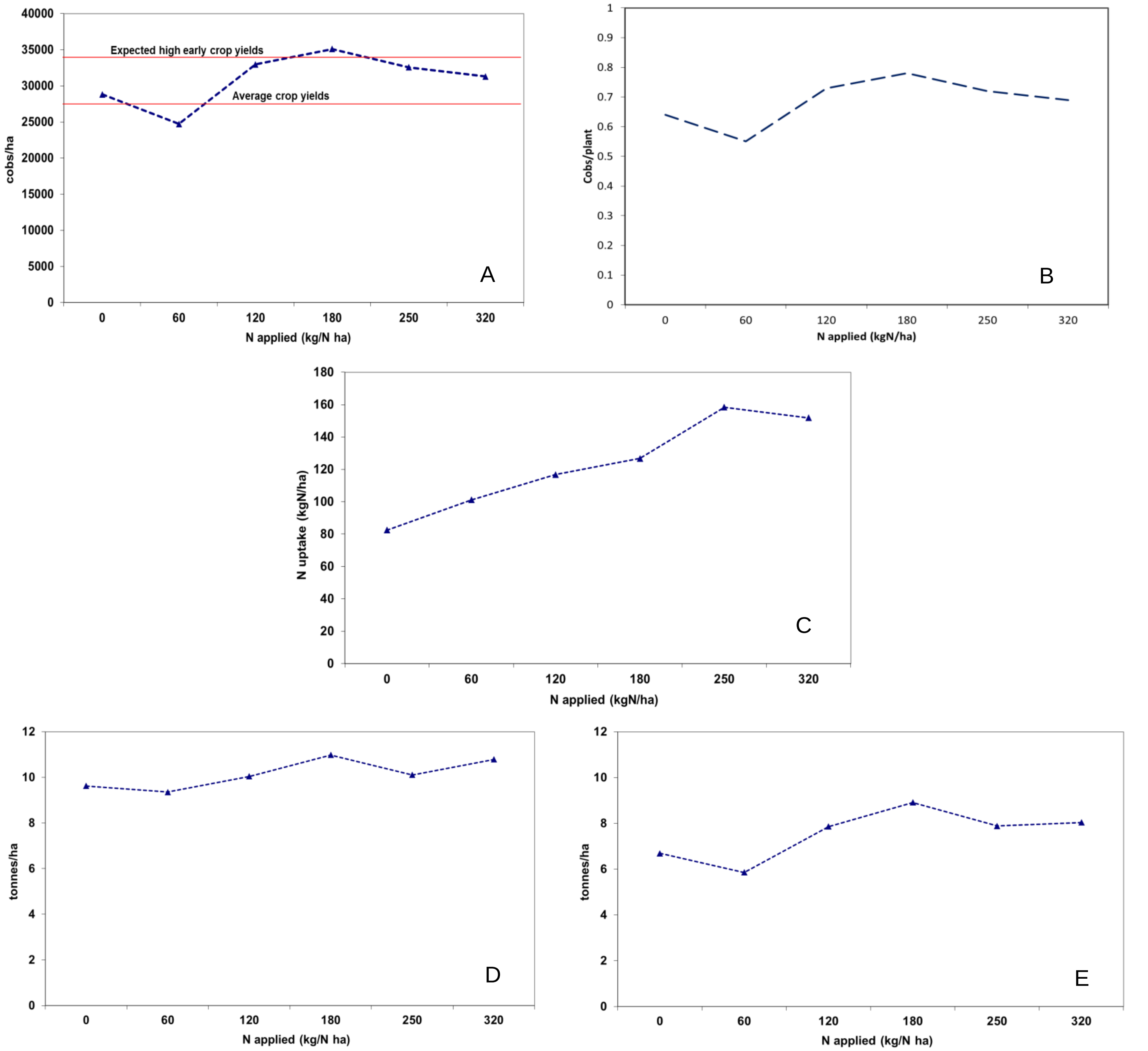

Figure 5. Effects of N rate on sweetcorn at site 13/E2 on A: Numbers of marketable cobs; B: Cobs per plant; C: N uptake; D: weight of total cobs (marketable and non-marketable cobs) and E: weight of marketable cobs. W. Sussex 2013 (data shown are means of the three N timings treatments in each experiment).

Site 13/E3, Isle of Wight

- Variety – 7403
- Soil type – sandy clay
- Plant population at harvest - 54,360 plants/ha
- Initial SMN in February was low at 29 kgN/ha, and rose to 58 - 61 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 24th April,
- This made the E3 site an Index 0 site with a recommended rate from RB209 of 150 kgN/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 maximum yields >30,000 cobs/ha,
- The crop showed no significant yield response in either numbers of marketable cobs or cobs per plant 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, 6B and 6E),
- N applied had significant effects on total N uptake ($p<0.001$) and total biomass ($p<0.01$), at higher rates of N the biomass increasing strongly up to 180 kgN/ha and then at a lower rate of increase between 250 and 320 kgN/ha (Figure 6C). Total N uptake followed a similar pattern,
- 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 kgN/ha (Figure 6D),
- Sweetness did not respond to N applied at this site, varying from 15.4 ^{0}Bx to 16.1 ^{0}Bx.

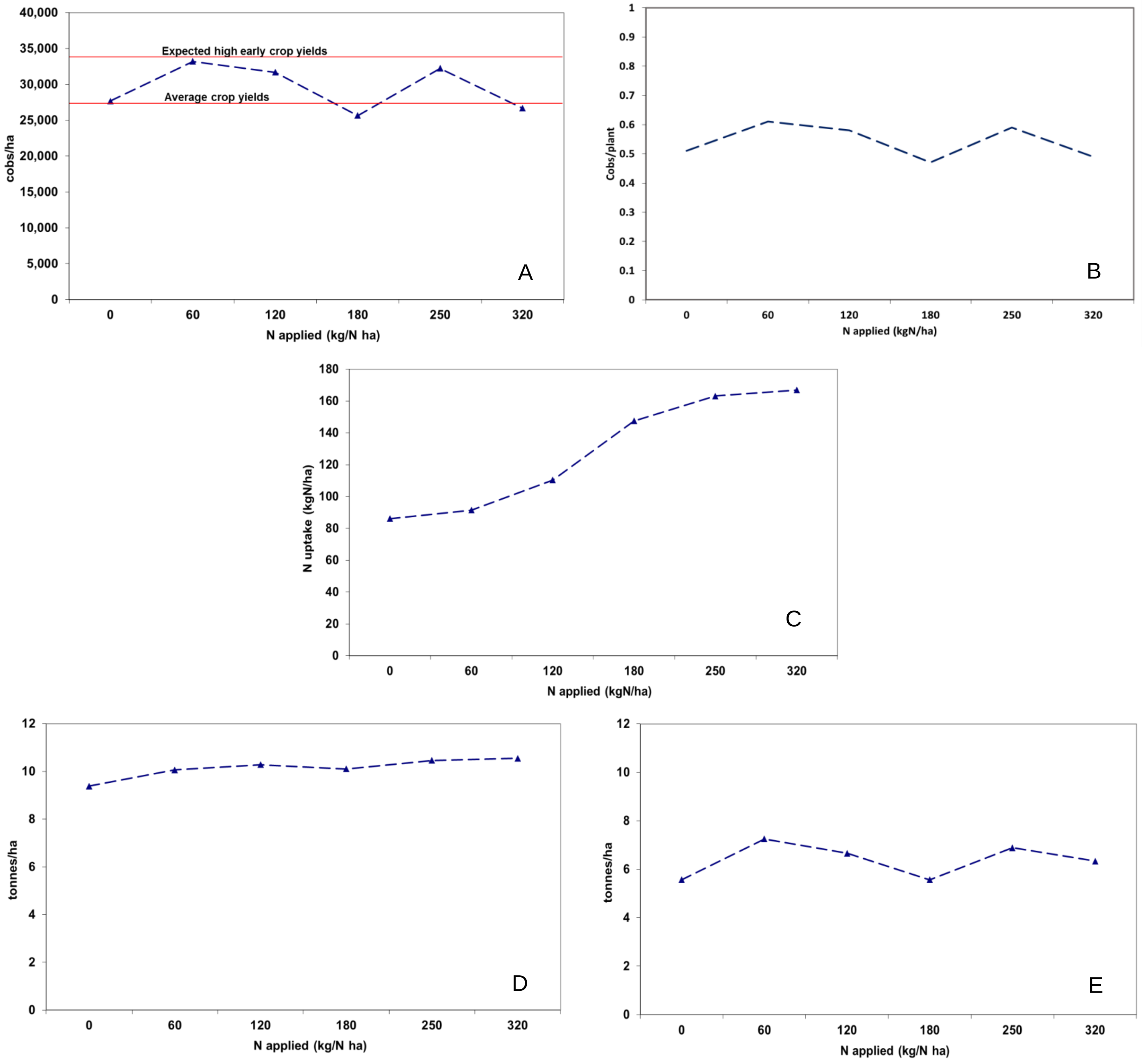

Figure 6. Effects of N rate on sweetcorn at site 13/E3 on A: Numbers of marketable cobs; B: Cobs per plant; C: N uptake; D: weight of total cobs (marketable and non-marketable cobs) and E: weight of marketable cobs. Isle of Wight, 2013 (data shown are means of the three N timings treatments in each experiment).

N responses – late sites

Site 13/L1, Hants

- Variety – 7403
- Shallow loamy sand with a high gravel content (70-80% in top 30cm),
- This was a low-moderate yielding crop compared to the other sites, as the site suffered from limited access to readily available water in the dry summer when irrigation pressure was 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 kgN/ha, and increased to 62 - 75 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 14th May,
- This made L1 an Index 1 site with a recommended rate from RB209 of 100 kgN/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 was much lower than all the other trial sites, and showed no significant differences between treatments (Figure 7A).

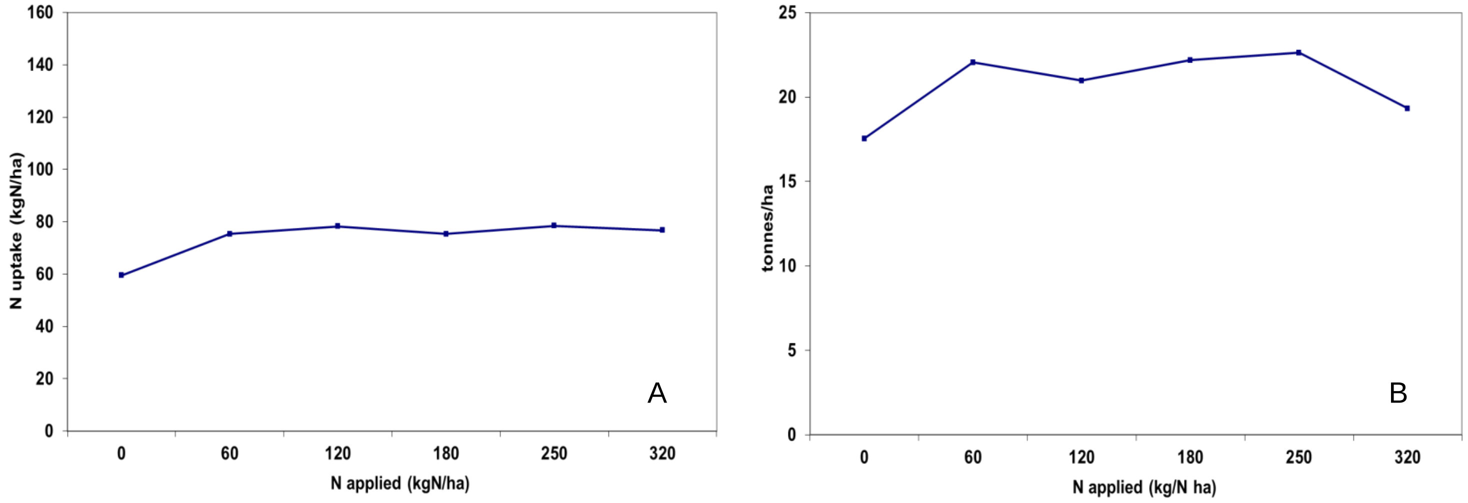

Figure 7. Effects of N rate on sweetcorn at site 13/L1 on A: N uptake; B: total plant weight. Hants 2013 (data shown are means of the three N timings treatments in each experiment).

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 kgN/ha, and rose to 67 - 87 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 15th May,
- This made the L2 site an Index 1 site with a recommended rate from RB209 of 100 kgN/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 maximum yields of >30,000 cobs/ha,
- The crop showed an increasing trend for numbers of marketable cobs per hectare and cobs per plant, with a peak at 180 kgN/ha, after which the yield declined (Figure 8A and 8B), with a statistically significant yield response to applied N fertiliser ($P = 0.021$). In addition, it was possible to carry out curve fitting on the trend to give a predicted economic optimum at 227 kgN/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 increased with a peak at 180 kgN/ha applied, and then the weight decreased between 180 and 320 kgN/ha (Figure 8D),
- However, total N uptake continued to increase up to 250 kgN/ha applied before decreasing slightly at the highest applied rate (Figure 8C),
- Sweetness did not respond to N applied at this site, varying from 17.1 ^{0}Bx to 18.4 ^{0}Bx.

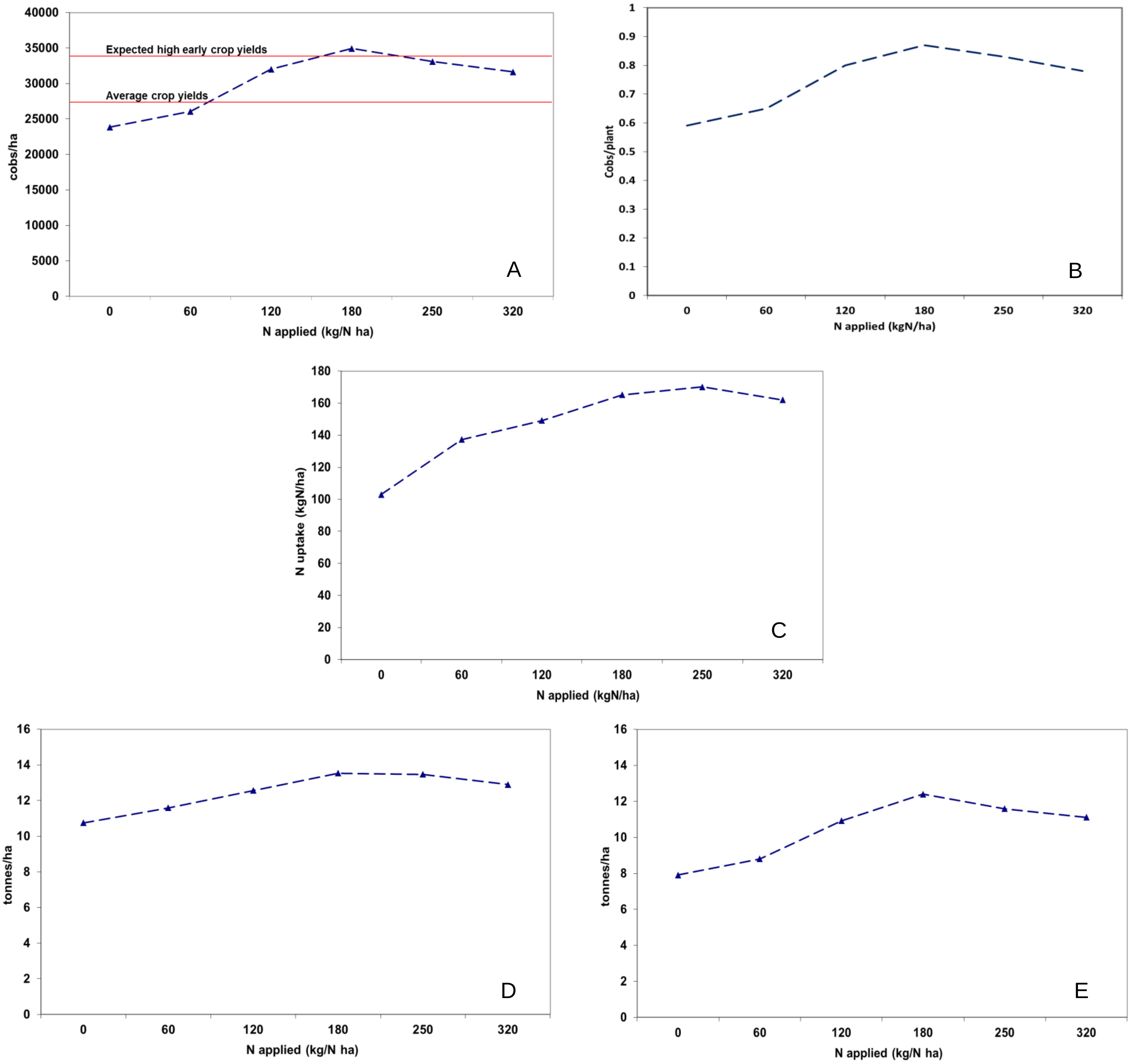

Figure 8. Effects of N rate on sweetcorn at site 13/L2 on A: Numbers of marketable cobs; B: Cobs per plant; C: N uptake; D: weight of total cobs (marketable and non-marketable cobs) and E: weight of marketable cobs. Isle of Wight, 2013 (data shown are means of the three N timings treatments in each experiment).

Site 13/L3, W. Sussex

- Variety – 7403
- Soil type – silty clay loam
- Plant population at harvest - 32,479 plants/ha
- Initial SMN in February was low at 52.9 kgN/ha, and rose to 90.2 – 108.7 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed 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 kgN/ha required and the previous cropping was courgette in 2012 (1 year grass ley in 2011),
- The site had a moderate initial P of 69 - 71 ppm (P Index 3), and was a low-moderate yielding site with maximum 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 or cobs per plant (Figure 9A and 9B), and at this site it was difficult to visually distinguish the zero N plots from the plots where N fertiliser had been applied,
- N applied had significant effects on total N uptake only ($p<0.01$), there was no response in either the weight of total cobs picked, or marketable cobs (Figures 9C – 9E),
- Sweetness did not respond to N applied at this site, varying from 14.4 ^{0}Bx to 15.6 ^{0}Bx.

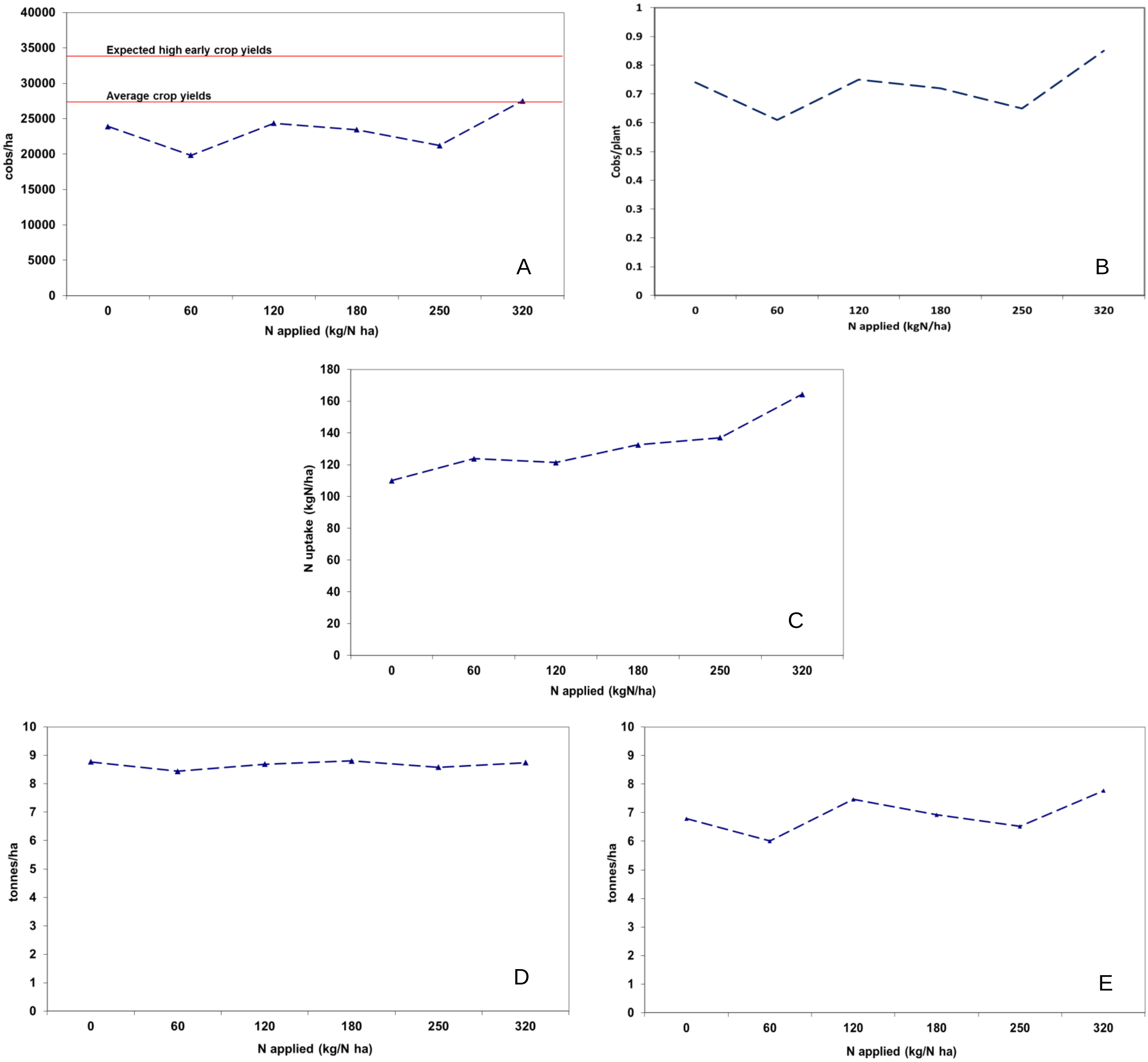

Figure 9. Effects of N rate on sweetcorn at site 13/L3 on A: Numbers of marketable cobs; B: N uptake; C: weight of total cobs (marketable and non-marketable cobs) and D: weight of marketable cobs. W. Sussex, 2013 (data shown are means of the three N timings treatments in each experiment).

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 maximum yields >30,000 cobs/ha,
- The crop showed no response to phosphate applied with respect to P uptake (Figure 10C),
- The marketable yield of sweetcorn as cobs per plant, weight or numbers of cobs did not show a response to phosphate (Figure 10A and 10B),
- The total weight of cobs (marketable and non-marketable) showed a slight increase of 0.38 tonnes/ha between zero and 120 kgP_2O_5/ha applied, and by a further 1.02 tonnes/ha between 120 and 320 kgP_2O_5/ha, but this was not significant (Figure 10D).

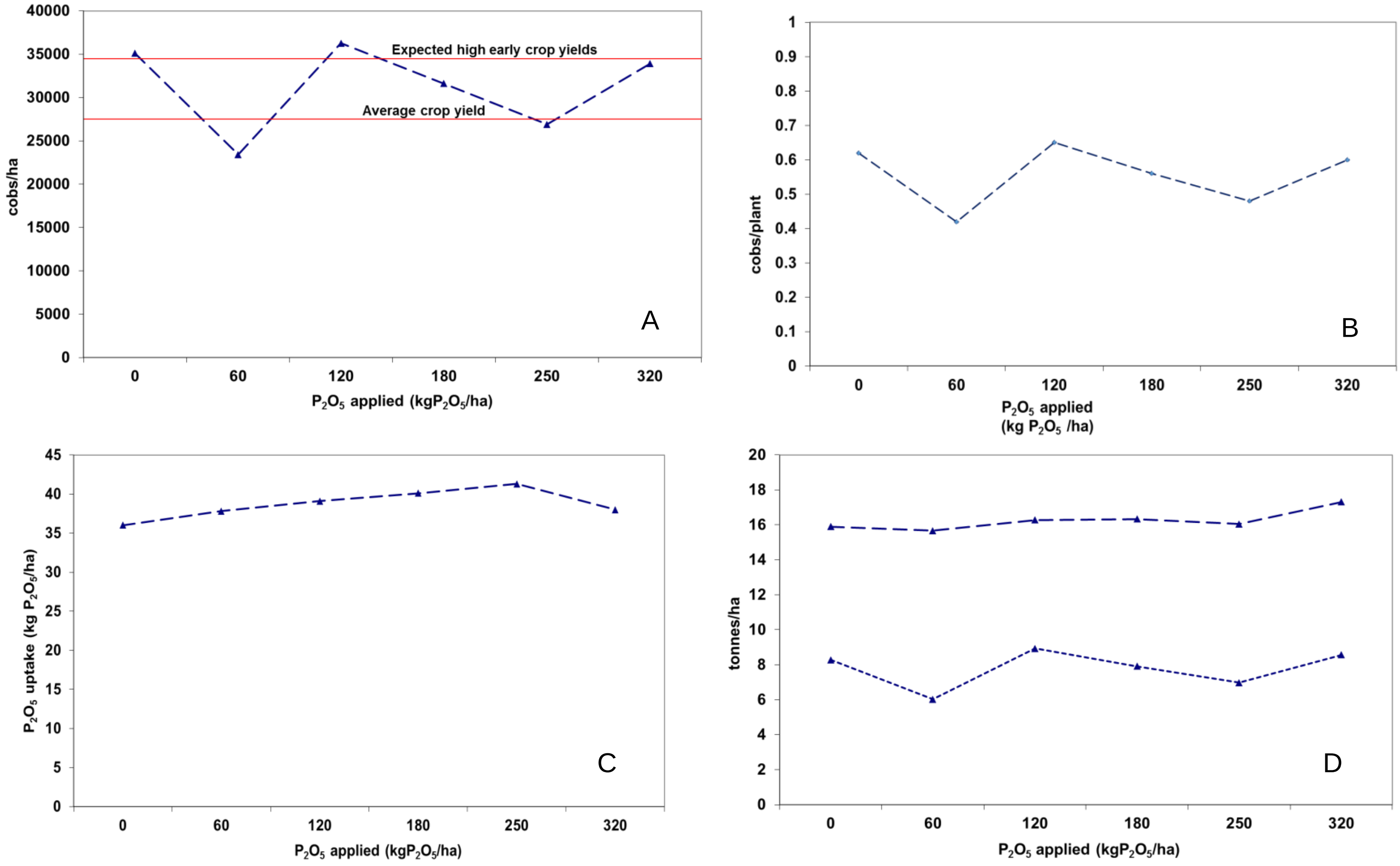

Figure 10. Effects of P_2O_5 rate on sweetcorn at site 13/E1 on A: Numbers of marketable cobs; B: cobs per plant; C: P_2O_5 uptake; D: weight of total cobs shown by dashed line (marketable and non-marketable cobs) and weight of marketable cobs shown by dotted line. Hants 2013.

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 maximum yields >30,000 cobs/ha,
- The crop showed a significant response to phosphate applied with respect to P uptake ($P = 0.054$), with an increase in uptake of 10 kgP_2O_5/ha between 120 and 180 kgP_2O_5/ha applied (Figure 11C),
- The marketable yield of sweetcorn as, cobs per plant, weight or numbers of cobs per hectare did not show a response to phosphate (Figure 11A, 11B and 11D),
- The total weight of cobs (marketable and non-marketable) showed a slight increase by 0.9 tonnes/ha between zero and 120 kgP_2O_5/ha, and by a further 0.6 tonnes/ha from 120 to 320 kgP_2O_5/ha but this was not significant (Figure 11D).

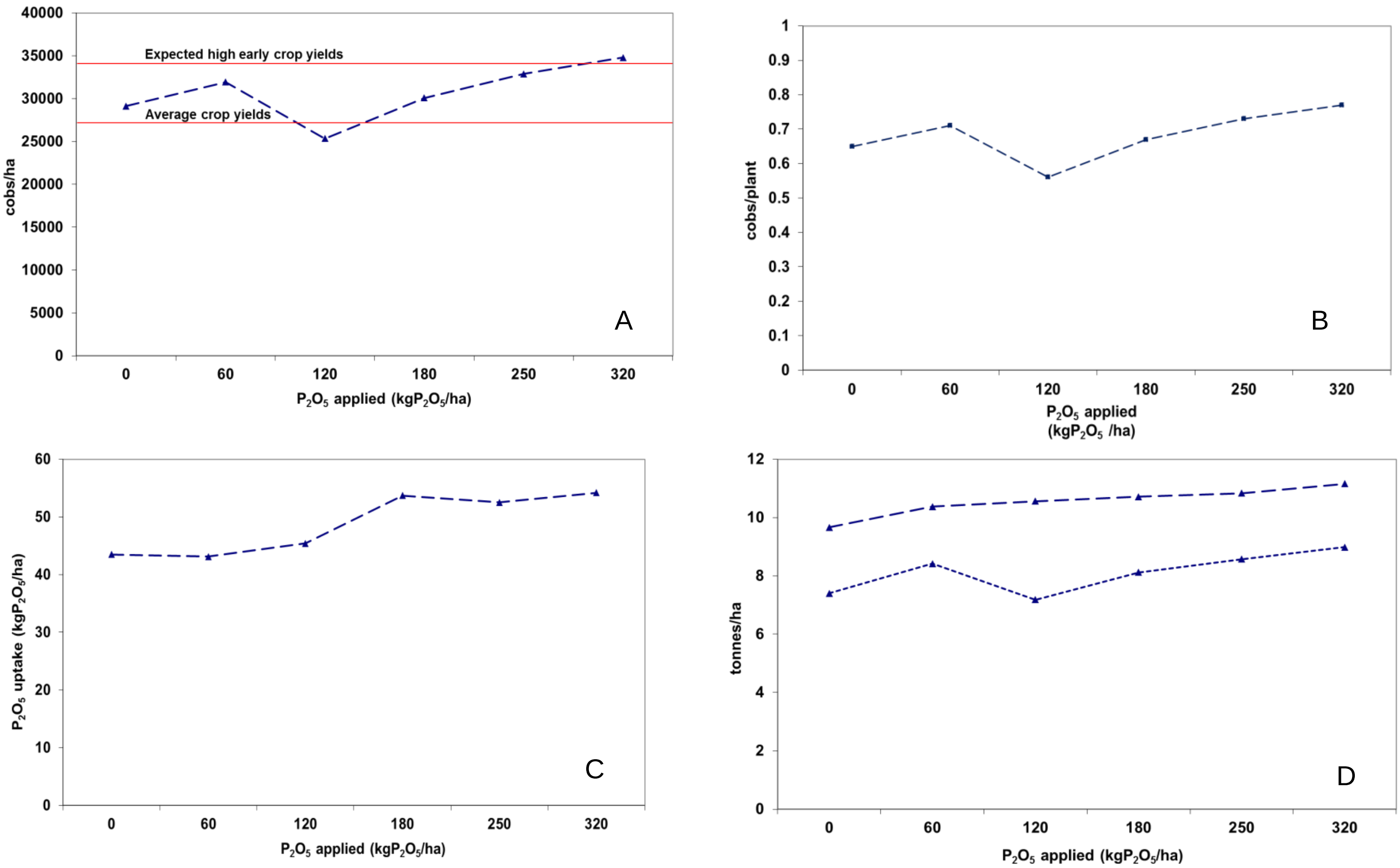

Figure 11. Effects of P_2O_5 rate on sweetcorn at site 13/E2 on A: Numbers of marketable cobs; B: cobs per plant; C: P_2O_5 uptake; D: weight of total cobs shown by dashed line (marketable and non-marketable cobs) and weight of marketable cobs shown by dotted line. W. Sussex, 2013.

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),
- There were no QA data available for this site.

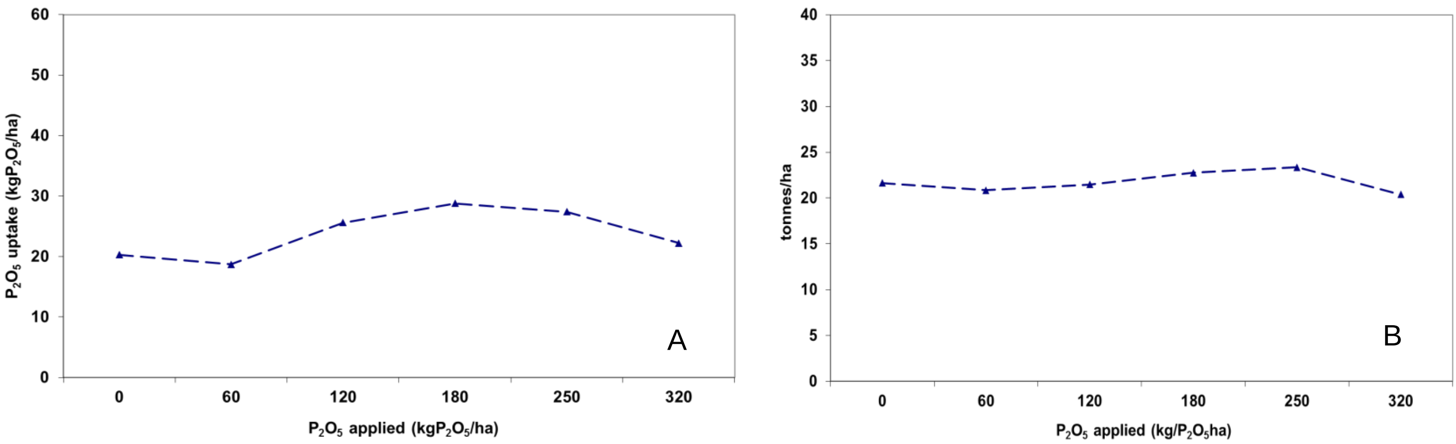

Figure 12. Effects of P_2O_5 rate on sweetcorn at site 13/E3 on A: P_2O_5 uptake; B: weight of above ground plant material, Hants, 2013.

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Results - 2014

The nitrogen and phosphorus response experiments were carried out at six sites across Hampshire, west Sussex and the Isle of Wight in 2014. Only five nitrogen response trials were carried through to harvest due to poor establishment of the late N response trial on the Isle of Wight.

Details of responses at each of the individual sites are given in the following pages, and in addition further summaries of the data sets from the ANOVA outputs are available in the Appendix.

N responses – early sites

Site 14/E1, Hants

- Variety – Earlybird,
- Shallow sandy clay loam with a very high gravel content (60-70% in the top 30cm),
- Plant population at harvest – 57,919 plants/ha,
- SMN was 108 - 196 kgN/ha at drilling, this made E1 an Index 4 site with a recommended rate from RB209 of 0 kgN/ha required (N.B. an N application is still recommended if the SMN in the top 0-30cm is low), and the previous crop was wheat in 2013 (tenderstem broccoli in 2012),
- The site had a high initial P of 75-97 ppm (P Index 5), and was a moderate yielding site with potential yields >28,000 cobs/ha,
- There was no response in N uptake to N applied (Figure 13C), due to sufficient SMN being available at the time of drilling to meet crop demand,
- The crop showed a statistically significant yield reduction to any rate of applied N fertiliser (P = 0.046), expressed as cobs per plant or numbers of marketable cobs per hectare (Figure 13A and 13B), and at this site it was difficult to visually distinguish the zero N plots from the plots where N fertiliser had been applied,
- There was no response in the weight of total cobs picked (Figures 13D – 13E),
- Sweetness did not respond to N applied at this site, varying from 15.7 ^{0}Bx to 15.9 ^{0}Bx.

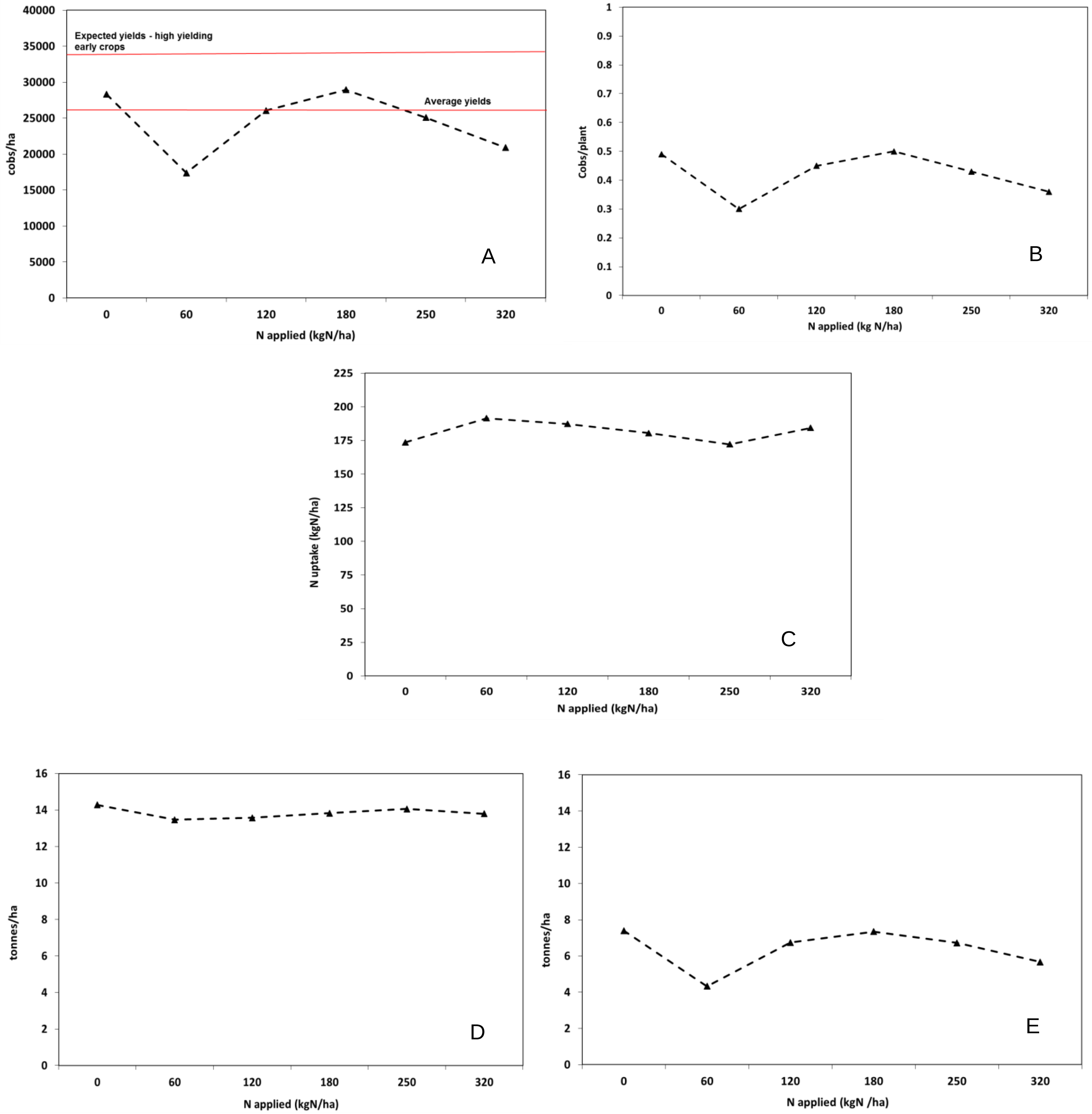

Figure 13. Effects of N rate on sweetcorn at site 14/E1 on A: Numbers of marketable cobs; B cobs per plant; C: N uptake; D: weight of total cobs (marketable plus non-marketable cobs) and E: weight of marketable cobs. Hants 2014 (data shown are means of the three N timings treatments in each experiment).

Site 14/E2, W. Sussex

- Variety – Earlybird,
- Silty clay loam,
- Plant population at harvest – 48,040 plants/ha,
- Initial SMN in February was low at 25 kgN/ha, and rose to 41 - 54 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 17th April,
- This made E2 an Index 0 site with a recommended rate from RB209 of 150 kgN/ha required, and the previous crop was sweetcorn in 2013 (wheat in 2012),
- The site had a low initial P of 18 ppm (P Index 2), and was a high yielding site with maximum yields >35,000 cobs/ha,
- The crop showed a significant response to applied N fertiliser and curve fitting indicated a significant yield increase up to the highest N rate applied, in cobs per plant and both numbers of marketable cobs and weight of marketable cobs (Figures 14A, 14B and 4E), with a predicted economically optimum N rate of 320 kgN/ha when data were analysed across all timings. However, there would be a very high risk of leaching to the environment at such an N rate as only 38% of the applied N was recovered from by the crop at this level (see discussion for further details),
- N had significant effects on most variables including cobs per plant ($p<0.001$), numbers of marketable cobs ($p<0.001$), total weight of all cobs picked ($p<0.01$), and marketable weight of cobs ($p<0.001$); this was manifested as a strong increase in all variables from 0-250 kgN/ha followed by a slight reduction from 250 - 320 kgN/ha (Figures 14A, 14B, 14D and 14E),
- Sweetness increased significantly ($p<0.05$) to 15.28 ^{0}Bx with the application of any rate of N applied, compared to 13.28 ^{0}Bx at nil N,
- N uptake by the crop increased significantly ($p<0.001$) with increasing N applied up to the highest N rate (320 kgN/ha). Maximum N uptake for this crop was 191 kgN/ha (Figure 14C).

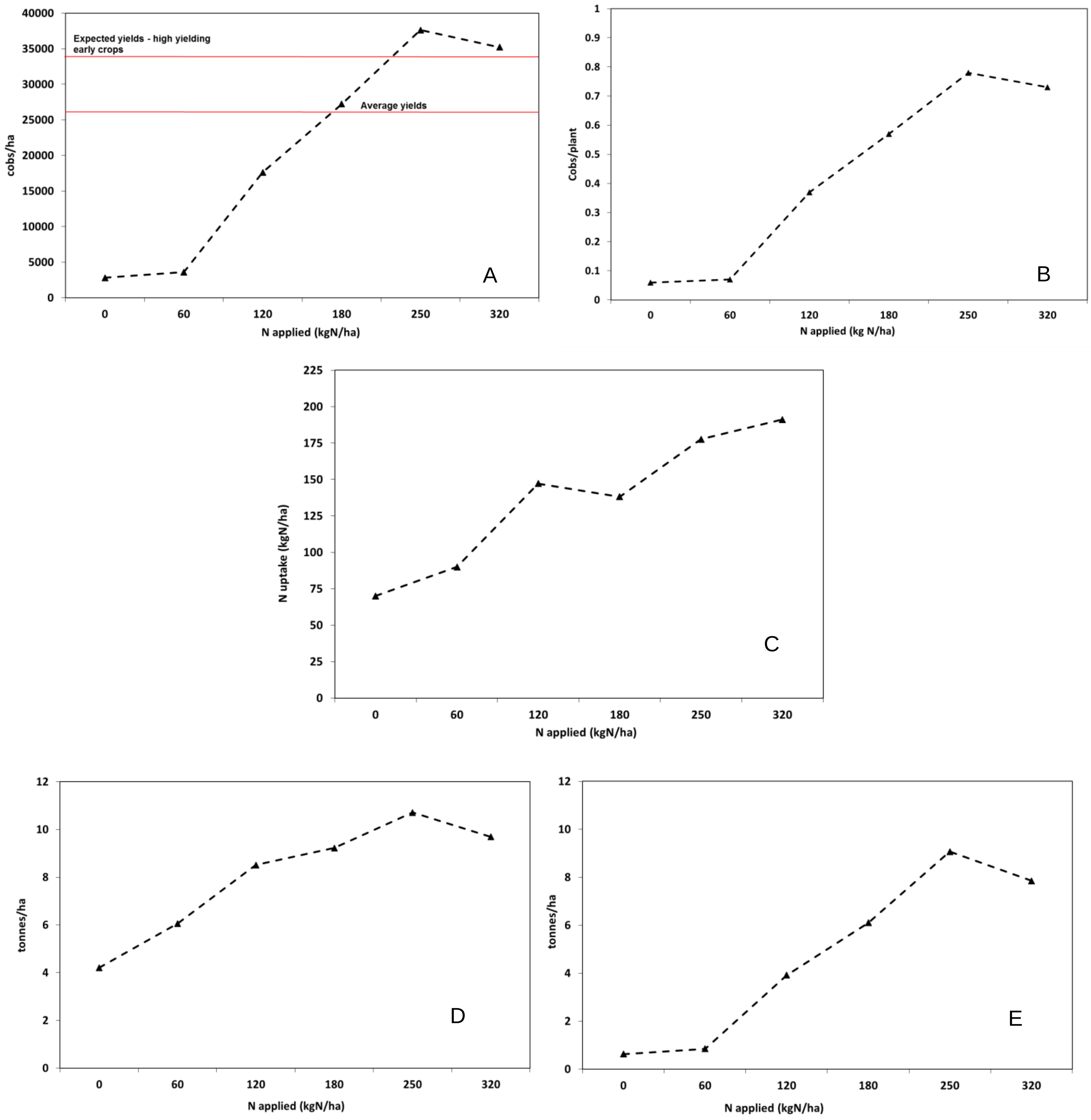

Figure 14. Effects of N rate on sweetcorn at site 14/E2 on A: Numbers of marketable cobs; B cobs per plant; C: N uptake; D: weight of total cobs (marketable plus non-marketable cobs) and E: weight of marketable cobs. W. Sussex, 2014 (data shown are means of the three N timings treatments in each experiment).

Site 14/E3, Isle of Wight

- Variety – Earlybird,
- Sandy loam,
- Plant population at harvest – 52,385 plants/ha,
- Initial SMN in February was low at 20 kgN/ha, and rose to 39 - 46 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 10th April,
- This made E3 an Index 0 site with a recommended rate from RB209 of 150 kgN/ha, and the previous crop was sweetcorn in 2013 (wheat in 2012),
- The site had a moderate initial P of 53 ppm (P Index 4), and was a moderate-high yielding site with maximum yields >30,000 cobs/ha,
- The crop showed a significant response to applied N fertiliser and curve fitting indicated a significant yield increase up to the highest N rate applied, in cobs per plant, numbers and weight of marketable cobs per hectare (Figures 15A, 15B and 15E), with a predicted economically optimum N rate of 320 kgN/ha when data were analysed across all timings. However, there would be a very high risk of leaching to the environment at such an N rate as only 48% of the applied N was recovered from by the crop at this level (see discussion for further details),
- N had significant effects on most variables including cobs per plant ($p<0.05$), numbers of marketable cobs ($p<0.05$), total weight of all cobs picked ($p <0.001$), and marketable weight of cobs ($p <0.001$) per hectare; this was manifested as a strong increase in all variables from 0 - 120 kgN/ha, then a slight increase from 120 – 320 kgN/ha (Figures 15A, 15B, 15E and 15F),
- Sweetness increased significantly ($p<0.05$) with N applied from 19.27 ^{0}Bx at nil N, to a maximum of 20.16 ^{0}Bx at 60 kgN/ha. At higher rates of N, sweetness varied from 18.96 to 19.82 ^{0}Bx,
- N uptake by the crop increased significantly with increasing N ($p <0.001$) applied up to the highest N rate (320 kgN/ha). Maximum N uptake for this crop was 213 kgN/ha (Figure 15C). Timing of application had a significant influence on crop N uptake at this site ($P = 0.021$), with the greatest uptake when the fertiliser is applied in the seedbed at drilling followed by the remainder at V5,
- Fill of mature cobs was also assessed at this site, and increased significantly with increasing N rate ($P = 0.034$), with a peak of fill (91.9%) at 250 kgN/ha (Figure 15D).

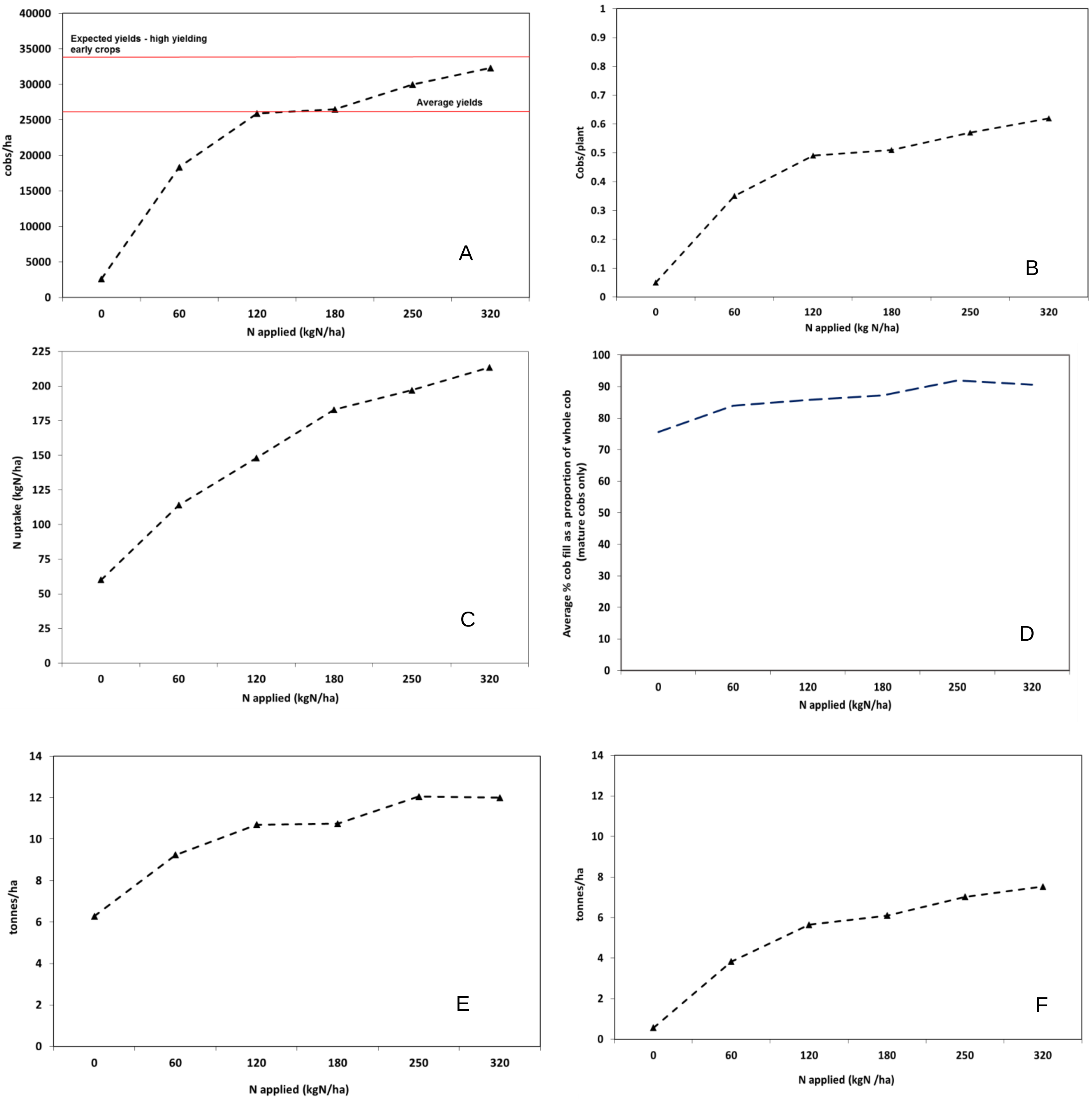

Figure 15. Effects of N rate on sweetcorn at site 14/E3 on A: Numbers of marketable cobs; B cobs per plant; C: N uptake; D: cob fill; E: weight of total cobs (marketable plus non-marketable cobs) and F: weight of marketable cobs. Isle of Wight, 2014 (data shown are means of the three N timings treatments in each experiment).

N responses – late sites

Site 14/L1, Hants

- Variety – 1138,
- Sandy loam with a high gravel content (30-50% in the top 30cm varying across blocks with the greatest percentage of stones in Block 1),
- Plant population at harvest – 36,906 plants/ha,
- Initial SMN in early March was very low at 9 kgN/ha (N.B. this seemed unusually low based on the experience of SMN sampling that ADAS has carried out across a number of farms, soil types and years), and rose to 112 - 114 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 20th May. There was higher mineralisation from crop residues at this site, due to a densely established crop of volunteer wheat, which was ploughed in 6 weeks before drilling in early April.
- This made L1 an SNS Index 4 site with an RB209 recommendation of nil N required (N.B. an N application is still recommended if the SMN in the top 0-30cm is low), and the previous crop was wheat in 2013 (sweetcorn in 2012),
- The site had a low initial P of 23 ppm (P Index 2), and was a low yielding site with yields of only 10,000 – 14,000 cobs/ha due to a pest infestation (N.B. the pest affected all plots relatively evenly so the data was still analysed for yield parameters),
- The crop showed no statistically significant yield response to applied N fertiliser for numbers of marketable cobs per hectare, cobs per plant, weight of total cobs picked or weight of marketable cobs (Figure 16A, 16B, 16D and 16E), and the nil N plots were difficult to distinguish visually,
- N applied had significant effects on total N uptake only ($p<0.05$) (Figures 16C),
- Timing of N application had significant effects on total N uptake ($p<0.01$), cobs per plant and numbers of marketable cobs per ha ($p<0.05$) with the greatest increase in uptake and yield when the fertiliser was applied as three equal splits. However, there was only 470 cobs/ha gain when compared with fertiliser applied at seedbed and V5 growth stage; conversely if no fertiliser was applied to the seedbed, then yield dropped by 5,228 cobs/ha when compared to the three way N timing,
- Sweetness did not respond to N applied at this site, varying from 16.7 ^{0}Bx to 17.1 ^{0}Bx.

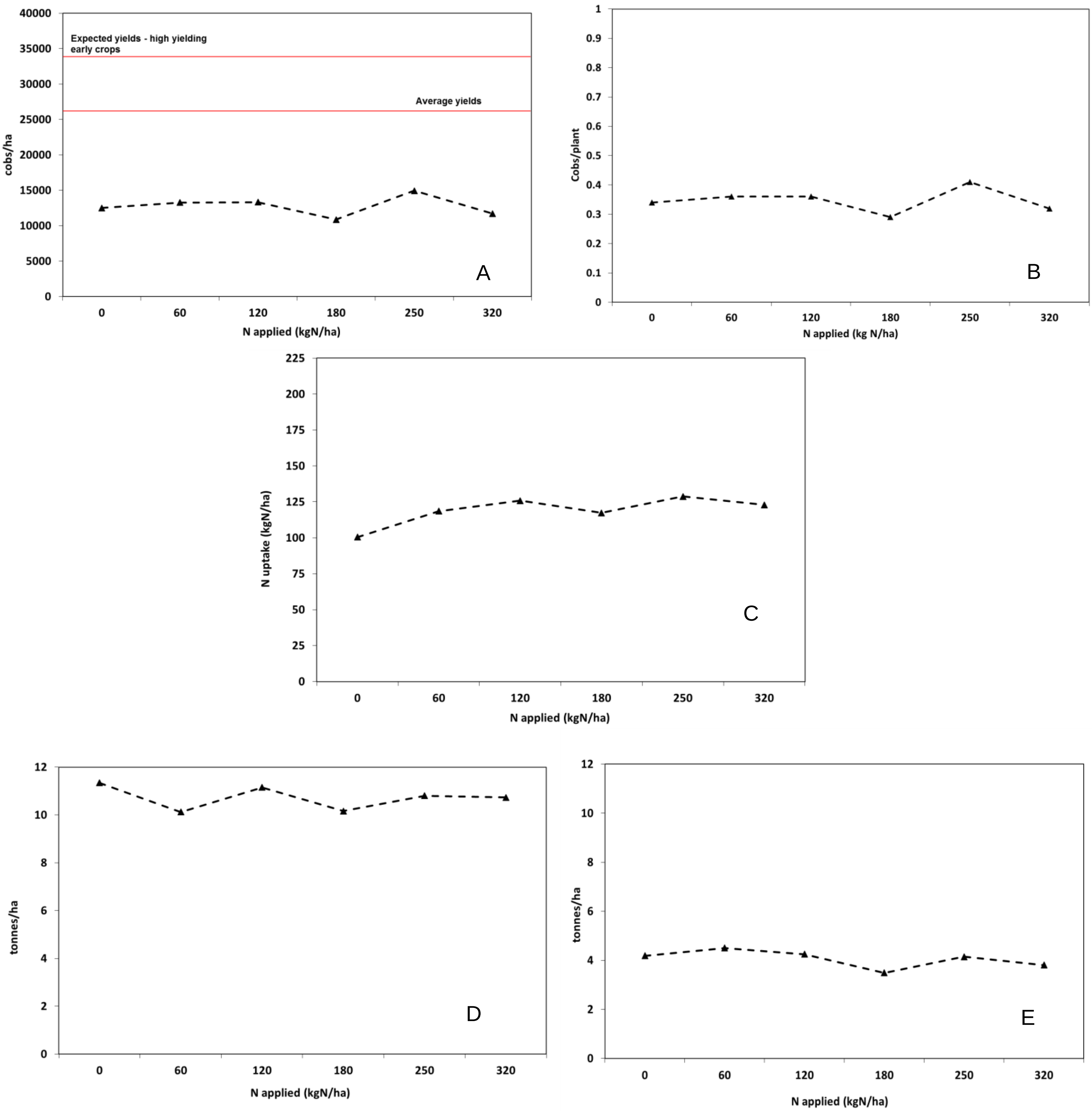

Figure 16. Effects of N rate on sweetcorn at site 14/L1 on A: Numbers of marketable cobs; B: cobs per plant; C: N uptake; D: weight of total cobs (marketable plus non-marketable cobs) and E: weight of marketable cobs. Hants, 2014 (data shown are means of the three N timings treatments in each experiment).

Site 14/L2, Isle of Wight

- This site was abandoned early in crop growth and not harvested due to poor establishment from wildlife damage.

Site 14/L3, W. Sussex

- Variety – 1138,
- Silty clay loam,
- Plant population at harvest – 38,879 plants/ha,
- Initial SMN in early April was low at 51 kgN/ha, and rose slightly to 53 - 59 kgN/ha by drilling due to mineralisation of N from organic matter as soils warmed prior to drilling on 1st June,
- This made L3 an Index 0 site with a recommended rate from RB209 of 150 kgN/ha required, and the previous crop was sweetcorn in 2013 (wheat in 2012),
- The site had a moderate initial P of 28 ppm (P Index 3), and was a moderate-high yielding site with a maximum yield >30,000 cobs/ha,
- The crop showed a significant response to applied N fertiliser and curve fitting indicated a significant yield increase up to the highest N rate applied, in cobs per plant and both numbers of marketable cobs and weight of marketable cobs per hectare (Figures 17A, 17B and 17E), with a predicted economically optimum N rate of 320 kgN/ha when data were analysed across all N timings. However, there would be a very high risk of leaching to the environment at such an N rate as only 19% of the applied N was recovered from by the crop at this level to leave 259 kgN/ha remaining in the soil.
- After harvest this would increase when combined with the N from crop residues to leave 362 kgN/ha remaining in the soil, particularly where mechanical harvesting is carried out and unmarketable cobs returned directly to the field (see discussion section).
- N had significant effects on most variables including cobs per plant ($P < 0.001$), numbers of marketable cobs ($P < 0.001$), total weight of all cobs picked ($P < 0.001$), and marketable weight of cobs per hectare ($P = 0.001$); this was manifested as a slight increase in all variables from 0 - 180 kgN/ha, which then plateaued from 180 – 320 kgN/ha (Figures 17A, 17B, 17D and 17E),
- N uptake by the crop increased significantly with N applied ($P < 0.001$). Maximum N uptake for this crop was 177 kgN/ha at the highest rate (Figure 17C).
- Timing of application had a weakly significant influence on total weight of all cobs picked ($P = 0.05$), with the greatest increase in weight when the fertiliser is applied in the seedbed at drilling followed by the remainder at V5. When the seedbed plus V5 timing was used for curve fitting, an economic optimum N of 227 kgN/ha was predicted,

- Sweetness did not respond to N applied at this site varying from 16.65 ^{0}Bx to 18.91 ^{0}Bx.

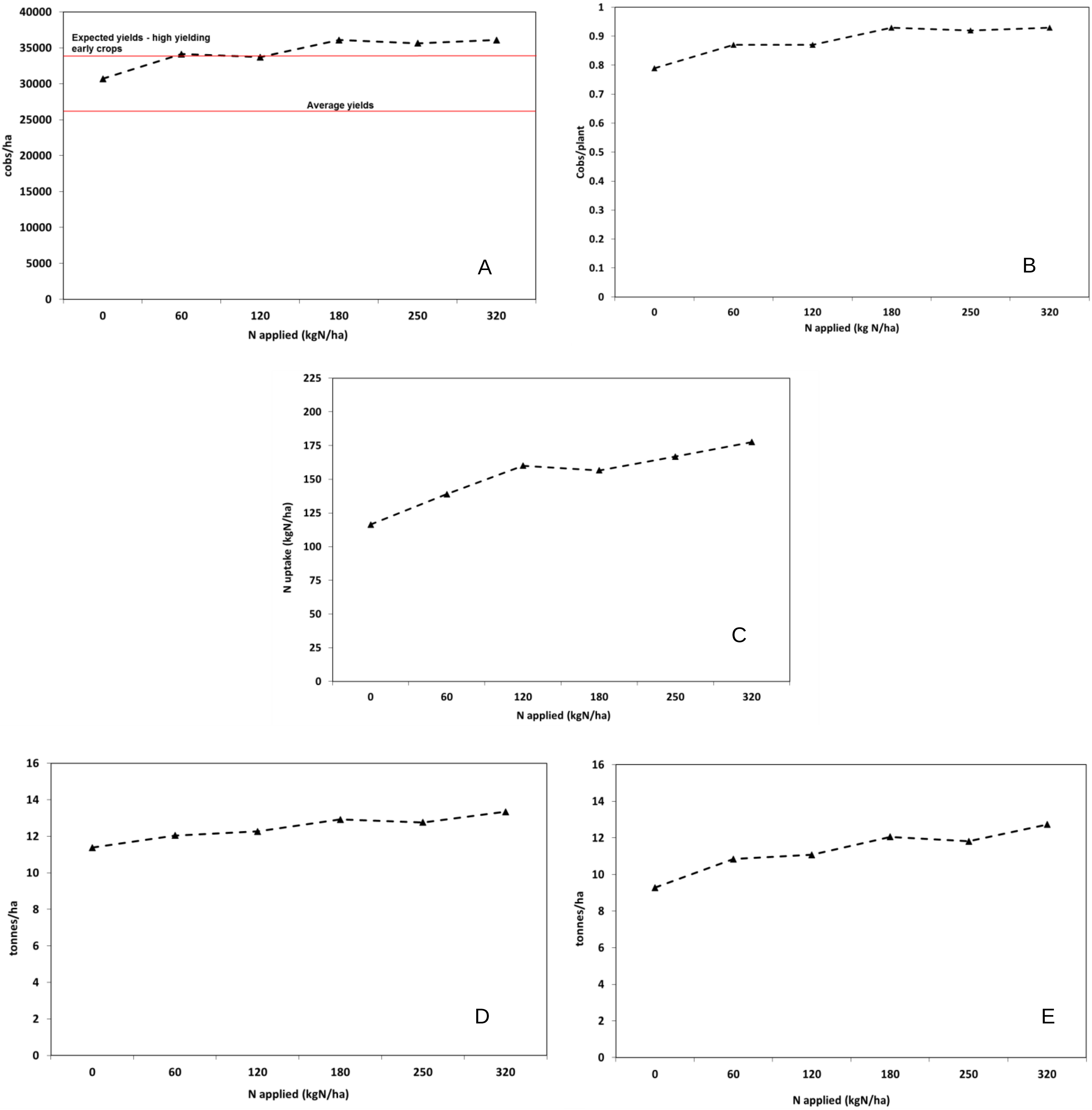

Figure 17. Effects of N rate on sweetcorn at site 14/L3 on A: Numbers of marketable cobs; B cobs per plant; C: N uptake; D: weight of total cobs (marketable plus non-marketable cobs) and E: weight of marketable cobs. W. Sussex, 2014 (data shown are means of the three N timings treatments in each experiment).

P responses

Site 14/E2, W. Sussex

- Variety, soil type, previous cropping and SMN as for early nitrogen response site,
- Plant population at harvest - 48,439 plants/ha
- The site had an acceptable initial P of 16 ppm (P Index 2), and was a high yielding site (>35,000 cobs/ha),
- The crop showed no significant response to phosphate applied with respect to P uptake (Figure 18C),
- The marketable yield of sweetcorn as cobs per plant and numbers of marketable cobs showed a slight increase by 5,450 cobs/ha between zero and 180 kgP_2O_5/ha applied (Figure 18A and 18B), however this was not significant,
- The yield as either total weight of all cobs picked or marketable weight of cobs showed no significant response to phosphate applied (Figure 18D).

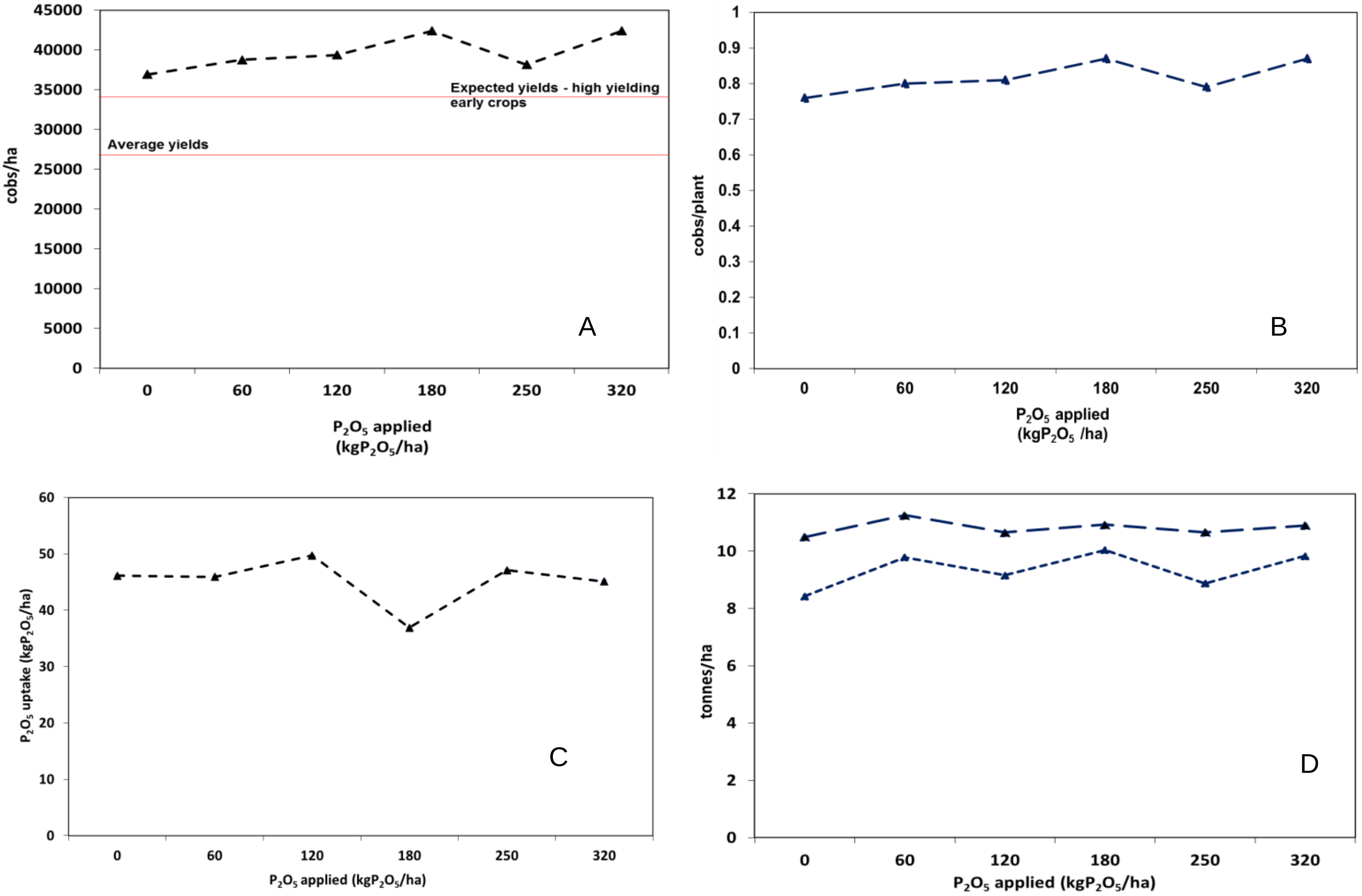

Figure 18. Effects of P_2O_5 rate on sweetcorn at site 14/E2 on A: Numbers of marketable cobs; B: cobs per plant; C: P_2O_5 uptake; D: weight of total cobs shown by dashed line (marketable and non-marketable cobs) and weight of marketable cobs shown by dotted line. W. Sussex, 2014.

Site 14/E3, Isle of Wight

- Variety, soil type, previous cropping and SMN as for early nitrogen response site,
- Plant population at harvest – 52,385 plants/ha
- The site had a moderate initial P of 53 ppm (P Index 4), and was a moderate to high yielding site (>30,000 cobs/ha),
- Although a peak in phosphorus uptake was seen at 180 kgP_2O_5/ha, this response was not significant (Figure 19C),
- The marketable yield of sweetcorn as cobs per plant and numbers of marketable cobs shows a marked decrease of 9,822 cobs/ha between zero and 120 kgP_2O_5/ha applied (Figure 19A and 19B), however this was not statistically significant,
- The yield as either total weight of all cobs picked or marketable weight of cobs showed no significant response to phosphate applied (Figure 19D).

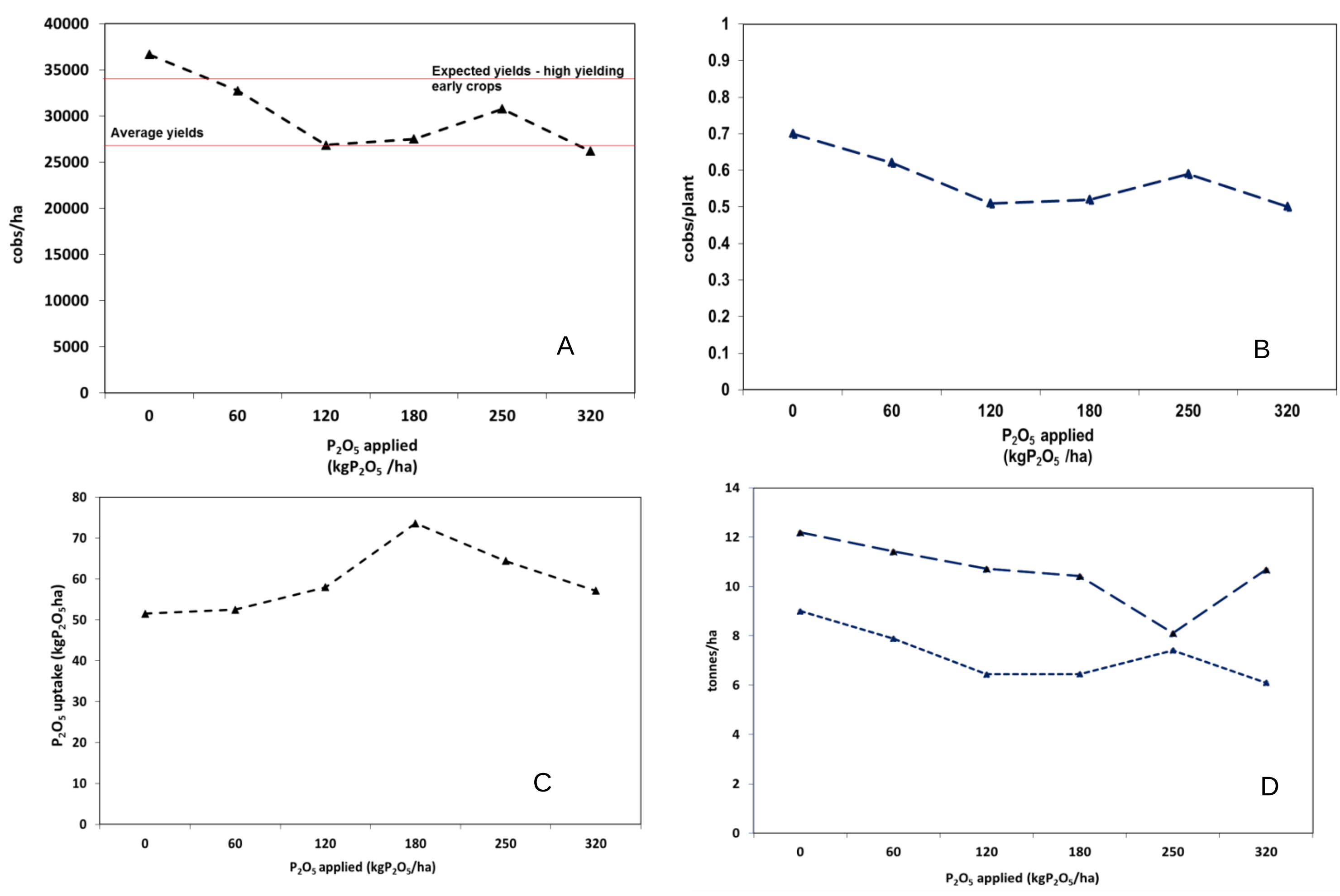

Figure 19. Effects of P_2O_5 rate on sweetcorn at site 14/E3 on A: Numbers of marketable cobs; B: cobs per plant; C: P_2O_5 uptake; D: weight of total cobs shown by dashed line (marketable and non-marketable cobs) and weight of marketable cobs shown by dotted line. Isle of Wight, 2014.

Site 14/L1, Hants

- Variety, soil type, previous cropping and SMN as for late nitrogen response site,
- Plant population at harvest – 35,560 plants/ha
- The site had an acceptable initial P level of 18 ppm (P Index 2),
- Although a general trend for an increase in phosphorus uptake was seen up to 320 kgP_2O_5/ha, this response was not significant (Figure 20A),
- The yield as total weight of all cobs picked showed no significant response to phosphate applied (Figure 20B).
- An assessment of number of tillers, and leaves per tiller was made at this site due to visual observations of denser foliage in the plots where the highest phosphate was applied. A trend for an increase in tillering and a greater number of leaves was recorded, but this is not significant (Figure 20C),
- There were no QA data available for this site.

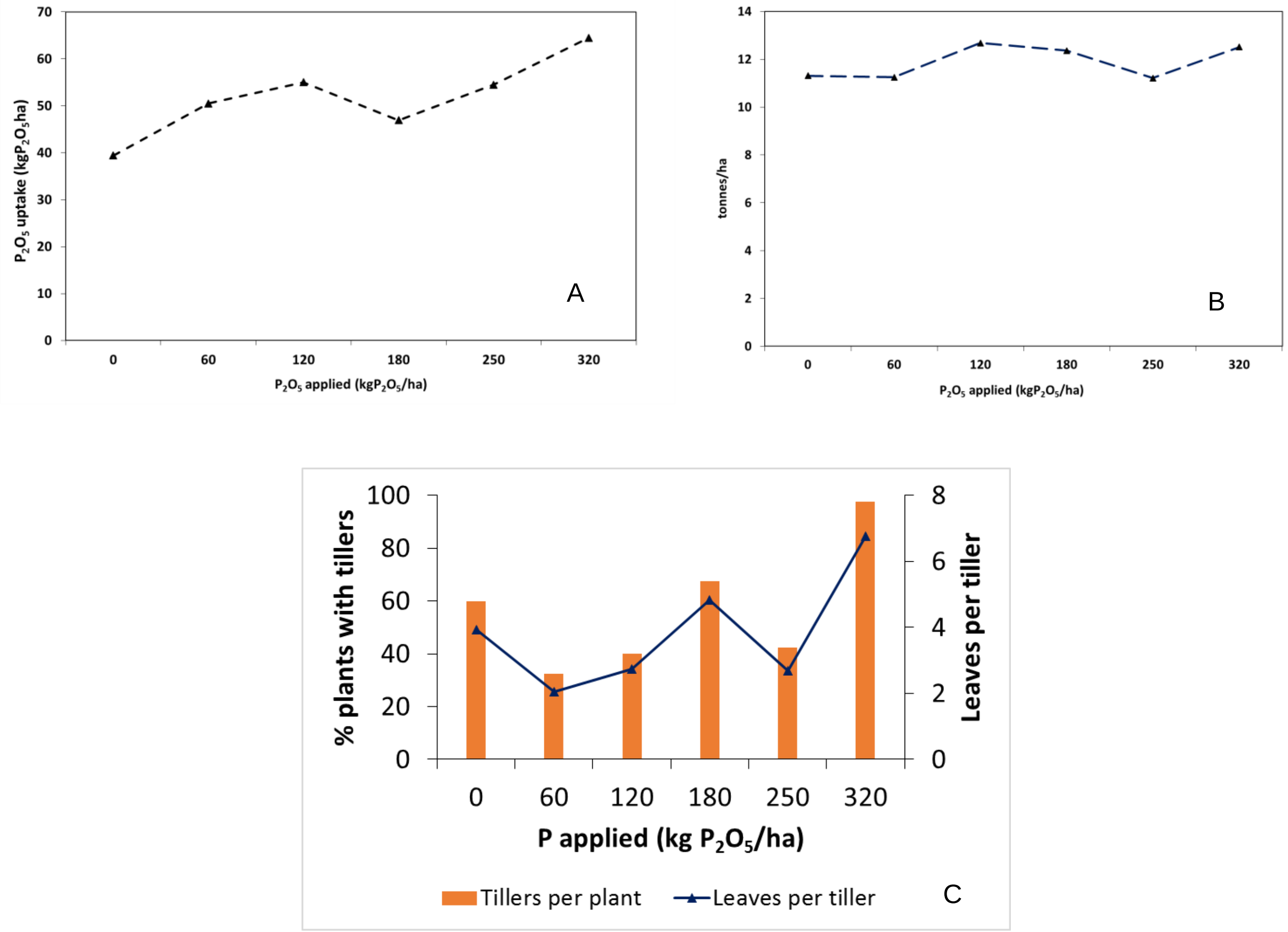

Figure 20. Effects of P_2O_5 rate on sweetcorn at site 14/L1 on A: P_2O_5 uptake; B: weight of total cobs; C: No of tillers and leaves per tiller. Hants, 2014.

Discussion

The aim of this project was to improve recommendations for N and P applications, and improve efficiency of production of modern sweetcorn varieties 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 selected commercial genotypes,
- Quantify N and P uptake to better guide fertiliser recommendations.

Results from both years are discussed against these objectives 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 with higher rates of N applied at both early and late sites in 2013 and 2014 (Figures 21 and 22), but only at sites where the measured SMN at drilling indicated a low SNS (Index 0 - 2). With a moderate SNS index of 3, site 14/L1 showed a lower yield response, and a lower but significant N uptake response. The exceptions were the late site 13/L1 and the early site 14/E1. Site 13/L1 was a low to moderate yielding crop arising from a low plant population and total biomass due to water stress, as described in the results section, and showed no N uptake response to applied nitrogen fertiliser (Figure 21). No marketable yield data were available for this site, so the potential yield estimate is based on reduced crop biomass alone, as the plants only reached a total biomass of approximately 20 tonnes/ha (in contrast, crops of the variety 7403 at all other trial sites in 2013 reached between 30 – 40 tonnes/ha of total biomass).

Site 14/E1 had approximately 138 kgN/ha available (0-90 cm depth) at drilling and the uptake in the nil N plots indicated a SNS of 175 kgN/ha therefore this crop had sufficient SMN for the crop's requirement based on the results from the trials where maximum uptake indicated a maximum crop requirement between 170 – 213 kgN/ha. Therefore this crop showed no response to applied nitrogen fertiliser.

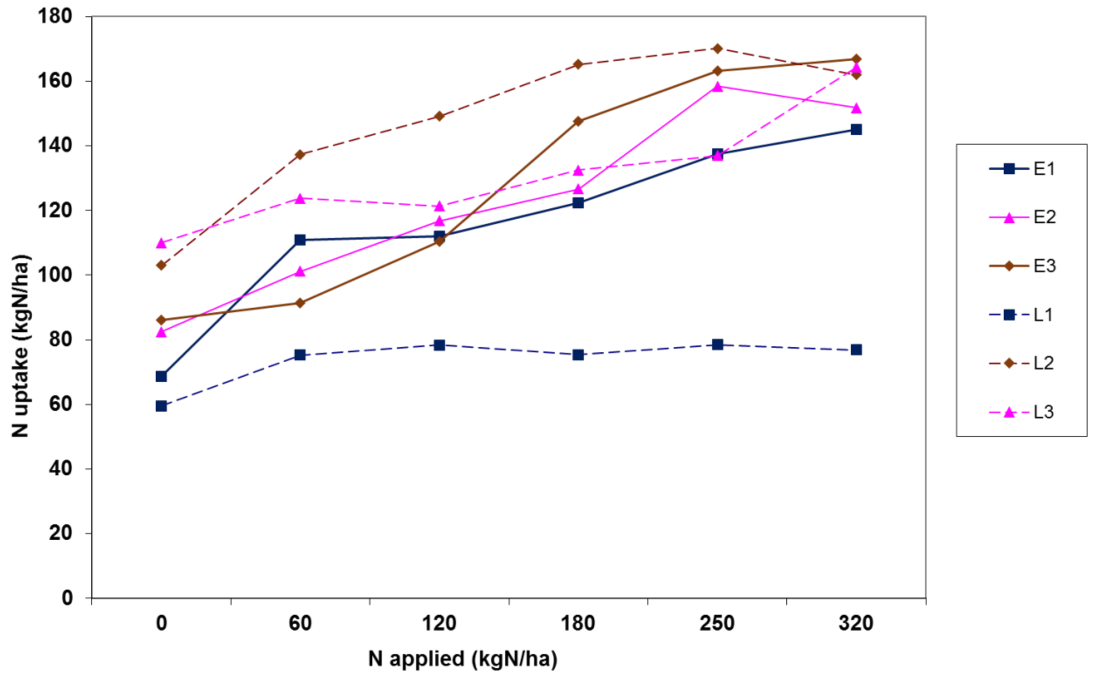

Figure 21. Effect of the application of increasing rates of nitrogen on N uptake, Hants, Sussex and Isle of Wight, 2013 at six sites (E, early; L, late sown).

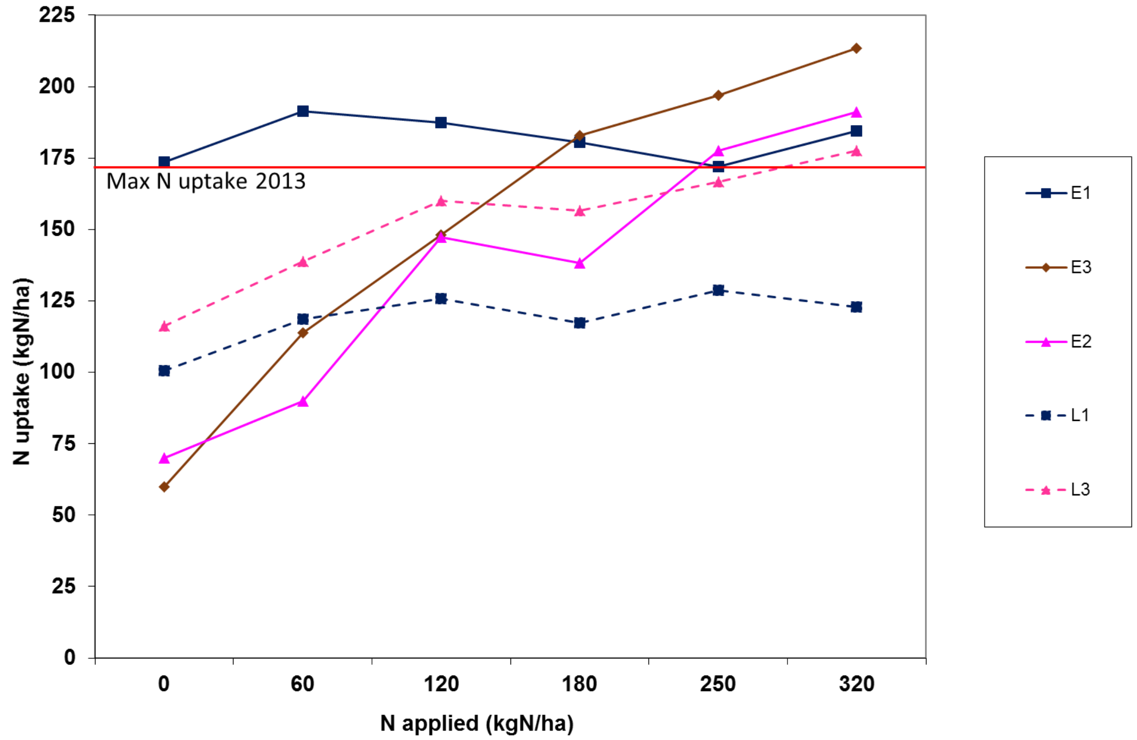

Figure 22. Effect of the application of increasing rates of nitrogen on N uptake, Hants, Sussex and Isle of Wight, 2014 at five sites (E, early; L, late sown).

From Figure 21 the maximum N uptake from the trials carried out in 2013 was 170 kgN/ha, while in Figure 22 it can be seen that the maximum N uptake in 2014 was higher at 213 kgN/ha. Though only based on two years of study, these data demonstrate the influence that a favourable growing season can have on crop N uptake and requirement, with the spring of 2014 being warmer and drier than 2013. In the first season the responses of N uptake to increasing N applied were low across all sites at 0.2 kgN uptake/kgN applied, but in the warmer growing season of 2014 a stronger response was seen at 0.5 kgN uptake/kgN applied, for the early drilled 14/E2 and 14/E3 sites (where the SNS was lower at drilling as estimated from the uptake from the nil N plots).

The soil nitrogen supply (SNS) actually available to the crop at drilling, could be estimated retrospectively from the crop N uptake measured in the experiments. Table 6 shows these estimates calculated in two different ways; (i) N uptake measured directly in the nil N treatments, and (ii) extrapolated to zero N using the data for N uptake plotted against N applied in the range 60 to 320 kgN/ha (linear function fitted in the form y=mx+c). The average difference between the two approaches was 17 kgN/ha, being higher when N uptake was estimated using approach (ii). Table 6 shows that because the sweetcorn crops are drilled in spring after soils have warmed, extra N has become available from the mineralisation of soil organic matter (OM) including previous crop residues compared to predicted SNS (based on the initial soil samples taken in February and March). Using the estimated SNS by extrapolation (method ii) the polythene-covered early crops on average recovered 88 kgN/ha from the soil where no fertiliser N was applied. With the longer time to drilling for the late crops, approximately 127 kgN/ha was available as SMN to 90 cm depth by the time these crops were drilled.

Using these figures combined with the crop requirement from the maximum N uptake over both years of the trials (170 - 213 kgN/ha), the fertiliser needed to meet the requirements of the early and late crops can be calculated. Assuming 60% recovery (RB209 value) of fertiliser N, a total of 150 - 220 kgN/ha would be required to meet the demands of an early polythene covered crop drilled in April, and 100 - 170 kgN/ha would be the amount required to meet the demands of a late drilled (May/June) crop. It is also worth noting that much of the seedbed N recommended in RB209 (100 kgN/ha) was already available as SMN at the time of drilling of the late crops.

Table 6. 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. (High rainfall – Table C – used from RB209)

	Early sites						Late sites				
	2013			2014			2013			2014	
	E1	E2	E3	E1	E2	E3	L1	L2	L3	L1	L3
SMN (kgN/ha) pre-drilling*	24	37	29	30	25	20	39	29	53	9	21
SMN at drilling (kgN/ha) (Index)	54 (0)	54 (0)	59 (0)	138 (4)	46 (0)	43 (0)	70 (1)	75 (1)	100 (2)	99 (2)	56 (0)
Drilling date	22 April	23 April	24 April	10 April	17 April	10 April	14 May	15 May	23 May	20 May	1 June
RB209 rec. based on SMN (kgN/ha)	150	150	150	0	150	150	100	100	50	50	150
SNS Index from RB209 based on FAM	0 (Shallow light soil, High N veg-incorp. Overwinter residues)	1 (Medium silt, Med N veg)	0 (Light sand, Cereal)	0 (Shallow med soil, Cereal)	1 Medium silt, Sweetcorn)	0 (Light sand, Sweet corn)	0 (Shallow light soil, Med N veg)	0 (Light sand, Cereal)	2 (Deep silt soil, Med N veg)	0 (Shallow light soil, Cereal)	1 (Medium silt, Sweetcorn)
SNS (kgN/ha) measured as N uptake at 0N applied	69	82	86	174	70	60	59	103	106	100	116
SNS (kgN/ha) estimated from potential N uptake extrapolated back to zero	99	90	78	191	82	101	76	137	108	119	136

* Sampled in February 2013, and early March in 2014, except site 14/L3 which was sampled 10 April.

At the early site 13/E2, the cobs were analysed separately from the vegetative parts (stems and tassels plus leaves) for N uptake to investigate nutrient partitioning between these two parts of the plant. The N was fairly evenly taken up by all parts of the plant at harvest, with 53 - 55% of the total N being partitioned to the cobs, mirroring the partitioning of total plant biomass, with cobs forming 51% to 53% of the total fresh weight (dry weight proportion of cobs to vegetative parts is 51% - 55%).

Nitrogen would be less preferentially moved into the cobs than phosphorus at this point in crop development. This is because sweetcorn is picked at R2-R3 (milk - dough) while the plant is still photosynthesising, and much of the N would be in the green leaves retained within chlorophyll and photosynthetic enzymes.

The separate analysis of the cobs, and vegetative parts was repeated in 2014 at site 14/E2. Results showed that in this crop 35 – 39% of the total N was partitioned to cobs, which again matches the proportion of cobs to total plant material, this time with the cobs forming less of the total fresh weight of the plant at 36 – 38% (dry weight proportion of cobs to vegetative parts is 31% - 37%) than in 2013. The different results between the two years of the trials with respect to cob/plant ratio, and thus ratio of partitioning of N to the separate parts of the plant is likely to have been influenced by variety and potential cob size at point of harvest. The variety Earlybird used in 2014 forms comparatively smaller cobs, being on average 100 g per cob less in weight than 7403 which was the early variety used in 2013. Although the cobs are smaller and therefore less N is partitioned to the cobs in Earlybird, this does not necessarily mean less N is required for this variety or is less important to the growth and development of the crop. Nitrogen is one of the major nutrients used by the plant to maintain a supporting green canopy for photosynthesis, growth and yield potential (see later section on requirements for economic optimum yield).

Timing effects of nitrogen application on N uptake

At four out of 11 sites (13/E1, 13/E2, 14/E3 and 14/L1) taken to harvest over both years of the trial there was a significant increase in N uptake when the nitrogen was applied in the seedbed with the remainder applied as a 2nd application at V5 (just before stem extension which occurs at V8) (Table 7). Other sites (13/E3, 13/L1, and 14/L3) also show this trend, and although it was not significant at these sites the effect is consistent and on average, 'early timing 1' leads to the greatest N uptake. On the whole, sites with a higher SMN at drilling (13/L2, 13/L3, and 14/E1), did not respond to higher N when applied to the seedbed, as more was available to the crop from SNS during early growth. The greater uptake of N when available from either SNS or applied fertiliser in the seedbed and at V5 coincides with the key stages of crop development particularly canopy expansion. Initially N is required soon after germination to initiate the growth of stems, leaves and ear structures, and according to Jones (1985) inadequate N availability during the first two to six weeks after planting can result in reduced yield potential. The highest period of N uptake is at stem extension from the early vegetative stage V6 – early reproduction R1 (silking) when demand for nitrogen escalates rapidly during the period of maximum vegetative development (Figure 23, Bender *et a*l., 2012). This later N requirement was supplied in these experiments, by the

SNS remaining from the seedbed application, plus the fertiliser N application made between V4 and V6. This suggests that as long as there is adequate N supplied at these two application timings, then there is little later crop requirement, indicated by the lack of additional N uptake when the applications are split across three timings (Table 7). In the work of Karlen *et al*. (1987) it was shown that the proportion of N taken up between silking and maturity (R6) in grain maize varieties ranged from less than 10% to about 40%. Figure 23 also shows that nitrogen is remobilised from the leaves and stem to supply the cobs and kernels during grain fill in addition to uptake of soil and fertiliser N. However, in years of high rainfall it would still be advised to assess the crop visually for any deficiencies at tasseling to avoid yield penalties.

Table 7. Effect of application timing of the nitrogen on crop N uptake, Hants, Sussex and Isle of Wight, 2013 (probability indicates significance of a timing effect).

		N uptake (kgN/ha)			
	*Nitrogen timing**	*T1 Early*	*T2 3 way split*	*T3 Late*	Proba-bility
Early crops 2013	E1	131.8	130.5	114.2	0.026
	E2	137.9	136.7	118.4	0.035
	E3	145.3	131.9	130.4	NS
Early crops 2014	E1	173.0	187.2	189.2	NS
	E2	152.6	140.5	153.6	NS
	E3	187.5	168.3	157.5	0.021
Late crops 2013	L1	81.5	77.7	72.8	NS
	L2	158.0	162.6	149.7	NS
	L3	140.6	126.8	140.0	NS
Late crops 2014	L1	141.2	108.3	118.5	0.007
	L3	169.9	154.7	155.3	NS
Average 2013		132.5	127.7	120.9	-
Average 2014		164.8	151.8	154.8	
Average early sites		154.7	149.2	143.8	-
Average late sites		138.3	126.1	127.3	-
Average all sites		147.2	138.6	136.3	-

* see Table 4 for details of N timing treatments

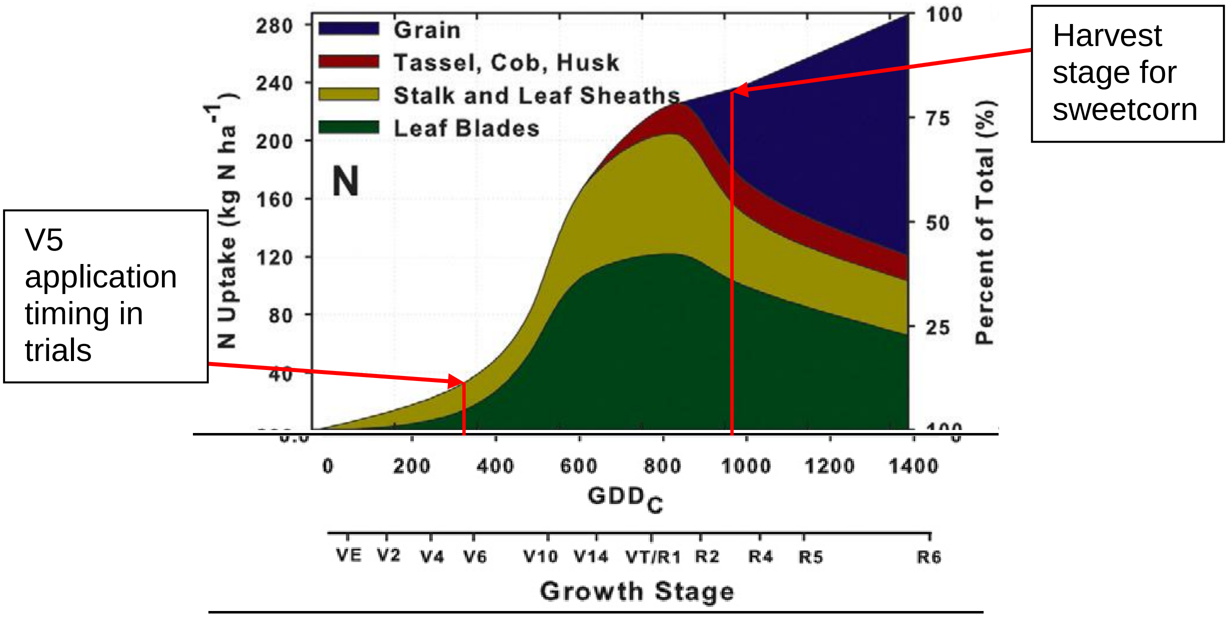

Figure 23. Accumulation, partitioning and N uptake in modern, insect-protected maize hybrids showing steep uptake between V6 and tasseling (adapted from Bender *et al.,* 2012).

Phosphorus uptake and utilisation

There was a significant response to P uptake at one site (13/E2) only in 2013, where the P index for the trial area was 3, and at the lower end of this index. The nitrogen response experiments were sited in this same field, and within this adjacent trial there was an area which was at a lower index of 2 showing variability across the field between P index 2 and 3. This shows that a low to medium index site is needed to elicit even a small response. The significant response was only 10 kg/ha increase in total phosphate uptake when 180 kgP_2O_5/ha was applied (Figure 24). In 2014 lower index sites were used and greater increases than 10 kg/ha in phosphate uptake were seen but due to the variability of the phosphate uptake within treatments these increases were not significant. This increased variability in 2014 is highlighted by the higher least significant differences (LSD; 5% level) for P uptake which were 17.46 for site 14/L1 and 18.04 for site 14/E2 in 2014 compared with 9.49 for site 13/E2 in 2013. So, a greater difference in uptake would have been needed for a statistically significant effect in 2014. However, although the response was not significant, it was consistent, with an increase in uptake of phosphorus of 5 kgP_2O_5/ha between rates of nil and 120 kgP_2O_5/ha applied at all sites. In addition, at nil N the maximum phosphate offtake was 51 kgP_2O_5/ha, therefore to maintain soil P indices at 3 in a vegetable rotation it is considered good practice to replace the phosphate that will be taken off by the crop, indicated to be on average 45 kgP_2O_5/ha in these experiments. The phosphate offtake, and amount needed to replace this offtake, will vary depending on the starting index and whether the full crop is harvested, or just the cobs are removed with the remaining residues being returned to the field.

At the early site E2 in both years, the cobs were separated from the plants and stems at harvest, and the analysis of the uptake of total P to either the cobs or the stems and leaves was measured in order to determine P harvest index. In 2013 the P_2O_5 was preferentially taken up into the cobs, with 65 - 70% being partitioned to the cobs of variety 7403 across all rates of P applied. However, in 2014 the P_2O_5 was slightly more partitioned to the stem and leaves with only 43 – 49% being partitioned to the cobs of Earlybird. Again, this is possibly a varietal effect.

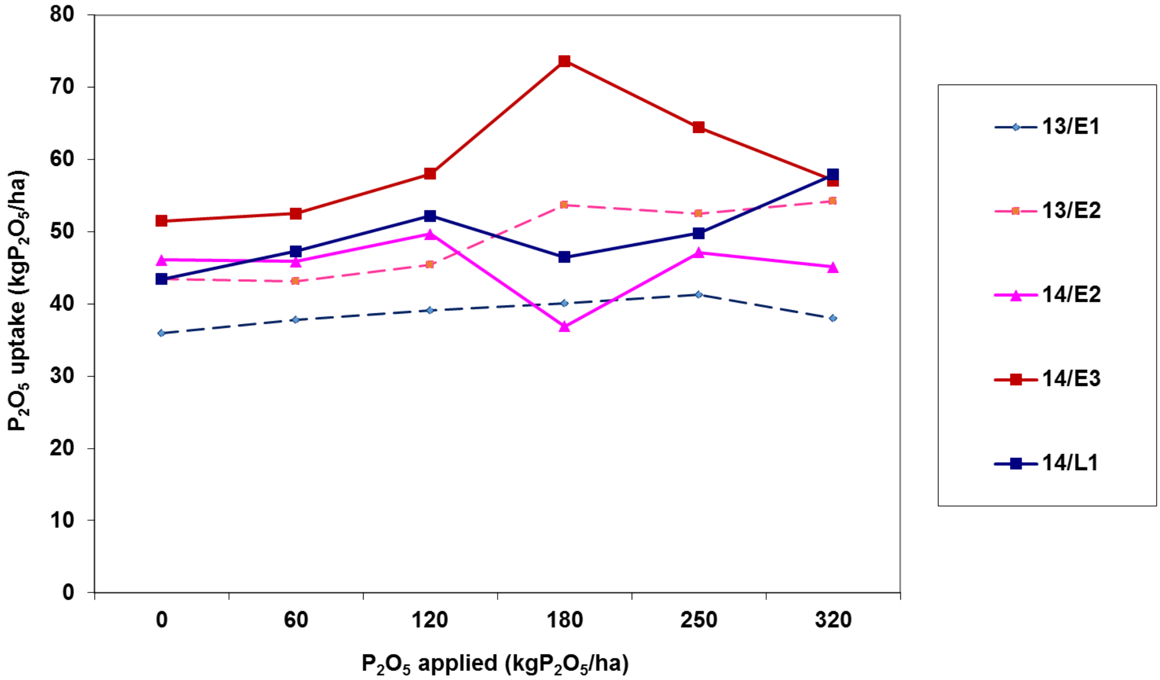

Figure 24. Effect of the application of increasing rates of phosphate on phosphate uptake, Hants and Sussex, 2013/14.

Yield responses of sweetcorn to N and P fertiliser application

Marketable yield responses to applied N

Marketable yield responses (cobs/plant and numbers of cobs/ha) to rates of applied nitrogen were seen at six out of eleven sites where marketable yield data were available, over both years of the trials; two of the early drilled sites (13/E1 and 13/E2) and one late drilled site (13/L2) in 2013, and two of the early drilled sites (14/E2 and 14/E3) and one late drilled site (14/L3) in 2014. No QA data were available for site 13/L1 therefore gross yields could not be converted to marketable yields. The lack of marketable yield response in numbers of marketable cobs at the third early drilled site in 2013 (13/E3) could have been caused by picking the crop too early when some immature cobs may not have met specification requirements causing a variable trend (Figure 25). The third late trial in 2013, the first late trial in 2014 (13/L3 and 14/L1), and the first early trial in 2014 (14/E1) showed variable responses to N applied which could be due to a high available soil mineral nitrogen (SMN) at drilling (106, 99 and 138 kgN/ha respectively).

In addition, at site 14/L1 the crop suffered pest damage which dramatically limited yield potential. During crop growth and at harvest it was difficult to visually distinguish the zero N plots from the applied N plots in all this trial, and SNS was very high at the start.

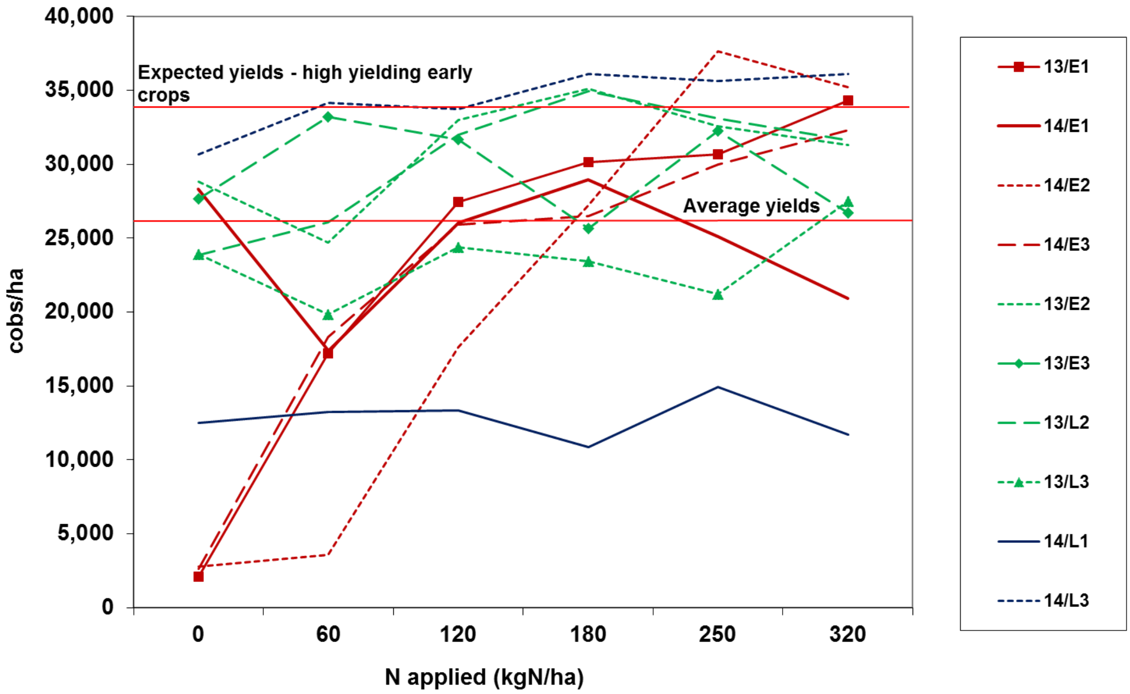

Figure 25. Effect of the application of increasing rates of nitrogen on the yield of marketable cobs in early and late drilled sweetcorn crops, Hants (solid line), Sussex (dotted line) and Isle of Wight (dashed line), 2013/14 (data shown are means of the three N timings treatments in each experiment).

Key: Red/brown = Earlybird, Green = 7403, Blue = 1138; E, early; L, Late.

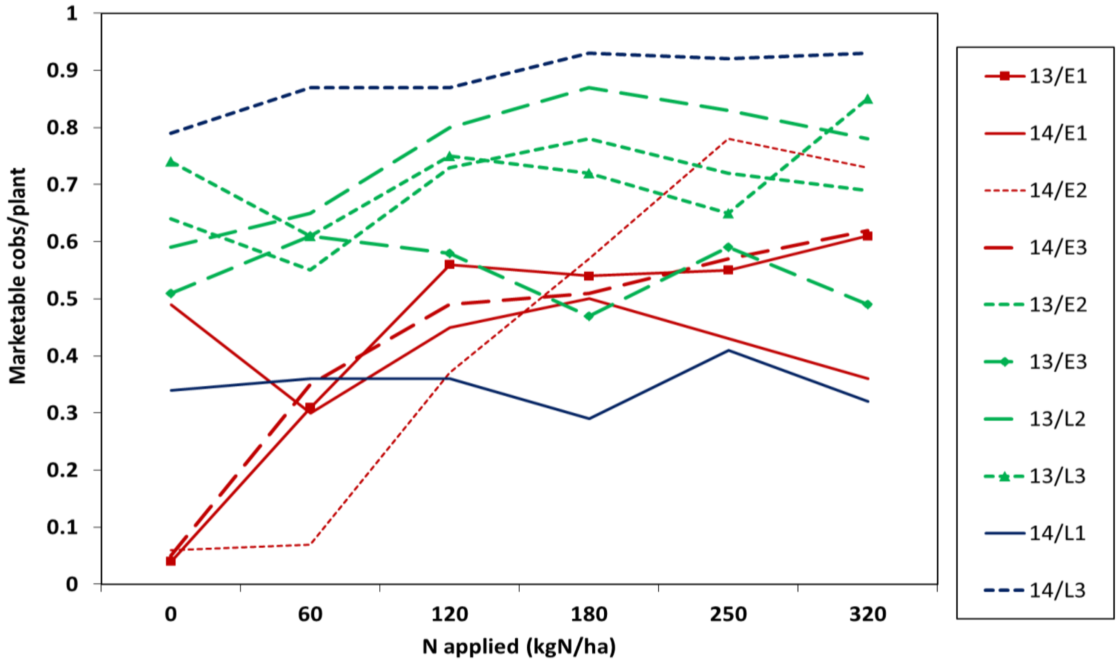

Figure 26. Effect of the application of increasing rates of nitrogen on marketable cobs per plant (yield potential) in early and late drilled sweetcorn crops, Hants (solid line), Sussex (dotted line) and Isle of Wight (dashed line), 2013/14 (data shown are means of the three N timings treatments in each experiment).

Key: Red/brown = Earlybird, Green = 7403, Blue = 1138; E, early; L, Late.

Yield is presented as both marketable cobs per ha in Figure 25 and marketable cobs per plant in Figure 26. While the former shows actual yield, the latter variable indicates yield potential to the grower because it is less influenced by the plant population at harvest. For example, unless there is a catastrophic failure (like crow damage), the grower aims to achieve a certain target plant population therefore the focus is on maximising the number of marketable cobs per plant. Plant population per ha can be influenced by a number of external factors such as pest damage, water stress and establishment.

There was a difference between early and main season varieties in terms of strength of response to applied N and yield potential. This is shown in Figure 26 where the yield is presented as cobs per plant and in comparison to the main season varieties (7403 and 1138), the early variety, Earlybird, responds very strongly to the first 120 kgN/ha applied where SNS Index is low. The early variety also typically has a lower maximum yield potential of 0.6 marketable cobs per plant when compared to the main crop varieties which achieve between 0.75 to 0.93 marketable cobs per plant at responsive sites. The newer, main crop varieties also achieve more marketable cobs with nil N applied even at low SNS Index sites (Table 8). Although late crops show a significant yield response at some sites, it is less marked than the older Earlybird variety due to their higher marketability at lower N inputs.

However, Earlybird can achieve high yields per plant, for example site 14/E2 which shows a high yield of 0.78 marketable cobs/plant at 250 kgN/ha applied. This could have been influenced by soil type with the site being a deep silt soil, with a greater available water holding capacity when compared with the lighter free-draining sandy loams in Hants.

With the later varieties it could be argued that the smaller yield response to applied N, and greater cob numbers at nil N (Table 8) are due to the later drilling date and higher available N from mineralised residues. However, in 2013 one of the early sites (13/E2) was drilled with the main crop variety 7403, had a low SNS, and still showed a similar response to the crops drilled later with a higher SNS. This suggests that the N response trends and possibly N requirements are influenced by variety as well as rate of nitrogen, but a bigger data set for each variety would be needed to confirm this.

Table 8. Comparison of numbers of marketable cobs achieved for early and main crop varieties at nil N applied, Hants and W. Sussex, 2013 and 2014.

Variety	Site	Actual SNS (kgN/ha) estimated from N uptake at 0N applied	Marketable cobs per ha at 0N applied
Earlybird	13/E1	69	2,076
(early)	14/E1	174	28,316
	14/E2	70	2,802
	14/E3	60	2,619
7403	13/E2	82	28,823
(main crop)	13/E3	86	27,669
	13/L2	103	23,839
	13/L3	106	23,905
1138	14/L1	100	12,507*
(main crop)	14/L3	116	30,682

*crop affected by pest damage

Timing effects of nitrogen application on cob weight

In 2013, the two early crops which were picked at the correct crop ripeness (13/E1 and 13/E2), there was a significant increase in total cob weight when the N was applied in the seedbed with the remainder applied as a 2nd application 45 days later just before stem extension (Table 9). There was no significant effect of the timing of the application of the nitrogen on the later drilled crops in 2013, 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 and N uptake, in future years the timing treatments could be refined to explore applying more N in the seedbed, greater than the 100 kgN/ha limit currently recommended and/or use of placed starter fertilisers. In 2014 there were no strong significant responses in cob weight to timing of N application.

Table 9. Effect of application timing of the nitrogen on the weight of cobs, Hants, Sussex and 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

Economic optimum yield responses to nitrogen

From those sites where a response to N applied was seen in marketable cob numbers, N response curves were fitted to give economic optimum N rates for each site. The economically optimum N rate was calculated using a price of 17 pence/cob and 96 pence/kg of N, and a summary of the optimum rates and yields are given in Table 10 with the optimum rates and timings in bold where there are several options. At the early sites 13/E1, 14/E2, and 14/E3, and the late sites 13/L2 and 14/L3, the economic optimum rate of nitrogen fell above the current recommendations. While at the early site 13/E2 the economic optimum matched current recommendations. It is likely that different sites will have different potential yields based on factors such as aspect, soil type and previous history. Therefore an understanding of the potential of each site is necessary when accurately estimating crop requirements.

Table 10. Economic optimum nitrogen application rates for the three sites showing a significant marketable yield response to applied N and where curve fitting could be carried out, Hants, Sussex and Isle of Wight, 2013 and 2014. (Data in bold were used for examining the differences in values between the RB209 recommendations and the revised economic optima [found in this project] in table 11

		Quantity or recommended N rate (kgN/ha)					
Site	N timing (treatment number in brackets †)	SMN (Feb)	Available N at drilling (SNS) *	RB209 Rec. rate	Economic Optimum	Cobs/ha at optimum	Curve fit used
13/E1	All timing data combined (1-18)	24	69	150	>320	33,510	Linear plus exponential
13/E1	**Seedbed + V4 to V6 (1-6)**	**24**	**69**	**150**	**196**	**38,257**	Linear plus exponential
13/E1	3-way timing (7-12)	24	69	150	170	33,153	Linear plus exponential
13/E1	No seedbed (13-18)	24	69	150	>320	36,142	Linear plus exponential
13/E2	**Seedbed timings combined (1-12)**	**37**	**82**	**150**	**157**	**33,752**	Linear plus exponential
13/L2	**All timing data combined (1-18)**	**29**	**103**	**100**	**227**	**33,026**	Linear plus exponential
14/E2	All timing data combined (1-18)	25	70	150	>320	39,671	Linear plus exponential
14/E2	Seedbed + V4 – V6 (1-6)	25	70	150	>320	42,751	Linear plus exponential
14/E2	**Seedbed + V4 – V6 (1-6)**	**25**	**70**	**150**	**250**	**38,432**	Used actual data fit
14/E3	All timing data combined (1-18)	20	60	150	>320	32,083	Linear plus exponential
14/E3	Seedbed + V4 – V6 (1- 6)	20	60	150	>320	31,087	Linear plus exponential
14/E3	**3-way timing (7-12)**	**20**	**60**	**150**	**232**	**29,745**	Linear plus exponential
14/L3	All timing data combined (1-18)	56	116	150	>320	36,023	Linear plus exponential
14/L3	**Seedbed + V4 – V6 (1-6)**	**56**	**116**	**150**	**227**	**36,369**	Linear plus exponential

*, Estimated from total N uptake in nil N plots

†, N treatment numbers (in brackets) defined in table 4

For the early drilled crop of sweetcorn at site 13/E1 there was a weakly significant timing effect (prob = 0.08), with higher optimum yields produced at lower rates of nitrogen (196 kgN/ha) when part of the N was applied to the seedbed and then the remainder applied at V5 just before stem extension. When N was not applied in the seedbed it took a larger amount (320 kgN/ha) applied as two later applications, to achieve a lower yield (Figure 27). Using these results, for an extra 46 kgN/ha applied above current recommendations at a cost of the extra fertiliser needed of £44.16/ha this would produce an additional 1,015 cobs to give additional revenue of £128.39/ha margin over fertiliser costs. N.B. this and the following calculations do not include the cost of spreading.

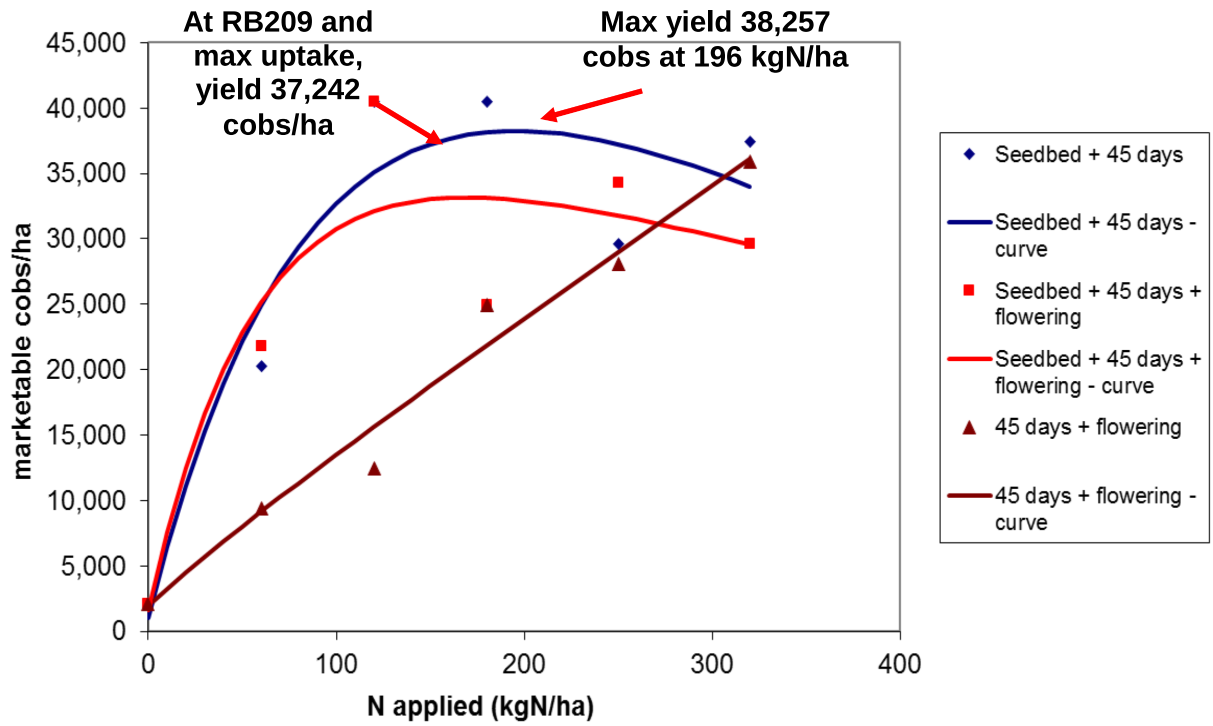

Figure 27. Economic optimum N curves for each of the separate nitrogen application timings for the early drilled crop, site 13/E1 Hants, 2013.

At the late site 13/L2 (Figure 28) 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 kgN/ha applied using any of the timing regimes. Using the same economic values as above, this gives a benefit of £350/ha for an increase of 2,059 cobs/ha for an extra cost per ha for N of £121.92/ha at current costs (a margin of £230/ha over fertilizer costs). The N rate giving maximum yield potential of for this site (227 kgN/ha) broadly matches the current international recommended guidelines (220 kgN/ha: IFA,1992)

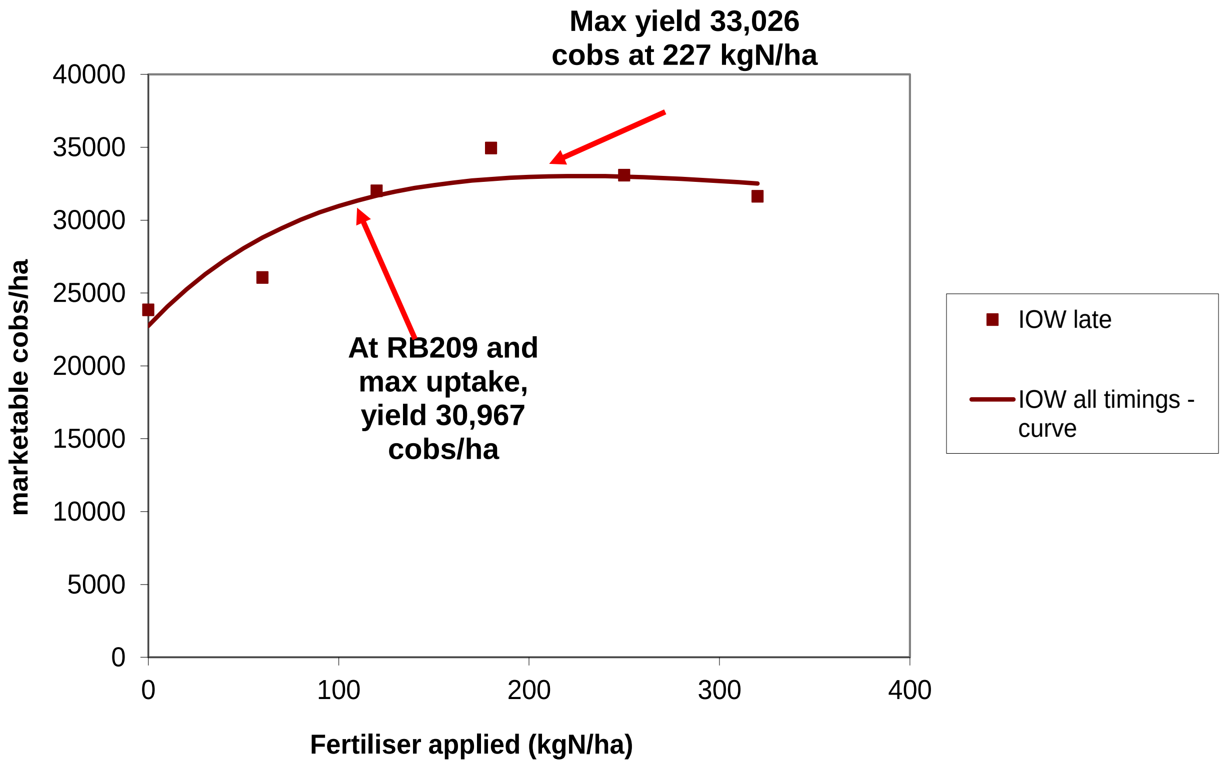

Figure 28. Economic optimum N curve for the late drilled crop, site 13/L2, Hants, 2013.

At the early site 14/E3 (Figure 29) there was no N timing effect so the economic optimum curve can be fitted through all the data to give a maximum yield of 32,083 cobs/ha at > 320 kgN/ha applied using any of the timing regimes. However, due to the maximum N uptake of 213 kgN/ha being less than the highest rate of N applied (320 kgN/ha) then applying such high amounts would potentially leave a significant amount of SMN after harvest and a more realistic approach would be to use the curve for for 3-way timing. If this is used, then the economic optimum N is estimated to be 232 kgN/ha. Using these values for the calculations this still gives a benefit of £380/ha for an increase of 2,234 cobs/ha for an extra cost per ha for N of £78.72/ha at current costs (margin over fertilizer N costs of £302/ha).

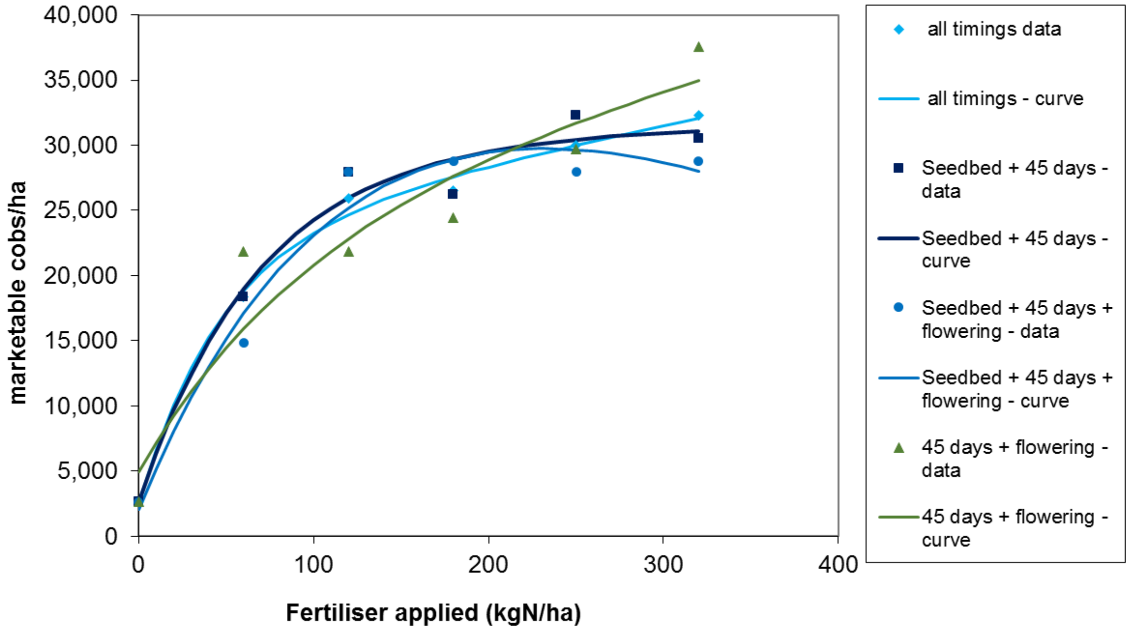

Figure 29. Economic optimum N curve for the early drilled crop, site 14/E3, Hants, 2014.

At the early site 14/E2 (Figure 30) there was no N timing effect so the economic optimum curve was be fitted through all the data to give a maximum yield of 39,671 cobs/ha at > 320 kgN/ha applied using any of the timing regimes. However, due to the maximum N uptake of 191 kgN/ha being less than the highest rate of N applied (320 kgN/ha) then applying such high amounts would potentially leave a significant amount of SMN after harvest and a more realistic approach would be to use the curve for the seedbed plus V5 timing application. If this is used, then the economic optimum N is estimated to be 250 kgN/ha. Using these values for the calculations this still gives a benefit of £2,210/ha for an increase of 13,001 cobs/ha with an extra cost per ha for N of £96/ha at current costs (margin over fertilizer N costs of £2,114/ha).

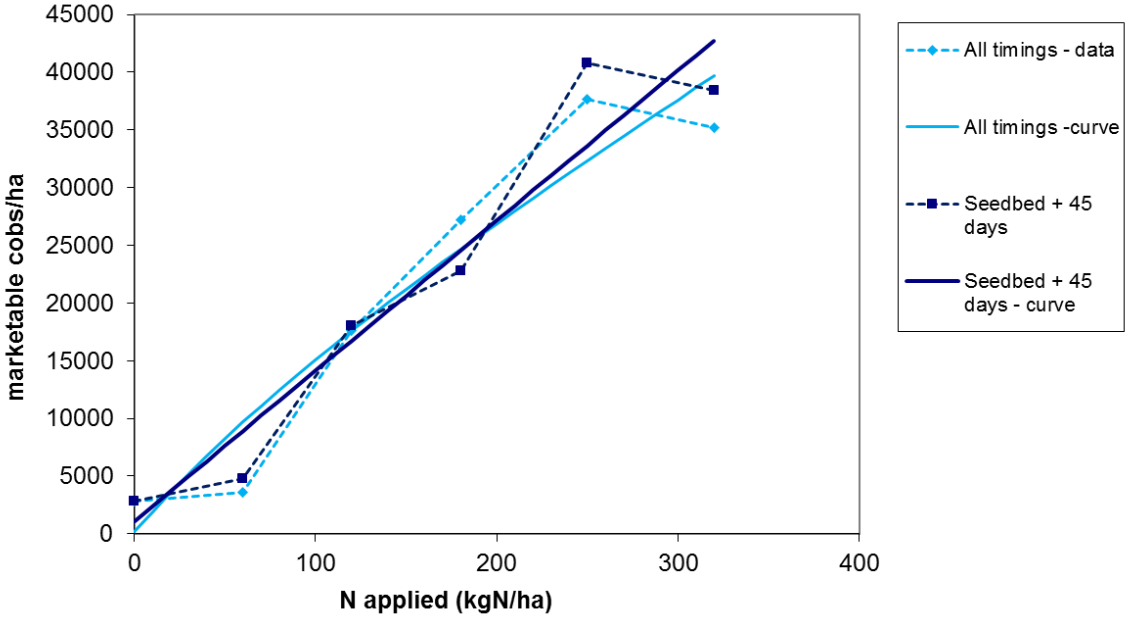

Figure 30. Economic optimum N curve for the early drilled crop, site 14/E2, W.Sussex, 2014.

At the late site 14/L3 (Figure 31) there was no N timing effect so the economic optimum curve can be fitted through all the data to give a maximum yield of 36,023 cobs/ha at > 320 kgN/ha applied using any of the timing regimes. However, due to the maximum N uptake of 178 kgN/ha being less than the highest rate of N applied (320 kgN/ha) then applying such high amounts would potentially leave a significant amount of SMN after harvest and a more realistic approach would be to use the curve for the seedbed plus V5 timing application. If this is used, then the economic optimum N is estimated to be 227 kgN/ha and at this rate of applied N, would give a benefit of £78/ha for an increase of 480 cobs/ha, with an extra cost per ha for N of £67/ha at current costs (margin over fertilizer N costs of £11/ha).

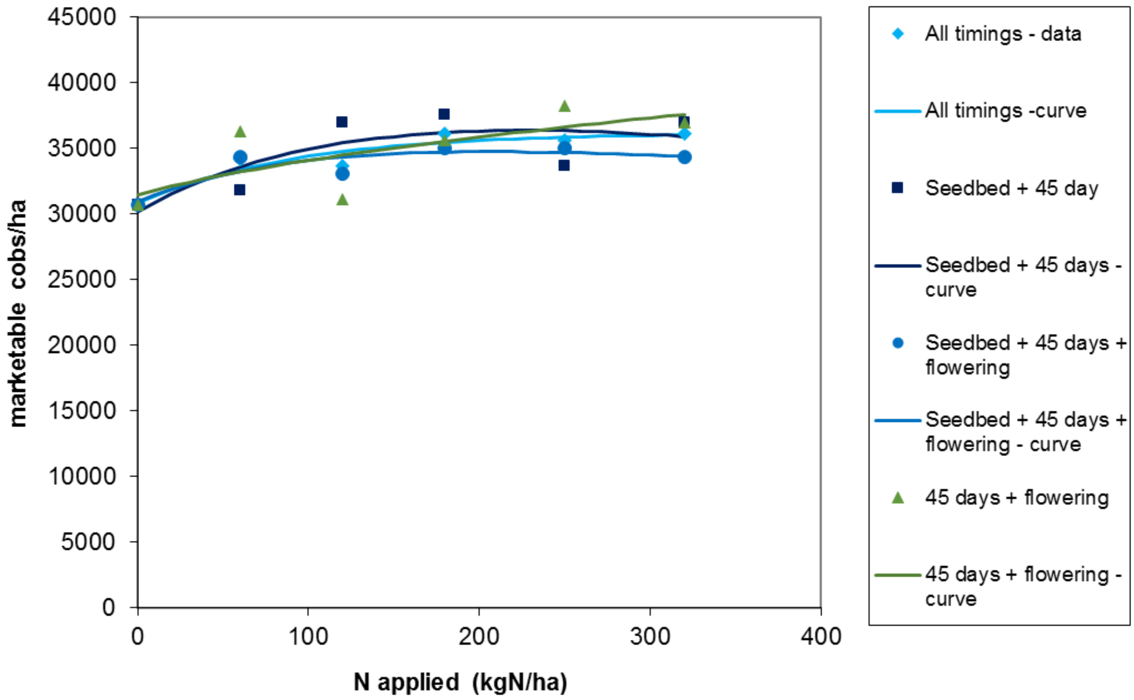

Figure 31. Economic optimum N curve for the late drilled crop, site 14/L3, W.Sussex, 2014.

Using this curve fitting approach, five out of 11 crops required a higher rate of N than RB209 recommendations to achieve a more economically optimal yield. Based on this conclusion, the requirements for current sweetcorn varieties may be higher in some situations, and there is scope to fine-tune the current recommendations for these circumstances. Table 11 compares the difference in value per ha between the current RB209 recommendation methods, the economic optimum and 'fine tuning' the recommendations by an additional 70 kgN/ha for Index 0 sites, and an additional 50 kgN/ha for the Index 1 site for the N responsive crops in the project. The figures for 'fine-tuning' have been arrived at by taking the average N optimum of all the sites at each Index (0 and 1) for both responsive and non-responsive sites. Incidentally the additional 70 kgN/ha would bring the highest recommendation at Index 0 up to the internationally published amount of 220 kgN/ha.

The first two columns show the economic gain per ha if the optimum yield is reached for each crop compared with current recommendations. The next columns show the values gained from applying either 70 or 50 kgN/ha above recommendations, and the final columns show how close in value this 'arbitrary' increase gets to the economic optimum. This again underlines the strong response of Earlybird drilled at low SNS Index sites and the associated benefit if N is applied above current recommendations. The site at 14/E2 gave an exceptionally strong response to increasing rates of N applied. At this site (14/E2) and site

14/L3 it also highlighted that if the field assessment method (FAM) was used for the medium silt soils it can give an SNS index one category higher than was actually measured by SMN testing. This could have implications for restricting yield potential if the SNS for these sites is overestimated by the FAM and thus the N recommendation is too low. It may be useful to take SMN samples at sites with medium soils or where the SNS is uncertain to increase the chance of achieve the economically optimum yield. Conversely at site 13/L2 on a light sandy clay in 2013 the SMN indicated a higher index than FAM for this site, and if taken into account could have restricted yield. This indicates that although measuring SMN is a useful tool, an agronomic knowledge of field history and yield performance is still needed to inform nutrient management decisions.

Table 11. Differences in value per ha (margin over N costs) from current recommendations if using the economic optima estimated from the field experiments for sites showing yield responses, or using an increase of 70 kgN/ha at Index 0 or 50 kgN/ha at Index 1 to fine tune the RB209 recommendations, Hants, Sussex and IOW, 2013/14 (note: economic optimum for site 14/E2 fitted to actual data)

Current practice = Using Farm Assessment Method (FAM) to determine SNS Index and RB209 for N recommendation.
Rainfall category for FAM = High (Table C)
Price per cob = 17p
Price per kg of N as CAN = 96p

							Differences in value comparing yield at N optimum to yield with current practice (£/ha)		Differences in value comparing RB209 rec. + 70 or + 50 kgN/ha to yield with current practice (£/ha)		Differences in value/ha comparing yield at N optimum to RB209 rec. + 70 or + 50 kgN/ha (£/ha)	
Year/ Site	**Variety**	**Index by Farm Assessment Method (FAM)**	**Index by SMN at drilling**	**RB209 rec. by FAM (kgN/ha)**	**RB209 rec. by SMN (kgN/ha)**	**Economic optimum N from trial (kgN/ha)**	**FAM**	**SMN**	**FAM**	**SMN**	**FAM**	**SMN**
13/E1	Earlybird	0 (Shallow light soil, High N Veg-incorp. overwinter residues)	0 (54)	150	150	200	124.61	124.61	87.44	87.44	-17.97	-17.97
13/E2	7403	1 (Medium silt, Med N Veg)	0 (54)	100	150	150	31.67	0.00	31.67	-81.46	0.00	2.07
13/L2	7403	0 (Light sand, wheat)	1 (75)	150	100	230	28.36	225.33	37.49	0.00	9.13	-28.36
14/E2	Earlybird	1 (Medium silt, sweetcorn)	0 (46)	100	150	250	1745.85	826.25	994.57	2268.10	-1793.85	-520.31
14/E3	Earlybird	0 (Light sand, sweetcorn)	0 (43)	150	150	230	302.96	302.96	306.14	306.14	60.78	60.78
14/L3	1138	1 (Medium silt, sweetcorn)	0 (56)	100	150	230	119.78	1.40	118.38	129.03	-1.40	34.08

If all the marketable yield data as cobs per ha are considered across all sites showing a yield response, the average % yield increase above RB209 from applying economic optimum N or ‘fine-tuning’ the recommendations can be calculated to summarise the yield gains that can be achieved per site (Table 12). If the numbers from the responsive sites are then calculated to give an average across all responsive and non-responsive sites, then an average % yield increase can be calculated for early and late crops and for each year of the trial. In 2013, there was no QA data for site 13/L1, and in 2014 site 14/L2 was not taken to harvest so the overall averages reflect this.

Table 12. Potential yield increase (%) from applying nitrogen at the actual economic optimum and using an increase of 70 kgN/ha or 50 kgN/ha to fine tune the recommendations at N responsive sites, compared to current practice, Hants, Sussex and IOW, 2013/14

				Marketable cobs/ha			% yield increase	
Site	**Index by SMN at drilling**	**RB209 rec. by SMN (kgN/ha)**	**Economic optimum N from trial (kgN/ha)**	**RB209**	**RB209 + 70 or 50 kgN/ha**	**Economic optimum**	**RB209 + 70 or 50 kgN/ha**	**Economic optimum**
13/E1	0 (54)	150	200	37242	38039	38257	2.09	2.66
13/E2	0 (54)	150	157	33,748	33,364	33,752	-1.99	1.18
13/L2	1 (75)	100	230	30967	32408	33026	4.45	6.24
14/E2	0 (46)	150	250	21215	29102	32332	27.10	34.40
14/E3	0 (43)	150	230	27511	29707	29745	7.39	7.50
14/L3	0 (56)	150	230	35909	36367	36369	1.26	1.26
Average early crops /6 (All years)	-	-	-	-	-	-	6.09(5.76)	7.43(7.62)
Late crops /4 (All years)	-	-	-	-	-	-	1.43	1.90
Average 2013 /5	-	-	-	-	-	-	1.31(0.91)	1.80(2.01)
Average 2014 /5	-	-	-	-	-	-	7.15	8.64
Overall average /10							3.76(3.59) -4.23 (4.03)	4.65(4.76) – 5.22 (5.32)

To achieve optimum yield in situations where a strong response to nitrogen is expected, N could be applied at higher rates than the recommended RB209 N rates at 196 kgN/ha for 13/E1, 227 kgN/ha for 13/L2, 250 kgN/ha for 14/E2, 232 kgN/ha for 14/E3, and 227 kgN/ha for 14/L3. However to do this, N would need to be applied in excess of the trial crop requirements (at 145, 170, 191, 213 and 178 kgN/ha total uptake, respectively). It may be possible to apply this extra N as long as measures are taken to mitigate against the environmental consequences of nitrate leaching over winter, such as removing the crop residues for anaerobic digestion and/or under-sowing cover crops in the autumn to capture remaining SMN. It is estimated that the application of fertiliser N above recommended rates would lead to an extra 60 kgN/ha on average remaining in crop residues and soil after harvest. If mechanised harvesting is used a lot of crop residues are left behind but as carbon:nitrogen (C:N) ratios are high (>20:1) for the remaining plant tissues then breakdown is likely to be slow, and leaching risk from these residues is lower than from fertiliser N left in soil. Typical C:N values are 66:1 for stems of corn, 98:1 for cobs and 35:1 for leaves, which is why maize cobs and stems are still frequently seen in the field the following year. The whole plant has an overall average C:N value of 69:1 and thus residues will tend to immobilise nitrogen overwinter especially as soil microbial activity slows in cool conditions. However, this reduction in soil microbial activity means that the greatest risk of leaching is from remaining SMN, and as seen in the following graphs (Figures 32-34) applying 70 kgN/ha for optimum yield increases the SMN remaining after harvest by 30 kgN/ha to 65 kgN/ha posing a potential leaching risk. The following graphs plot the increase in yield against % recovery of nitrogen to show this increase in SMN, at N applied higher than RB209 at sites 14/E2, 14/E3 and 14/L3. This is because generally the efficiency of % recovery of nitrogen decreases as rate of N applied increases.

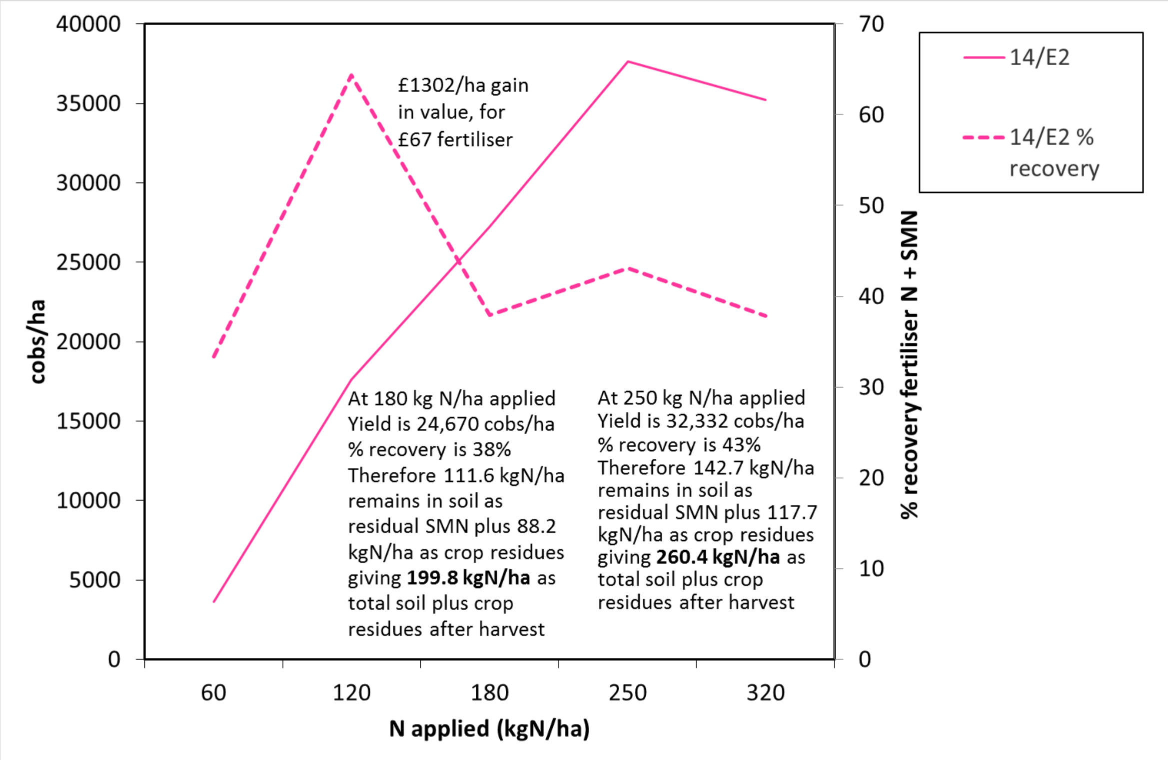

Figure 32. Effect of increasing the rate of fertiliser N on yield and % recovery of fertiliser N by the marketable cobs and therefore the amount of N estimated to remain in soil and crop residues post-harvest, site 14/E2, Sussex, 2014

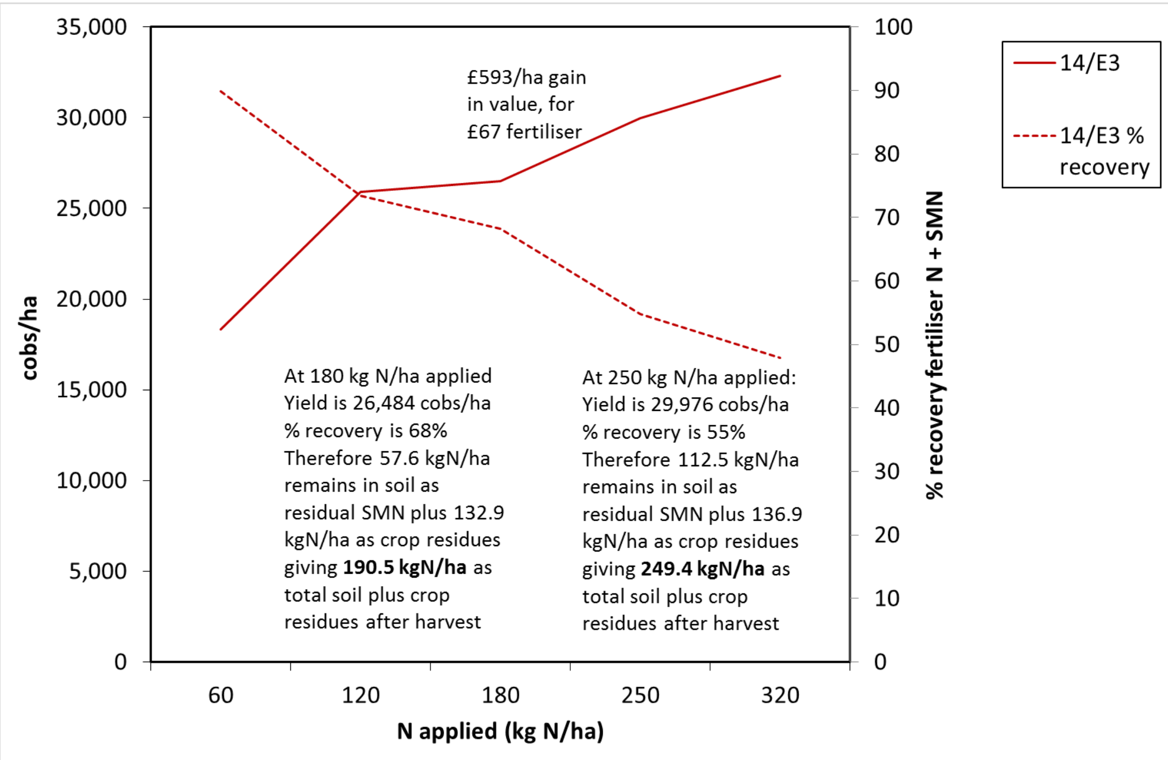

Figure 33. Effect of increasing the rate of fertiliser N on yield and % recovery of fertiliser N by the marketable cobs and therefore the amount of N estimated to remain in soil and crop residues post-harvest, site 14/E3, Isle of Wight, 2014

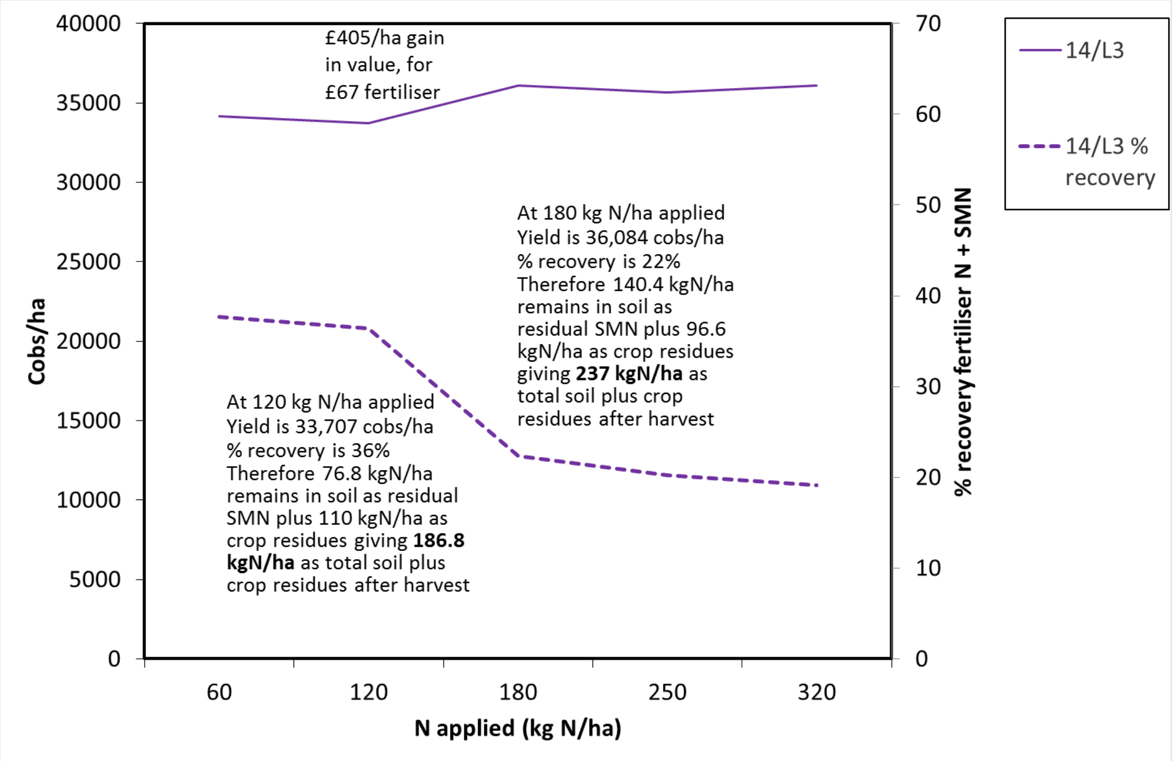

Figure 34. Effect of increasing the rate of fertiliser N on yield and % recovery of fertiliser N by the marketable cobs and therefore the amount of N estimate to remain in soil and crop residues post-harvest, site 14/L3, Sussex, 2014

This increase in potential SMN remaining after harvest of up to 65 kgN/ha from applying 70 kgN/ha extra N to achieve higher yields could be mitigated against by using non-legume overwinter cover crops to capture the remaining N. Overwinter cover crops such as grasses, cereals, radish and non-legume mixes can typically capture approximately 50 kgN/ha, and once ploughed in, in spring will release this N for use by the following crop. Crop residues could also be removed to be used for silage or anaerobic digestion where facilities exist.

To conclude, the work on nitrogen indicated that at sites where a strong response is expected, it is necessary to apply N at rates above those currently recommended in RB209 to achieve economically optimum yields. However, it is also necessary to identify the situations in which the extra N is required in order to avoid unnecessary wastage of fertiliser if the crop requirement is lower than expected. At a known high yielding site, more N may be utilised by the crop and extra fertiliser N justified, but this can only be advised where high yields are consistently achieved. Situations where a strong response is likely are at early, low SNS index sites drilled with the variety Earlybird. Later drilled sites and newer varieties such as 7403 and 1138 also respond to extra applied N but it is harder to predict the strength of these responses and thus a knowledge of agronomic parameters such as site history, aspect and soil type that may inform yield potential should be considered before increasing N above those recommended in RB209.

Phosphorus yield and growth responses

There were no significant yield responses to P applied in 2013 and 2014 at the four early sites (cob quality data were unavailable for the late sites). Total cob weight of both marketable and non-marketable sweetcorn increased slightly by 0.3 to 0.9 tonnes/ha when up to 120 kgP_2O_5/ha was applied, and increased by a further 0.6 to 1.03 tonnes/ha between 120 kgP_2O_5/ha and 320 kgP_2O_5/ha (Figure 35). The only exception was site 14/E3 which had a P index of 4, and at which weight of total cobs and yield declined with increasing rates of phosphate applied. It should be noted that the data were examined with the possibility of fitting curves to the yield responses to applied P. However it was decided that due to the lack of good curve fits to the means, in most cases, together with the variability between the individual values for each P level, there was no benefit in proceeding with this approach

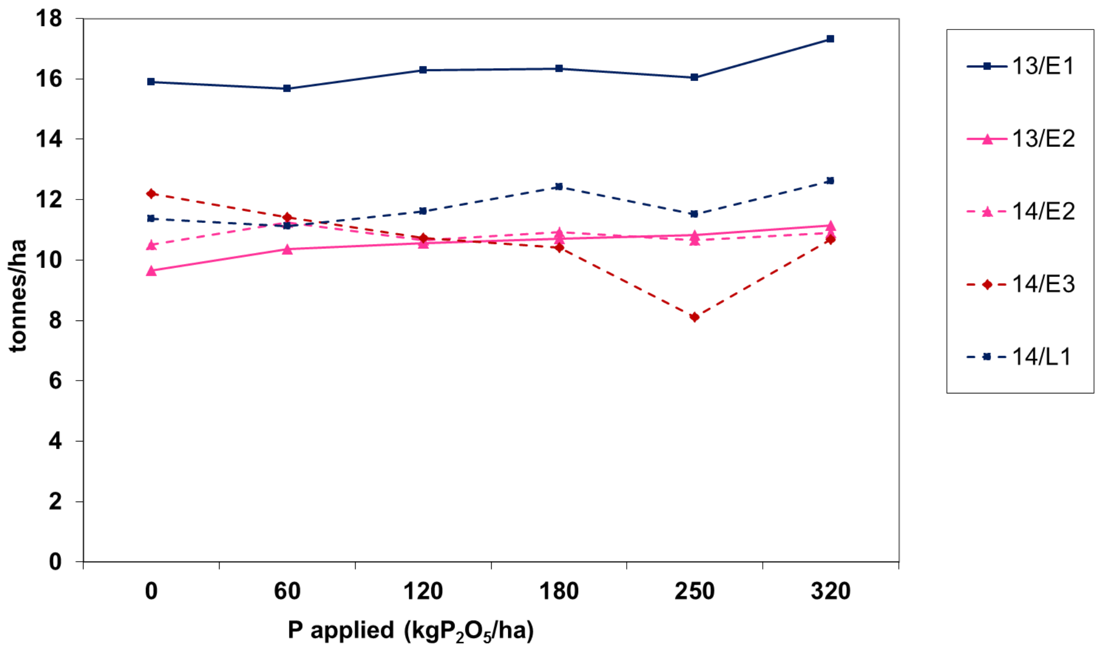

Figure 35. Effect of the application of increasing rates of P_2O_5 on the weight of all cobs in 2013 (unbroken line) and 2014 (broken line), Hants and Sussex.

Marketable yields of cobs per ha (Figure 36) were more variable with no significant differences in response to applied phosphate, but a trend, though not significant, for increasing number of cobs was seen at the lowest P index site at 14/E2. Using the data in Figure 36, a value of 17 pence/cob and 64 pence/kg of P_2O_5 it can be seen that at site 14/E2 an extra 605 cobs can be gained by applying 120 kg P_2O_5/ha when compared to 60 kg P_2O_5/ha to give an increase in margin over costs of £64.45/ha. If the rate of phosphate is increased further still to 180 kg P_2O_5/ha this gives an increase of 3,633 cobs over the marketable cobs/ha produced at 60 kg P_2O_5/ha to give an increase in margin over costs to the grower of £540.20/ha. This is just one site and to confirm the trend, further trials would be needed on P index 0-2 sites to determine if the increase in yield seen can be repeated to justify the application of consistently higher rates of phosphate than those currently recommended on lower P indices. Also, methods of application such as using banding and a more available form of the nutrient such as di-ammonium phosphate (DAP) should also be investigated.

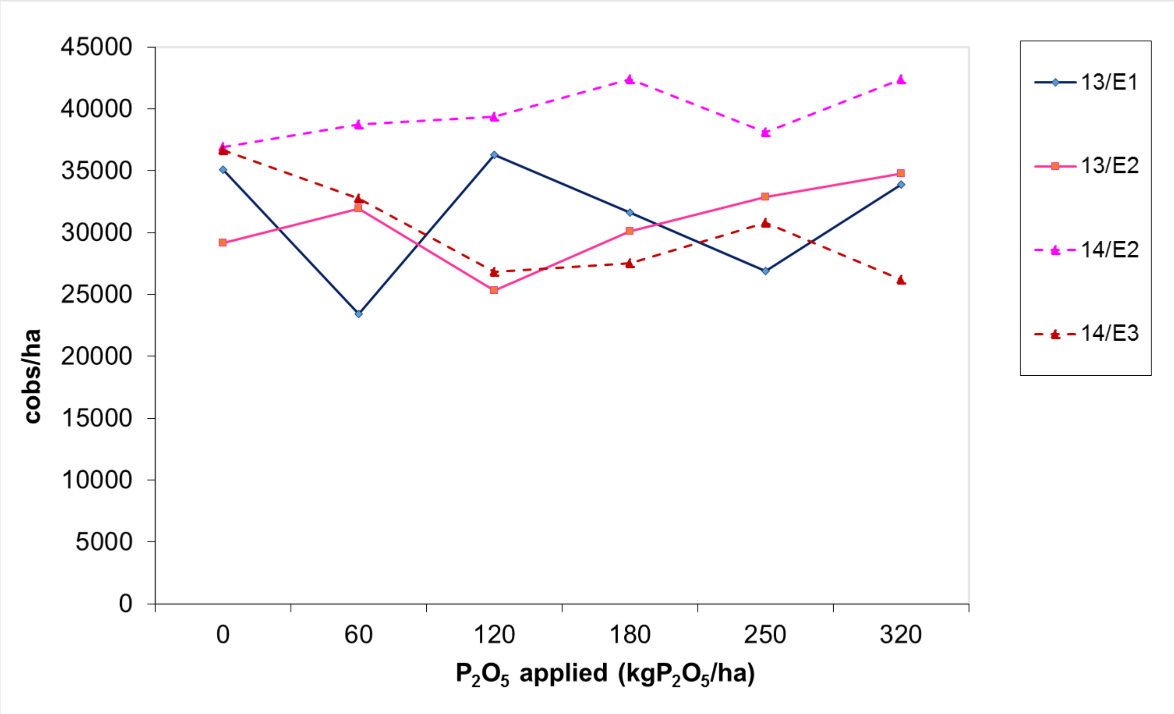

Figure 36. Effect of the application of increasing rates of P_2O_5 on the numbers of marketable cobs in 2013 (unbroken line) and 2014 (broken line), Hants and Sussex.

Sites at 13/E1, 13/E2 and 14/E3 where the trials were located had P indices of 3-4, which would have decreased the likelihood of a response to phosphate fertiliser. At the low P Index site 14/L1 (P Index 2), a trend was seen for increasing weight of all cobs but unfortunately no QA data were available for this site to corroborate if this was translated to an increase in marketable yield. However, at this site at growth stage V6 and at tasselling/flowering, visual differences in crop growth stage could be observed between the nil phosphate plots and those with phosphate applied (Figure 37) showing a positive effect on crop development. In the nil phosphate applied plots the growth stage was retarded throughout the trial, such as that when the plots with phosphate applied reached flowering/tasselling (VT), those where no phosphate was applied were a few days behind, being still at V18 where the male flower had not yet fully emerged. This shows the importance of phosphate for increasing vigour in early growth, and this has been reported by a number of authors including Grant *et.al*. (2000) who reviewed a number of studies on the effects of phosphorus on yield who states that ‘withholding P during early plant growth will limit crop production and cause a restriction in crop growth from which the plant may not recover’. Fletcher *et al.* (2008) reported that in sweetcorn crops grown in New Zealand under cool conditions with a low P index (0), at nil phosphate applied the emergence of leaf tips was delayed and leaf area was reduced. Although no significant yield effects were seen from applications of phosphate, even on Index 2 sites, this could be because the phosphate was applied as broadcast triple superphosphate (TSP) in our studies, rather than as di-ammonium phosphate (DAP) which is placed in a band below and to the side of the seed as commonly used in commercial systems. The use of TSP was to avoid the confounding effect of N in the DAP, but the disadvantage of this form and application method, is that the phosphate may have not been in as readily available form and concentrated close enough to the seed early in the sweetcorn plant’s life when the rooting system is small and soils are cool. The effect of banded DAP was observed in 2013 where the commercial crop surrounding the trial at site 13/E1 (see Figure 2, p17) was drilled on the same day, yet was always at least 2-3 days ahead in development possibly due to the effect of the starter fertiliser in a cool spring. Stone (2000) stated that starter fertiliser can significantly boost the early growth of a diverse range of wide-spaced row crops including forage maize, and it could be argued that much of the early effect may be due to the phosphate component of the ammonium phosphate used. Swaider and Shoemaker (1998) also report increased early seedling growth even on high P index soils where a starter fertiliser containing N and P (10:34:0) as ammonium polyphosphate (APP) was studied for effects on yield, growth and maturity in sweetcorn in Illinois. They observed that although significant yield response wasn’t always realised, the enhanced speed of seedling growth may be a benefit as more vigorous plants are more tolerant of adverse environmental conditions, and in UK systems would allow the timely application of herbicides before weeds reach a size which is detrimental to sweetcorn establishment and thus yield. Van Rotterdam *et al.* (2014) also reported a positive effect of P containing fertiliser placed in the row at the start of the growing season on high P soils in the Netherlands. It is not certain whether this increased growth effect is due to the N or P placement as DAP contains both nutrients and both have a role in plant growth, and on high P soils which often occur in vegetable rotations it may be beneficial to determine which nutrient is causing the increased growth effect.

Figure 37. Effect of the application of P_2O_5 as broadcast triple superphosphate on crop development at P Index 2, Hants, 2014.

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

Cob sweetness was measured by Barfoots quality assessment team using BRIX. There was no effect on BRIX values with increasing N rates or timings, or with respect to applied P. There was a significant response in sweetness from two early crops (13/E1 and 14/E2) and two late crops (13/L2 and 13/L3) comparing zero N (control plots) to all rates of N applied (Table 13). In the early crops 13/E1 and 14/E2, BRIX levels increased by 1-2 ^{0}Bx when N was applied. Conversely the BRIX levels were significantly reduced when N was applied to both late crops in 2013, but this trend was not repeated in 2014. However, all samples submitted to the lab achieved a BRIX greater than 10 ^{0}Bx, which is the minimum specification required by the retail market. Therefore, although applying N to the late crops in 2013 appeared to reduce sweetness by 0.75 ^{0}Bx, these would both have met the specifications required. Moreover, a greater financial benefit is to be gained by applying N, from the additional yield which is realised.

Table 13. Effect of nitrogen on the sweetness (BRIX) of cobs, Hants, Sussex and Isle of Wight, 2013 and 2014.

	BRIX value (^{0}Bx)			
	Control (0N)	+N applied*	Probability	LSD (95%)
13/E1	14.40	15.62	<0.01	0.832
13/E2	16.28	16.38	NS	
13/E3	15.36	15.81	NS	
13/L2	18.37	17.64	<0.001	0.353
13/L3	15.58	14.82	<0.05	0.713
14/E1	15.91	15.91	NS	
14/E2	13.28	15.28	<0.05	1.792
14/E3	19.27	19.58	NS	
14/L1	16.71	16.86	NS	
13/L3	16.65	17.26	NS	

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

Leaning was recorded at site 13/L3 in 2013 where SMN at drilling was highest but this was not significant, and also at site 14/L3 in 2014 which was a very exposed site and was caused by the remains of a hurricane ('Bertha') giving a period of very high winds, but again there were no significant differences.

Conclusions

- Results from this study suggest that for just over half of the UK's crops, using the current recommendations given in RB209 is the most appropriate strategy in sweetcorn, to both maximise cob yield, while minimising the environmental impacts from over-fertilising.
- However, for 45% of crops in the study where a strong response to N fertiliser was seen at SNS Index 0 – 1 sites, rates of between 200 – 250 kgN/ha were necessary to achieve economically optimal yields, and recommendations could be increased for these crops above those stated in the RB209.

- At present such higher recommendations should only be used where there is evidence of a history of high yields, and/or the advice of a FACTS qualified advisor is used.
- There was a difference in the strength of yield responses between early (Earlybird) and main crop (7403 and 1138) varieties which could be used to guide recommendations, but further work would be needed to increase the dataset and confirm trends and N requirements as main crop varieties are sown later and therefore any responses are confounded with higher starting SMN.
- Providing most of the nitrogen early in growth to ensure it is available prior to the sweetcorn's maximum period of demand for vegetative growth (V6 – R1) appears to be the best strategy with respect matching crop uptake to optimise cob yield.
- Growers should consider measuring SMN to 90 cm depth prior to drilling before deciding on the SNS index of a site, particularly for late sown crops and medium soils where consistently predicting the correct SNS index using the field assessment method (FAM) can be difficult.
- With respect to the effects of N on cob sweetness, the results suggest that growers should not have any concerns about under or over fertilising the 'supersweet' varieties, as Brix values were always above the marketing standard and the greater effect of N is on yield.
- While sweetcorn is known to be sensitive to P deficiency, there is little evidence that current best practice guidelines should be changed at present.
- At nil N the average phosphate offtake was 45 kgP_2O_5/ha, therefore to maintain soil P indices it is considered good practice to replace the phosphate that will be taken off by the crop.

Recommendations for further work

Further work is desirable to:

- Explore the feasibility of applying greater than 100 kgN/ha in the seedbed, and the placement and form of such fertiliser N.
- Investigate whether different varietal types (i.e. early vs main crop) require fundamentally different N requirements, or whether the differences in N responses simply reflect different soil conditions at the time of sowing.

- Revisit rates, form and placement of P in the seedbed and quantify the potential benefits for crop growth and development, as well as yield at sites at Index 2 and below.

Knowledge and Technology Transfer

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

Field trial open day – A.E. (Brown) Farms, Isle of Wight, 29th July 2014

Field trial open day – Broadlands Estate, Barfoot Farms Ltd. Hants, 4th Sept 2014

Project meeting - Barfoots of Botley, 13th November 2014.

Poster presentation – International Fertiliser Society Conference, Cambridge, 11th – 12th December 2014

References

Assured Food Standards (2011). Crop-specific Protocol - Sweetcorn. April, 2011.

Archer, J. (1985). Crop Nutrition and Fertiliser Use. Farming Press Ltd.

Bender, R.R., Haegele, J.W., Ruffo, M.L & Below, F.E. (2013). Nutrient uptake, partitioning and remobilization in modern, transgenic insect-protected maize hybrids. Agronomy Journal, Volume 105, Issue 1; 161-170.

Defra (2010). Fertiliser Manual, RB209. Defra, 8th Edition, June 2010.

Fletcher, A.L., Moot, D.J & Stone, P.J. (2006). The effect of fertiliser P on crop biomass production, partitioning and quality in ‘Challenger’ sweet corn. Aust. J. Agric. Res., 57; 1213–1219.

Grant, C.A., Flaten, D.N., Tomasciewicz, D.J & Sheppard, S.C. (2001). The importance of early season phosphorus nutrition. Can. J. Plant Sci., 81; 211-224.

Jones, C. A. (1985). *C4* grasses and cereals: growth, development, and stress response. John Wiley & Sons, Inc., New York.

IFA. (1992). World Fertiliser Use Manual. International Fertiliser Industry Association, Paris. ISBN 2-9506299-0-3.

Karlen, D.L., Sadler, E.J. & Camp, C.R. (1987). Dry matter, nitrogen, phosphorus and potassium accumulation rates by corn on Norfolk loamy sand. Agronomy Journal, 79; 649-656.

Pessaraklia, M., Hubera, J.T. & Tuckera, T.C. (1989). Dry matter yield, nitrogen absorption, and water uptake by sweet corn under salt stress. Journal of Plant Nutrition, Volume 12, Issue 3; 279-290.

Shenker, M., Ben-Gal, A. & Shani, U. (2003). Sweet corn response to combined nitrogen and salinity environmental stresses. Plant and Soil, Volume 256, Number 1; 139-147.

Stone, D. (2000) Nitrogen requirement of wide-spaced row crops in the presence of starter fertilizer. Soil Use and Management, Volume 16, 285-292.

Swaider, M.S. & Shoemaker, W.H. (1998). In-furrow starter fertilization enhances growth and maturity in early sweet corn. Hort. Science, Vol. 33, 6; 1007-1010.

Van Rotterdam, A.M.D., Bussink, D.W. & Reijneveld, J.A. (2014). Improved phosphorus fertilisation based on better prediction of availability in soil. Proceedings International Fertiliser Society 755; 1-24.

Appendix – Complete data sets for each site

2013 sites

13/E1 early N – Hants

SMN February	23.8 kgN/ha	Previous crop (2012)	Tenderstem broccoli
SMN pre drilling	45.7 – 66.9 kgN/ha	Previous crop (2011)	Sweetcorn
P pre drilling	(Index 3-4)	Previous crop (2010)	Bulbs
pH	7 – 7.2	Soil type	sandy clay loam over gravel
Drilled 22 April	Harvest 13 August	Variety - Earlybird	Plant population = 42.1 plants/10m (56,133 plants/ha)

N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**
N Uptake (kg/ha)	68.7	110.8	112.0	122.4	137.4	145.0	0.001	18.12
Total N (%)	1.69	1.76	1.71	1.74	1.93	1.97	0.012	0.178
Fresh weight whole plant (t/ha)	21.5	33.6	33.8	35.6	37.2	38.3	NS	-
Dry weight whole plant (t/ha)	3.8	6.1	6.4	6.8	6.8	7.2	0.037	0.768
Dry matter (%)	18.6	18.5	19.4	19.8	19.2	19.4	NS	-
Weight main cobs (t/ha)	8.7	13.7	16.1	16.5	17.8	16.9	<0.001	0.809
% marketable cobs	3.7	30.6	55.6	53.7	54.6	61.1	0.009	17.03
Marketable cobs (numbers/ha)	2076	17176	27466	30143	30648	34297	0.009	9,559
Marketable cobs (t/ha)	0.4	3.9	7.4	7.2	7.7	8.4	0.01	1.244

N timing	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + flowering**	**F Prob**	**LSD**
N Uptake (kg/ha)	131.8	130.5	114.2	0.026	16.21
Total N (%)	1.85	1.86	1.75	NS	-
Fresh weight whole plant (t/ha)	36.5	36.9	33.6	0.091	1.8556
Dry weight whole plant (t/ha)	6.9	6.7	6.3	0.062	0.687
Dry matter (%)	19.6	18.9	19.3	NS	-
Weight main cobs (t/ha)	16.9	16.2	15.5	0.099	0.463
% marketable cobs	60.0	53.9	39.4	0.010	15.23
Marketable cobs (numbers/ha)	33680	30256	22116	0.010	8,549
Marketable cobs (t/ha)	8.2	7.2	5.4	0.024	1.113

N rate (kgN/ha)	0	60	120	180	250	320	F Prob	LSD
BRIX	14.4	15.18	15.56	16.01	15.89	15.48	NS	-

N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
BRIX	15.77	15.39	15.71	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
N rate (kgN/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
Total N (%)	1.69	1.83	1.62	1.77	1.96	2.04	1.69	1.87	1.86	1.80	1.86	1.93	1.69	1.57	1.65	1.64	1.97	1.93	NS	-
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
Dry weight whole plant (t/ha)	3.8	6.1	7.6	6.9	7.3	6.7	3.8	7.1	6.2	6.6	6.6	7.4	3.8	4.8	5.3	6.9	6.8	7.4	0.021	1.086
Dry matter (%)	18.6	18.9	20.3	19.9	19.3	19.6	18.6	17.9	18.9	19.4	19.5	19.1	18.6	18.6	19.1	20.2	18.8	19.4	NS	-
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
% 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 kgN/ha	Previous crop (2012)	Courgettes
SMN pre drilling	51.3 - 57 kgN/ha	Previous crop (2011)	Grass
P pre drilling	(Index 2-3)	Previous crop (2010)	Sweetcorn
pH	6.8– 7.7	Soil type	Silty clay
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 + V4 to V6	Three equal apps	V4 to V6 + 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	-
Cob N (%)	1.54	1.48	1.46	1.49	1.63	1.64	0.007	0.061		Cob N (%)	1.60	1.53	1.50	NS	-
Stem/leaves N (%)	1.35	1.38	1.38	1.47	1.59	1.67	<0.001	0.069		Stem/leaves N (%)	1.59	1.47	1.44	0.022	0.062
% 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 plant (t/ha)	29.1	36.7	42.9	44.4	47.9	48.5	<0.001	4.643		Total fresh weight whole plant (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	14.1	18.1	21.2	21.6	22.6	22.9	0.002	2.415		Total fresh weight	21.3	22.2	20.4	NS	-

N rate (kg N/ha)	0	60	120	180	240	300	F Prob	LSD		N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
stem/leaves (t/ha)										stem/leaves (t/ha)					
% cob total fresh 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	-
Dry weight whole plant (t/ha)	5.7	7.1	8.2	8.5	9.8	9.2	<0.001	0.597		Dry weight whole plant (t/ha)	8.6	9.1	8.0	0.093	0.534
Dry weight cobs (t/ha)	2.8	3.7	4.4	4.6	5.1	5.1	<0.001	0.277		Dry weight cobs (t/ha)	4.6	4.8	4.2	<0.001	0.247
Dry weight stem/leaves (t/ha)	2.8	3.4	3.7	3.9	4.8	4.1	0.011	0.389		Dry weight stem/leaves (t/ha)	3.9	4.3	3.8	NS	-
% cob total dry matter as a proportion of total biomass (Harvest Index)	50.2	52.1	54.2	54.1	52.1	55.3	NS	-		% cob total dry matter as a proportion of total biomass (Harvest Index)	54.3	53.6	52.7	NS	-
Dry matter total biomass (%)	19.3	19.1	19.1	19.3	20.4	18.8	NS	-		Dry matter total biomass (%)	19.2	19.6	19.2	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
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	

N rate (kg N/ha)	0	60	120	180	240	300	F Prob	LSD		N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
% 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 + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
N rate (kgN/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	-
Cob N (%)	1.54	1.67	1.54	1.47	1.67	1.65	1.54	1.43	1.34	1.52	1.66	1.69	1.54	1.35	1.51	1.50	1.56	1.58	NS	-
Stem/ leaves N (%)	1.35	1.42	1.55	1.48	1.76	1.76	1.35	1.34	1.25	1.52	1.51	1.73	1.35	1.39	1.35	1.42	1.52	1.53	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	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
% 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	-
Dry weight whole plant (t/ha)	5.7	7.2	7.7	8.6	9.5	9.9	5.7	8.3	8.1	9.2	11.2	8.7	5.7	5.6	8.7	7.9	8.8	8.8	NS	-
Dry weight cobs (t/ha)	2.8	3.6	4.3	4.6	5.3	5.6	2.8	4.5	4.4	5.1	5.4	4.7	2.8	2.8	4.6	4.3	4.4	4.8	0.019	0.392
Dry weight stem/leaves (t/ha)	2.8	3.5	3.5	3.9	4.3	4.3	2.8	3.7	3.6	4.1	5.8	3.9	2.8	2.8	4.1	3.7	4.5	3.9	NS	-
% cob total dry matter as a proportion of total biomass (Harvest Index)	50.2	50.8	55.2	53.3	55.7	56.4	50.2	55.1	54.3	54.9	49.2	54.5	50.2	50.3	53.1	53.8	51.5	54.9	NS	-
Dry matter total biomass (%)	19.3	19.3	18.7	19.6	19.1	19.4	19.3	19.6	19.1	19.3	21.7	18.2	19.3	18.3	19.3	18.7	20.4	18.9	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 kgN/ha	Previous crop (2012)	Wheat
SMN pre drilling	58 – 61.1 kgN/ha	Previous crop (2011)	Asparagus
P pre drilling	(Index 4)	Previous crop (2010)	Asparagus
pH	6.1– 6.6	Soil type	Sandy silt loam
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 (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**	**N timing**	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + 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	-
Total N (%)	1.66	1.38	1.53	1.67	1.78	1.83	<0.001	0.158	Total N (%)	1.72	1.60	1.59	0.042	0.213
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	-
Dry weight whole plant (t/ha)	5.5	7.1	7.7	9.3	9.6	9.7	0.002		Dry weight whole plant (t/ha)	8.8	8.6	8.6	NS	-
Dry matter (%)	17.1	17.5	17.7	17.7	17.9	18.5	NS	-	Dry matter (%)	17.6	18.3	17.7	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	-
% 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 + V4 to V6						**(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)**						**(T3) Timing 3 At V4 to V6 + flowering**						**F Prob**	**LSD**
N rate (kgN/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	-
Total N (%)	1.66	1.42	1.52	1.86	1.85	1.93	1.66	1.34	1.47	1.63	1.76	1.80	1.66	1.37	1.58	1.54	1.73	1.76	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	-
Dry weight whole plant (t/ha)	5.5	6.8	8.0	9.6	10.4	9.4	5.5	7.2	6.8	9.6	9.5	10.2	5.5	7.1	8.3	8.7	9.2	9.6	NS	-
Dry matter (%)	17.1	16.7	17.6	17.7	17.9	18.1	17.1	17.5	17.9	17.9	18.2	19.7	17.1	18.2	17.7	17.5	17.6	17.8	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	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	NS	-

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	NS	-
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 kgN/ha	Previous cropping (2012)	Pumpkins
SMN pre drilling	61.9 – 75.5 kgN/ha	Previous cropping (2011)	Sweetcorn
P pre drilling	(Index 3)	Previous cropping (2010)	Wheat
pH	6.3– 6.9	Soil type	Loamy sand (high stone content) over gravel
Drilled 14 May	Harvest 18 September	Variety – 7403 Plant population = variable	

N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**	**N timing**	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + 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	-
Total N (%)	1.52	1.77	1.84	1.88	1.91	2.01	0.017	0.064	Total N (%)	1.91	1.91	1.84	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	-
Dry weight whole plant (t/ha)	3.7	4.3	4.2	4.4	4.4	3.7	NS	-	Dry weight whole plant (t/ha)	4.4	4.2	4.1	NS	-
Dry matter (%)	21.5	19.4	19.6	19.7	19.2	19.3	NS	-	Dry matter (%)	19.6	19.5	19.3	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 + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
N rate (kgN/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	-
Total N (%)	1.52	1.84	1.87	1.92	1.89	1.98	1.52	1.71	1.94	1.91	1.95	2.01	1.52	1.77	1.72	1.82	1.87	2.01	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	-
Dry weight whole plant (t/ha)	3.7	4.2	4.4	4.2	5.3	3.6	3.7	4.1	4.5	4.5	4.1	3.7	3.7	4.7	3.4	4.4	3.8	3.8	NS	-

Dry matter (%)	21.5	19.9	18.9	19.8	19.6	19.8	21.5	19.6	20.1	20.4	19.5	18.3	21.5	18.7	19.9	19.1	18.5	19.7	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 kgN/ha	Previous cropping (2012)	Wheat
SMN pre drilling	67.5 – 87.3 kgN/ha	Previous cropping (2011)	Asparagus
P pre drilling	(Index 4-5)	Previous cropping (2010)	Asparagus
pH	6.5– 6.9	Soil type	Sandy silt loam
Drilled 15 May	Harvest 11 September	Variety – 7403 Plant population = 33.5 plants/10m (40,200 plants/ha)	

N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**	**N timing**	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + 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	-
Total N (%)	1.18	1.35	1.45	1.47	1.54	1.56	0.002	0.446	Total N (%)	1.48	1.46	1.47	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	-
Dry weight whole plant (t/ha)	6.6	7.7	7.8	8.5	8.4	7.9	NS	-	Dry weight whole plant (t/ha)	8.1	8.5	7.7	NS	-
Dry matter (%)	20.4	20.6	19.6	19.7	20.1	19.9	NS	-	Dry matter (%)	19.8	20.5	19.6	0.011	0.348
Weight main cobs (t/ha)	10.8	11.6	12.6	13.5	13.5	12.9	0.064	1.457	Weight main cobs (t/ha)	12.8	12.5	13.2	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 + V4 to V6						**(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)**						**(T3) Timing 3 At V4 to V6 + flowering**						**F Prob**	**LSD**
N rate (kgN/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	-
Total N (%)	1.18	1.29	1.51	1.49	1.61	1.53	1.18	1.32	1.39	1.47	1.55	1.57	1.18	1.44	1.44	1.44	1.47	1.57	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	-
Dry weight whole plant (t/ha)	6.6	7.6	8.6	8.3	7.9	8.2	6.6	8.3	7.9	9.3	8.7	8.1	6.6	7.4	7.1	8.1	8.6	7.6	NS	-
Dry matter (%)	20.4	20.5	19.2	19.3	20.2	19.9	20.4	21.8	20.4	19.9	20.4	20.2	20.4	19.5	19.1	20.2	19.5	19.8	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	-
% 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 kgN/ha	Previous cropping (2012)	Courgette
SMN pre drilling	90.2 – 108.7 kgN/ha	Previous cropping (2011)	Grass
P pre drilling	(Index 3)	Previous cropping (2010)	Sweetcorn
pH	7.1 – 7.4	Soil type	Silty clay loam
Drilled 23 May	Harvest 19 September	Variety – 7403 Plant population = 24.4 plants/10m (32,479 plants/ha)	

N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**	**N timing**	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + 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	-
Total N (%)	1.82	2.11	2.16	2.22	2.24	2.32	0.061	0.059	Total N (%)	2.23	2.19	2.19	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	-
Dry weight whole plant (t/ha)	6.1	5.9	5.6	6.1	6.2	7.2	0.018	0.411	Dry weight whole plant (t/ha)	6.4	5.8	6.4	NS	-
Dry matter (%)	18.2	18.7	18.8	18.4	19.9	22.2	0.002	1.861	Dry matter (%)	20.6	18.7	19.5	0.031	1.665
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	-

% 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 + V4 to V6						**(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)**						**(T3) Timing 3 At V4 to V6 + flowering**						**F Prob**	**LSD**
N rate (kgN/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	-
Total N (%)	1.82	2.09	2.22	2.22	2.21	2.39	1.82	2.00	2.11	2.21	2.27	2.39	1.82	2.22	2.17	2.21	2.22	2.17	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	-
Dry weight whole plant (t/ha)	6.1	6.2	5.8	5.5	6.4	7.8	6.1	5.6	5.6	6.2	6.1	5.5	6.1	6.1	5.4	6.4	6.1	8.1	NS	-
Dry matter (%)	18.2	19.4	21.1	18.2	20.2	24.6	18.2	17.1	18.0	18.6	21.9	17.7	18.2	19.6	17.5	18.4	17.8	24.3	0.005	2.632
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	-

% 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 kgN/ha	Previous crop (2012)	Tenderstem broccoli
SMN pre drilling	45.7 – 66.9 kgN/ha	Previous crop (2011)	Sweetcorn
P pre drilling	(Index 3-4)	Previous crop (2010)	Bulbs
pH	7 – 7.2	Soil type	sandy clay loam over gravel
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	-
Total P (%)	0.24	0.23	0.24	0.24	0.23	0.24	NS	-
Fresh weight whole plant (t/ha)	32.7	33.8	33.9	35.2	36.2	33.9	NS	-
Dry weight whole plant (t/ha)	6.3	6.8	6.7	7.1	7.5	6.8	NS	-
Dry matter (%)	19.9	21.1	20.6	20.7	21.4	20.8	NS	-

Weight main cobs (t/ha)	15.9	15.7	16.3	16.3	16.0	17.3	NS	-
% marketable cobs	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 kgN/ha	Previous crop (2012)	Courgettes
SMN pre drilling	51.3 - 57 kgN/ha	Previous crop (2011)	Grass
P pre drilling	(Index 2-3)	Previous crop (2010)	Sweetcorn
pH	6.8– 7.7	Soil type	Silty clay
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	-
Cob P (%)	0.27	0.31	0.27	0.29	0.29	0.31	NS	-
Stem/leaves P (%)	0.18	0.18	0.18	0.18	0.17	0.19	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	-

P rate (kg P_2O_5/ha)	**0**	**60**	**120**	**180**	**240**	**320**	**F Prob**	**LSD**
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	-
Dry weight whole plants (t/ha)	8.2	7.5	8.4	9.5	9.4	9.2	0.077	1.458
Dry weight cobs (t/ha)	4.5	4.4	4.7	5.4	5.4	5.2	NS	-
Dry weight stem/leaves (t/ha)	3.6	3.2	3.6	4.1	4.1	4.1	NS	-
% cob total dry matter as a proportion of total biomass (Harvest Index)	55.5	57.7	56.8	57.3	57.3	56.0	NS	-
Dry matter total biomass (%)	19.4	19.8	20.2	19.9	21.2	20.3	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 kgN/ha	Previous cropping (2012)	Pumpkins
SMN pre drilling	61.9 – 75.5 kgN/ha	Previous cropping (2011)	Sweetcorn
P pre drilling	(Index 3)	Previous cropping (2010)	Wheat
pH	6.3– 6.9	Soil type	Loamy sand (high stone content) over gravel
Drilled 14 May	Harvest 18 September	Variety – 7403 Plant population = variable/average 27,066 plants/ha	

P_2O_5 rate (kgN/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	-
Total P (%)	0.24	0.24	0.25	0.26	0.26	0.25	NS	-
Fresh weight whole plant (t/ha)	21.7	20.8	21.5	22.8	23.4	20.4	NS	-

Dry weight whole plant (t/ha)	4.3	4.3	4.4	4.7	4.7	4.4	NS	-
Dry matter (%)	19.9	20.6	20.6	20.6	20.3	21.7	NS	-
Plant population /10m	22.7	18.7	16.6	13.3	17.3	18.5	0.008	4.196

2014 sites

14/E1 early N – Hants

SMN March	30 kgN/ha	Previous crop (2013)	Wheat
SMN pre drilling	138 kgN/ha	Previous crop (2012)	Tenderstem broccoli
P pre drilling	(Index 5)	Previous crop (2011)	Pumpkins
pH	6.5	Soil type	sandy clay loam over gravel
Drilled 10 April	Harvest 30 July	Variety - Earlybird	Plant population = 43.4 plants/10m (57,919 plants/ha)

N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**
N Uptake (kg/ha)	173.6	191.5	187.3	180.5	172.1	184.4	NS	-
Total N (%)	1.87	1.96	1.95	1.96	1.84	1.91	NS	-
Fresh weight whole plant (t/ha)	39.1	41.6	39.3	38.7	38.2	38.9	NS	-
Dry weight whole plant (t/ha)	9.5	9.7	9.8	9.3	9.3	9.3	NS	-

N timing	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + flowering**	**F Prob**	**LSD**
N Uptake (kg/ha)	173.0	187.2	189.2	NS	-
Total N (%)	1.91	1.96	1.91	NS	-
Fresh weight whole plant (t/ha)	39.2	39.4	39.5	NS	-
Dry weight whole plant (t/ha)	9.4	9.3	9.6	NS	-

N rate (kgN/ha)	0	60	120	180	250	320	F Prob	LSD		N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
Dry matter (%)	24.4	23.5	24.8	23.8	24.3	23.9	NS	-		Dry matter (%)	24.2	23.6	24.4	NS	-
Weight main cobs (t/ha)	14.3	13.5	13.6	13.8	14.1	13.8	NS	-		Weight main cobs (t/ha)	14.1	13.1	14.1	NS	-
% marketable cobs	48.9	30.0	45.0	50.0	43.3	36.1	0.046	6.78		% marketable cobs	39.3	40.0	43.3	NS	-
Marketable cobs (numbers/ha)	28316	17376	26064	28960	25098	20915	0.046	7964.3		Marketable cobs (numbers/ha)	22781	23168	25098	NS	-
Marketable cobs (t/ha)	14.2	12.8	13.7	13.9	14.2	13.6	NS	-		Marketable cobs (t/ha)	13.3	13.5	14.2	NS	-
BRIX	15.9	15.9	15.7	15.9	15.9	15.9	NS	-		BRIX	15.8	15.8	16.1	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						**(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)**						**(T3) Timing 3 At V4 to V6 + flowering**						**F Prob**	**LSD**
N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	173.6	170.6	170.1	186.6	161.1	176.5	173.6	222.2	189.1	186.3	167.8	170.6	173.6	181.8	202.5	168.5	187.3	206.0	NS	-
Total N (%)	1.87	2.04	1.87	1.91	1.75	1.94	1.87	2.01	2.07	2.02	1.87	1.85	1.87	1.84	1.90	1.97	1.89	1.94	NS	-
Fresh weight whole plant (t/ha)	39.1	41.4	37.3	40.1	39.3	37.5	39.1	42.6	38.6	40.3	36.2	39.2	39.1	40.8	41.9	35.8	39.0	40.1	NS	-
Dry weight whole plant (t/ha)	9.5	9.7	9.3	9.6	9.5	9.1	9.5	10.1	8.9	9.7	8.8	8.9	9.5	9.4	11.2	8.4	9.4	9.8	NS	-
Dry matter (%)	24.4	23.6	24.8	24.2	24.2	24.3	24.4	23.6	23.2	24.2	24.3	22.9	24.4	23.3	26.5	23.4	24.3	24.6	NS	-
Weight main cobs (t/ha)	14.3	14.8	12.9	14.3	13.9	14.1	14.3	12.8	13.2	12.9	13.6	13.1	14.3	12.7	14.6	14.3	14.6	14.3	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
% marketable cobs	48.9	25.0	36.7	63.3	45.0	26.7	48.9	35.0	40.0	48.3	45.0	31.7	48.9	30.0	58.3	38.3	40.0	50.0	NS	-
Marketable cobs (numbers/ha)	28316	14480	21237	36682	26064	15445	28316	20272	23168	27994	26064	18341	28316	17376	33786	22202	23168	28960	NS	-
Marketable cobs (t/ha)	14.2	12.8	12.8	13.5	13.9	13.4	14.2	13.8	13.3	13.4	14.2	13.1	14.2	11.8	15.1	14.8	14.6	14.2	NS	-
BRIX	15.9	15.8	15.7	16.3	15.8	15.5	15.9	15.9	15.5	15.8	16.3	15.6	15.9	16.0	16.0	15.6	15.7	16.7	NS	-

14/E2 early N – W. Sussex

SMN March	25 kgN/ha	Previous crop (2013)	Sweetcorn
SMN pre drilling	46 kgN/ha	Previous crop (2012)	Wheat
P pre drilling	(Index 2)	Previous crop (2011)	Sweetcorn
pH	6.5	Soil type	Silty clay loam
Drilled 17 April	Harvest 31 July	Variety – Earlybird	Plant population = 36.03 plants/10m (48,040 plants/ha)

N rate (kg N/ha)	0	60	120	180	240	300	F Prob	LSD		N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
N Uptake total (kg/ha)	70.0	90.0	147.2	138.2	177.7	191.2	<0.001	41.31		N Uptake total (kg/ha)	152.6	140.5	153.6	NS	-
N Uptake cobs (kg/ha)	24.3	33.5	56.0	50.2	65.9	74.0	0.001	17.54		N Uptake cobs (kg/ha)	59.4	51.9	56.6	NS	-
N Uptake stem/leaves (kg/ha)	45.7	56.5	91.2	88.1	111.8	117.2	<0.001	24.87		N Uptake stem/leaves (kg/ha)	93.2	88.7	97.0	NS	-

N rate (kg N/ha)	0	60	120	180	240	300	F Prob	LSD		N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
Cob N (%)	1.81	1.93	1.83	1.84	1.86	1.91	NS	-		Cob N (%)	1.83	1.89	1.91	NS	-
Stem/leaves N (%)	1.45	1.63	1.55	1.78	1.77	1.79	0.003	0.143		Stem/leaves N (%)	1.62	1.74	1.77	0.024	0.128
% proportion N uptake to cobs	34.3	37.1	37.8	36.1	36.9	38.6	NS	-		% proportion N uptake to cobs	38.4	36.9	36.6	NS	-
Total fresh weight whole plant (t/ha)	22.2	28.7	39.1	39.9	44.9	50.3	<0.001	7.247		Total fresh weight whole plant (t/ha)	41.7	41.2	38.9	NS	-
Total fresh weight cobs (t/ha)	7.9	10.5	14.6	14.6	16.8	19.1	<0.001	2.510		Total fresh weight cobs (t/ha)	15.6	15.2	14.6	NS	-
Total fresh weight stem/leaves (t/ha)	14.3	18.3	24.4	25.3	28.1	31.2	<0.001	4.792		Total fresh weight stem/leaves (t/ha)	26.1	25.9	24.3	NS	-
Dry weight whole plant (t/ha)	4.7	5.1	7.5	7.8	8.3	9.9	<0.001	1.308		Dry weight whole plant (t/ha)	8.1	7.5	7.6	NS	-
Dry weight cobs (t/ha)	1.5	1.7	2.6	2.7	2.9	3.7	<0.001	0.566		Dry weight cobs (t/ha)	2.9	2.6	2.7	NS	-
Dry weight stem/leaves (t/ha)	3.2	3.4	4.8	5.1	5.3	6.2	<0.001	0.793		Dry weight stem/leaves (t/ha)	5.1	4.9	4.9	NS	-
% cob total dry matter as a proportion of total biomass (Harvest Index)	31.3	33.3	34.8	34.7	36.1	37.6	0.08	3.095		% cob total dry matter as a proportion of total biomass (Harvest Index)	36.2	34.1	35.5	NS	-
Dry matter total biomass	19.8	20.1	20.6	19.8	20.2	20.2	NS	-		Dry matter total biomass	20.4	20.2	19.9	NS	-

N rate (kg N/ha)	0	60	120	180	240	300	F Prob	LSD		N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
(%)										(%)					
Weight all main cobs (t/ha)	4.2	6.1	8.5	9.2	10.7	9.7	0.001	1.934		Weight all main cobs (t/ha)	8.8	8.9	8.7	NS	-
Weight marketable cobs (t/ha)	1.3	0.8	3.9	6.1	9.1	7.8	<0.001	3.159		Weight marketable cobs (t/ha)	5.8	5.7	5.2	NS	-
Marketable cobs (numbers/ha)	2802	3603	17615	27223	37631	35229	<0.001	13656		Marketable cobs (numbers/ha)	24981	25221	22579	NS	-
% marketable cobs	5.8	7.5	36.7	56.7	78.3	73.3	<0.001	28.43		% marketable cobs	52.0	52.5	47.0	NS	-
BRIX	13.6	14.4	15.5	14.9	15.5	15.8	NS	-		BRIX	14.9	15.1	15.6	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
N rate (kgN/ha)	0	60	120	180	250	320	0	60	120	180	250	320	0	60	120	180	250	320		
N Uptake (kg/ha)	70.0	88.2	129.3	135.0	193.4	217.0	70.0	71.5	155.1	112.6	176.6	186.9	70.0	110.4	157.2	167.1	163.2	169.9	NS	-
N Uptake cobs (kg/ha)	24.3	32.7	48.2	51.2	79.0	85.7	24.3	26.1	61.6	40.3	63.9	67.4	24.3	41.7	58.3	59.0	54.9	68.9	NS	-
N Uptake stem/leaves (kg/ha)	45.7	55.5	81.0	83.8	114.5	131.2	45.7	45.3	93.5	72.3	112.7	119.5	45.7	68.8	98.9	108.1	108.2	100.9	NS	-
Cob N (%)	1.81	1.85	1.69	1.84	1.88	1.87	1.81	2.01	1.79	1.91	1.75	1.99	1.81	1.94	2.01	1.76	1.96	1.86	NS	-
Stem/ leaves N (%)	1.45	1.52	1.49	1.68	1.72	1.68	1.45	1.66	1.46	1.83	1.74	1.99	1.45	1.72	1.70	1.84	1.87	1.71	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
% proportion N uptake to cobs	34.3	37.6	37.1	36.8	41.2	39.4	34.3	36.6	39.4	36.4	36.2	36.1	34.3	37.1	37.2	35.2	33.7	40.2	NS	-
Fresh weight whole plant (t/ha)	22.2	30.7	36.6	42.7	48.2	50.3	22.2	27.2	43.6	38.9	45.9	49.8	22.2	28.3	36.8	37.9	40.8	50.6	NS	-
Total fresh weight cobs (t/ha)	7.9	11.1	14.2	15.8	18.1	18.9	7.9	9.9	15.9	14.3	17.2	18.4	7.9	10.4	13.7	13.6	15.4	20.1	NS	-
Total fresh weight stem/leaves (t/ha)	14.3	19.7	22.4	26.9	30.1	31.4	14.3	17.3	27.7	24.7	28.8	31.4	14.3	17.8	23.2	24.4	25.5	30.6	NS	-
Dry weight whole plant (t/ha)	4.7	5.5	7.1	8.8	8.3	10.6	4.7	4.3	7.8	7.1	8.9	9.5	4.7	5.5	7.6	7.7	7.7	9.7	NS	-
Dry weight cobs (t/ha)	1.5	1.8	2.6	3.2	3.1	4.2	1.5	1.4	2.7	2.4	3.2	3.4	1.5	1.9	2.6	2.7	2.8	3.7	NS	-
Dry weight stem/leaves (t/ha)	3.2	3.6	4.5	5.6	5.3	6.4	3.2	2.8	5.1	4.6	5.8	6.1	3.2	3.6	5.1	5.1	4.9	6.1	NS	-
% cob total dry matter as a proportion of total biomass (Harvest Index)	31.3	33.4	36.5	35.8	35.8	39.5	31.3	32.2	34.1	33.5	35.3	35.6	31.3	34.2	33.8	34.7	36.9	37.7	NS	-
Dry matter total biomass (%)	19.8	20.7	19.9	19.8	20.7	20.6	19.8	19.3	20.7	19.9	20.9	19.9	19.8	20.3	21.1	19.8	18.7	19.9	NS	-
Weight all main cobs (t/ha)	4.2	5.8	8.3	8.7	11.4	9.8	4.2	6.5	8.7	9.5	10.6	9.5	4.2	5.8	8.5	9.5	10.1	9.6	NS	-
% marketable cobs	5.8	10.0	37.5	47.5	85.0	80.0	5.8	7.5	42.5	70.0	70.0	72.5	5.8	5.0	30.0	52.5	80.0	67.5	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
Marketable cobs (numbers/ha)	2802	4804	18015	22819	40834	38432	2802	3603	20417	33628	33628	34829	2802	2402	14412	25221	38432	35229	NS	-
Marketable cobs (t/ha)	1.3	1.2	4.1	5.2	10.3	8.4	1.3	0.8	4.7	7.2	8.3	7.5	1.3	0.6	3.1	5.9	8.7	7.6	NS	-
BRIX	13.3	13.8	15.3	13.1	16.2	15.5	13.3	15.2	15.7	15.4	15.3	15.9	13.3	15.4	14.7	16.1	15.8	15.7	NS	-

14/E3 early N – IOW

SMN March	20 kgN/ha	Previous crop (2013)	Sweetcorn
SMN pre drilling	43 kgN/ha	Previous crop (2012)	Wheat
P pre drilling	(Index 4)	Previous crop (2011)	Sweetcorn
pH	6.7	Soil type	Sandy loam
Drilled 10 April	Harvest 5 August	Variety – Earlybird	Plant population = 43.4 plants/10m (52,385 plants/ha)

N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**	**N timing**	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + flowering**	**F Prob**	**LSD**
N Uptake (kg/ha)	60.0	113.9	148.1	182.9	196.9	213.4	<0.001	27.14	N Uptake (kg/ha)	187.5	168.3	157.5	0.021	24.27
Total N (%)	1.43	1.47	1.67	1.75	1.85	2.06	<0.001	0.1594	Total N (%)	1.78	1.76	1.74	NS	-
Fresh weight whole plant (t/ha)	20.8	32.7	37.3	43.9	46.8	43.8	<0.001	5.872	Fresh weight whole plant (t/ha)	43.5	38.9	40.3	NS	-
Dry weight whole plant (t/ha)	3.9	6.8	7.8	9.5	9.7	9.1	<0.001	1.167	Dry weight whole plant (t/ha)	9.1	8.4	8.3	NS	-
Dry matter (%)	18.6	20.8	21.2	21.6	20.9	20.7	NS	-	Dry matter (%)	21.1	21.6	20.4	0.014	0.963
Weight main cobs (t/ha)	6.3	9.3	10.7	10.7	12.1	12.0	<0.001	1.358	Weight main cobs (t/ha)	10.8	11.2	10.8	NS	-
% marketable cobs	5.0	35.0	49.4	50.6	57.2	61.7	0.012	15.0	% marketable cobs	51.7	49.0	51.7	NS	-
Marketable cobs (numbers/ha)	2619	18335	25902	26484	29976	32304	0.012	7859.6	Marketable cobs (numbers/ha)	27066	25669	27066	NS	-
Marketable cobs (t/ha)	0.6	3.8	5.6	6.1	7.1	7.5	0.001	1.736	Marketable cobs (t/ha)	6.1	5.8	6.2	NS	-
BRIX	19.3	20.2	19.8	19.5	18.9	19.5	0.021	0.704	BRIX	19.4	19.7	19.7	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	60.0	148.0	154.9	193.5	206.1	234.9	60.0	90.8	143.9	176.4	206.9	223.3	60.0	102.9	145.6	178.9	177.9	182.0	NS	-
Total N (%)	1.43	1.55	1.63	1.73	1.81	2.17	1.43	1.36	1.68	1.68	1.97	2.09	1.43	1.51	1.71	1.83	1.76	1.89	NS	-
Fresh weight whole plant (t/ha)	20.8	37.3	41.6	45.8	48.9	43.7	20.8	29.9	34.6	42.9	43.6	43.3	20.8	30.8	35.5	43.1	47.8	44.4	NS	-
Dry weight whole plant (t/ha)	3.9	8.2	8.6	9.8	9.7	9.3	3.9	6.3	7.4	9.4	9.9	9.3	3.9	6.1	7.5	9.3	9.7	8.6	NS	-
Dry matter (%)	18.6	21.9	20.6	21.7	19.8	21.2	18.6	20.8	21.6	21.7	22.6	21.5	18.6	19.7	21.2	21.5	20.2	19.4	0.098	1.53
Weight main cobs (t/ha)	6.3	9.1	10.9	9.9	12.8	11.2	6.3	8.9	10.7	11.4	11.7	13.3	6.3	9.7	10.5	10.9	11.5	11.5	NS	-
% marketable cobs	5.0	35.0	53.3	50.0	61.7	58.3	5.0	28.3	53.3	55.0	53.3	55.0	5.0	41.7	41.7	46.7	56.7	71.7	NS	-
Marketable cobs (numbers/ha)	2619	18335	27939	26193	32304	30558	2619	14843	27939	28812	27939	28812	2619	21827	21827	24447	29685	37543	NS	-
Marketable cobs (t/ha)	0.6	3.6	5.9	6.1	7.6	6.8	0.6	3.3	6.1	6.5	6.6	6.9	0.6	4.6	4.9	5.6	6.8	8.8	NS	-
BRIX	19.3	20.1	19.8	18.9	18.7	19.4	19.3	20.0	19.8	19.8	19.3	19.3	19.3	20.4	19.7	19.7	18.8	19.7	NS	-

14/L1 late N – Hants

SMN March	9 kgN/ha	Previous cropping (2013)	Wheat (lot of volunteer wheat remaining before cultivation in spring 2014)
SMN pre drilling	99 kgN/ha	Previous cropping (2012)	Sweetcorn
P pre drilling	(Index 2)	Previous cropping (2011)	Sweetcorn
pH	6.6	Soil type	Sandy loam over gravel
Drilled 20 May	Harvest 16 September	Variety – 1138 Plant population = 27.68 plants/10m (36,906 plants/ha)	

Note: Marketable crop yields depressed by pest damage, but this was even across the trial.

N rate (kgN/ha)	0	60	120	180	250	320	F Prob	LSD	N timing	Seedbed + V4 to V6	Three equal apps	V4 to V6 + flowering	F Prob	LSD
N Uptake (kg/ha)	100.5	118.5	125.9	117.3	128.8	122.9	NS	-	N Uptake (kg/ha)	141.2	108.3	118.5	0.007	23.18
Total N (%)	1.72	1.92	1.94	2.01	1.91	1.98	NS	-	Total N (%)	1.99	1.92	1.94	NS	-
Fresh weight whole plant (t/ha)	35.7	34.1	33.8	34.6	37.5	35.6	NS	-	Fresh weight whole plant (t/ha)	36.9	34.7	33.7	NS	-
Dry weight whole plant (t/ha)	6.1	5.6	5.9	5.8	6.1	6.1	NS	-	Dry weight whole plant (t/ha)	6.3	5.7	5.7	NS	-
Dry matter (%)	17.1	17.1	17.6	16.9	16.7	17.5	NS	-	Dry matter (%)	17.5	16.7	17.2	NS	-
Weight main cobs (t/ha)	11.4	10.2	11.2	10.2	10.8	10.7	NS	-	Weight main cobs (t/ha)	10.5	10.8	10.5	NS	-
% marketable cobs	33.9	35.9	36.1	29.4	40.5	31.8	NS	-	% marketable cobs	38.6	39.9	25.7	0.013	11.65
Marketable cobs (numbers/ha)	12507	13262	13327	10867	14939	11724	NS	-	Marketable cobs (numbers/ha)	14253	14723	9495	0.013	4298
Marketable cobs (t/ha)	4.2	4.4	4.3	3.5	3.8	3.8	NS	-	Marketable cobs (t/ha)	4.1	4.4	3.3	NS	-
BRIX	16.7	16.9	16.7	16.8	16.7	17.1	NS	-	BRIX	17.1	16.7	16.7	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	100.5	130.7	146.4	138.4	166.4	124.0	100.5	124.1	119.9	90.8	87.5	119.3	100.5	100.9	111.3	122.7	132.5	125.4	NS	-
Total N (%)	1.72	1.90	2.04	1.99	2.02	1.99	1.72	1.93	1.92	2.01	1.75	2.01	1.72	1.93	1.84	2.02	1.95	1.95	NS	-
Fresh weight whole plant (t/ha)	35.7	36.8	36.4	35.4	39.1	36.8	35.7	35.1	32.5	32.6	36.4	37.3	35.7	30.4	32.7	35.6	37.2	32.6	NS	-
Dry weight whole plant (t/ha)	6.1	5.6	6.5	6.1	6.6	6.6	6.1	6.1	5.6	5.6	5.2	6.3	6.1	5.2	5.8	5.8	6.4	5.4	NS	-
Dry matter (%)	17.1	16.7	17.9	17.2	17.8	17.9	17.1	17.3	17.2	17.2	15.3	16.8	17.1	17.1	17.6	16.3	17.3	17.7	NS	-
Weight main cobs (t/ha)	11.4	10.8	11.1	10.8	10.3	9.4	11.4	10.3	10.7	10.1	11.7	11.5	11.4	9.3	11.7	9.6	10.5	11.4	NS	-
% marketable cobs	33.9	34.5	43.3	28.3	47.0	40.0	33.9	40.0	46.7	35.0	34.5	43.3	33.9	33.3	18.3	25.0	40.0	12.0	NS	-
Marketable cobs (numbers/ha)	12507	12721	15993	10457	17334	14763	12507	14763	17223	12917	12721	15993	12507	12302	6766	9227	14763	4417	NS	-
Marketable cobs (t/ha)	4.2	4.8	5.1	3.6	2.6	4.4	4.2	4.5	5.2	4.1	3.9	4.5	4.2	3.9	2.4	2.8	4.9	2.4	NS	-
BRIX	16.7	17.1	17.1	16.6	17.2	17.3	16.7	16.7	16.5	16.7	16.4	17.6	16.7	17.3	16.6	17.3	16.5	16.3	NS	-

14/L2 late N – IOW – NOT HARVESTED

14/L3 late N – W. Sussex.

SMN April	21 kgN/ha	Previous cropping (2013)	Sweetcorn
SMN pre drilling	56 kgN/ha	Previous cropping (2012)	Wheat
P pre drilling	(Index 3)	Previous cropping (2011)	Sweetcorn
pH	7.2	Soil type	Silty clay loam
Drilled 1 June	Harvest 19 September	Variety – 1138 Plant population = 29.2 plants/10m (38,893 plants/ha)	

N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**	**N timing**	**Seedbed + V4 to V6**	**Three equal apps**	**V4 to V6 + flowering**	**F Prob**	**LSD**
N Uptake (kg/ha)	116.3	138.9	160.0	156.6	166.8	177.6	NS	-	N Uptake (kg/ha)	169.9	154.7	155.3	NS	-
Total N (%)	1.74	1.75	1.75	1.94	1.92	1.95	0.013	0.1548	Total N (%)	1.85	1.91	1.83	NS	-
Fresh weight whole plant (t/ha)	31.9	37.3	41.8	41.7	43.8	41.3	0.005	3.227	Fresh weight whole plant (t/ha)	43.6	40.4	39.5	0.005	2.886
Dry weight whole plant (t/ha)	6.6	7.8	8.8	8.7	8.9	8.7	0.057	0.818	Dry weight whole plant (t/ha)	9.2	8.5	8.3	0.026	0.731
Dry matter (%)	20.5	21.0	21.2	20.9	20.5	21.1	NS	-	Dry matter (%)	20.9	20.9	20.9	NS	-
Weight main cobs (t/ha)	11.4	12.1	12.3	12.9	12.7	13.4	0.01	0.674	Weight main cobs (t/ha)	13.1	12.6	12.4	0.05	0.674
% marketable cobs	78.9	87.8	86.7	92.8	91.7	92.8	NS	-	% marketable cobs	91.0	88.3	91.7	NS	-
Marketable cobs (numbers/ha)	30682	34139	33707	36084	35652	36084	NS	-	Marketable cobs (numbers/ha)	35393	34355	35652	NS	-
Marketable cobs (t/ha)	9.3	10.8	10.2	12.1	11.8	12.7	0.033	1.667	Marketable cobs (t/ha)	12.3	10.8	11.5	0.063	1.491
BRIX	16.6	16.8	16.6	18.9	16.9	16.9	NS	-	BRIX	16.8	16.8	18.2	NS	-

	(T1) Timing 1 Seedbed + V4 to V6						(T2) Timing 2 Three equal applications (Seedbed, V4 to V6 and flowering)						(T3) Timing 3 At V4 to V6 + flowering						F Prob	LSD
N rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**	**0**	**60**	**120**	**180**	**250**	**320**		
N Uptake (kg/ha)	116.3	148.1	180.9	182.6	167.1	170.6	116.3	124.8	166.4	158.6	171.0	152.7	116.3	143.7	132.5	128.8	162.2	209.4	NS	-
Total N (%)	1.74	1.73	1.77	1.96	1.83	1.96	1.74	1.81	1.75	2.05	2.01	1.93	1.74	1.70	1.73	1.80	1.92	1.97	NS	-
Fresh weight whole plant (t/ha)	31.9	38.8	44.7	46.1	47.5	41.2	31.9	34.4	42.4	42.1	43.4	39.8	31.9	38.7	38.3	36.9	40.5	42.9	0.094	4.564
Dry weight whole plant (t/ha)	6.6	8.2	9.2	9.9	9.8	8.5	6.6	7.2	9.2	8.8	8.7	8.4	6.6	8.2	8.2	7.5	8.3	9.3	0.075	1.156
Dry matter (%)	20.5	21.2	20.5	21.6	20.7	20.6	20.5	20.8	21.6	20.9	20.2	21.2	20.5	20.9	21.4	20.4	20.6	21.5	NS	-
Weight main cobs (t/ha)	11.4	11.9	13.6	13.4	12.6	13.8	11.4	12.3	12.1	12.7	12.9	13.1	11.4	11.9	11.2	12.7	12.8	13.2	NS	-
% marketable cobs	78.9	81.7	95.0	96.7	86.7	95.0	78.9	88.3	85.0	90.0	90.0	88.3	78.9	93.3	80.0	91.7	98.3	95.0	0.061	9.551
Marketable cobs (numbers /ha)	30682	31763	36948	37597	33707	36948	30682	34355	33059	35004	35004	34355	30682	36300	31114	35652	38245	36948	0.061	3715
Marketable cobs (t/ha)	9.3	10.2	13.4	13.1	11.4	13.6	9.3	11.5	7.9	11.3	11.4	11.8	9.3	10.8	9.4	11.8	12.6	12.8	0.093	2.358
BRIX	16.6	17.2	16.6	17.2	16.7	16.3	16.6	16.9	16.7	16.7	16.6	17.1	16.6	16.4	16.7	22.7	17.4	17.6	NS	-

14/E2 early P – W. Sussex

SMN March	25 kgN/ha	Previous crop (2013)	Sweetcorn
SMN pre drilling	46 kgN/ha	Previous crop (2012)	Wheat
P pre drilling	(Index 2)	Previous crop (2011)	Sweetcorn
pH	6.7	Soil type	Silty clay loam
Drilled 17 April	Harvest 1 August	Variety – Earlybird	Plant population = 36.03 plants/10m (48,040 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)	46.1	45.9	49.7	36.9	47.1	45.1	NS	-
P_2O_5 Uptake cobs (kg/ha)	22.3	22.6	24.4	16.7	20.4	19.9	NS	-
P_2O_5 Uptake stem/leaves (kg/ha)	23.8	23.3	25.3	20.2	26.7	25.2	NS	-
Cob P (%)	0.24	0.25	0.26	0.24	0.25	0.24	NS	-
Stem/leaves P (%)	0.16	0.16	0.16	0.16	0.18	0.15	NS	-
% proportion P_2O_5 uptake to cobs	48.4	49.3	48.8	45.1	43.2	44.8	NS	-
Total fresh weight whole plants (t/ha)	55.1	49.7	54.1	44.1	49.1	50.8	NS	-
Total fresh weight cobs (t/ha)	19.9	18.3	19.4	15.7	17.2	17.7	NS	-
Total fresh weight stem/leaves (t/ha)	35.2	31.4	34.7	28.4	31.9	33.1	NS	-
% cob total weight as a proportion of whole plant	34.6	36.8	35.8	35.6	35.1	34.8	NS	-
Dry weight whole plants (t/ha)	11.3	10.1	11.1	9.1	9.9	10.2	NS	-
Dry weight cobs (t/ha)	4.3	3.8	4.2	3.3	3.6	3.5	NS	-
Dry weight stem/leaves (t/ha)	7.1	6.2	6.8	5.7	6.4	6.6	NS	-

P rate (kg P_2O_5/ha)	0	60	120	180	240	320	F Prob	LSD
% cob total dry matter as a proportion of total biomass (Harvest Index)	37.5	38.2	37.6	35.9	35.7	34.3	0.016	2.218
Dry matter total biomass (%)	20.4	20.2	20.3	20.4	20.3	19.9	NS	-
Weight all main cobs (t/ha)	10.5	11.3	10.6	10.9	10.6	10.9	NS	-
Weight marketable cobs (t/ha)	8.4	9.8	9.2	10.1	8.8	9.8	NS	-
Marketable cobs (numbers/ha)	36935	38752	39357	42385	38146	42385	NS	-
% marketable cobs	76.2	80.0	81.2	87.5	78.8	87.5	NS	-
BRIX	15.7	15.9	16.0	15.6	15.6	15.7	NS	-

14/E3 early P – IOW

SMN March	20 kgN/ha	Previous crop (2013)	Sweetcorn
SMN pre drilling	43 kgN/ha	Previous crop (2012)	Wheat
P pre drilling	(Index 4)	Previous crop (2011)	Sweetcorn
pH	6.4	Soil type	Sandy loam
Drilled 10 April	Harvest 6 August	Variety – Earlybird	Plant population = 43.4 plants/10m (52,385 plants/ha)

P rate (kg P2O5/ha)	**0**	**60**	**120**	**180**	**240**	**300**	**F Prob**	**LSD**
P2O5 Uptake (kg/ha)	51.5	52.5	58.0	73.6	64.4	57.1	NS	-
Total P (%)	0.25	0.25	0.27	0.29	0.27	0.26	NS	-
Fresh weight whole plant (t/ha)	39.6	39.4	40.9	44.0	42.3	41.6	NS	-
Dry weight whole plant (t/ha)	8.3	8.4	8.6	9.7	9.2	8.8	NS	-
Dry matter (%)	21.1	21.5	21.2	22.2	21.7	21.3	NS	-
Weight main cobs (t/ha)	12.2	11.4	10.7	10.4	8.1	10.7	NS	-
% marketable cobs	70.0	62.5	51.2	52.5	58.8	50.0	NS	-
Marketable cobs (numbers/ha)	36670	32741	26848	27502	30776	26193	NS	-
Marketable cobs (t/ha)	9.0	7.9	6.4	6.5	7.4	6.1	NS	-
BRIX	19.8	19.6	19.9	19.9	19.6	20.1	NS	-

13/L1 late P – Hants

SMN March	9 kgN/ha	Previous cropping (2013)	Wheat (lot of volunteer wheat remaining before cultivation in spring 2014)
SMN pre drilling	99 kgN/ha	Previous cropping (2012)	Sweetcorn
P pre drilling	(Index 2)	Previous cropping (2011)	Sweetcorn
pH	6.6	Soil type	Sandy loam over gravel
Drilled 20 May	Harvest 17 September	Variety – 1138 Plant population = 26.67 plants/10m (35,559 plants/ha)	

Note: No marketable crop yields as quality data was not available

P_2O_5 rate (kgN/ha)	**0**	**60**	**120**	**180**	**250**	**320**	**F Prob**	**LSD**
P_2O_5 Uptake (kg/ha)	43.4	47.3	52.2	46.5	49.8	57.9	NS	-
Total P (%)	0.29	0.29	0.29	0.31	0.31	0.32	NS	-
Fresh weight whole plant (t/ha)	36.4	34.3	37.7	36.6	33.9	37.8	NS	-
Dry weight whole plant (t/ha)	6.8	6.7	7.5	7.1	6.9	7.6	NS	-
Weight main cobs (t/ha)	11.4	11.2	11.6	12.4	11.5	12.6	NS	-
Dry matter (%)	18.6	19.6	20.1	19.3	20.5	20.2	NS	-
Average number of tillers	0.60	0.33	0.40	0.67	0.43	0.97	NS	-
Average height pf lowest cob (cm)	39.3	36.3	35.2	36.2	37.2	35.9	NS	-