HORTICULTURE

Grower Summary

FV 409

Sweetcorn: responses to Nitrogen and Phosphorus

Final 2014

Project title:	Sweetcorn: responses to Nitrogen and Phosphorus
Project number:	FV 409
Project leader:	Dr Richard M. Weightman, ADAS UK Ltd.
Report:	Final report, December 2014
Previous report:	Annual report, December 2013
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Location of project:	Grower sites in Hants, Sussex and Isle of Wight
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Date project commenced:	1 April 2012
Date project completed:	31 December 2014

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Use of pesticides

Further information

If you would like a copy of the full report, please email the AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

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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).

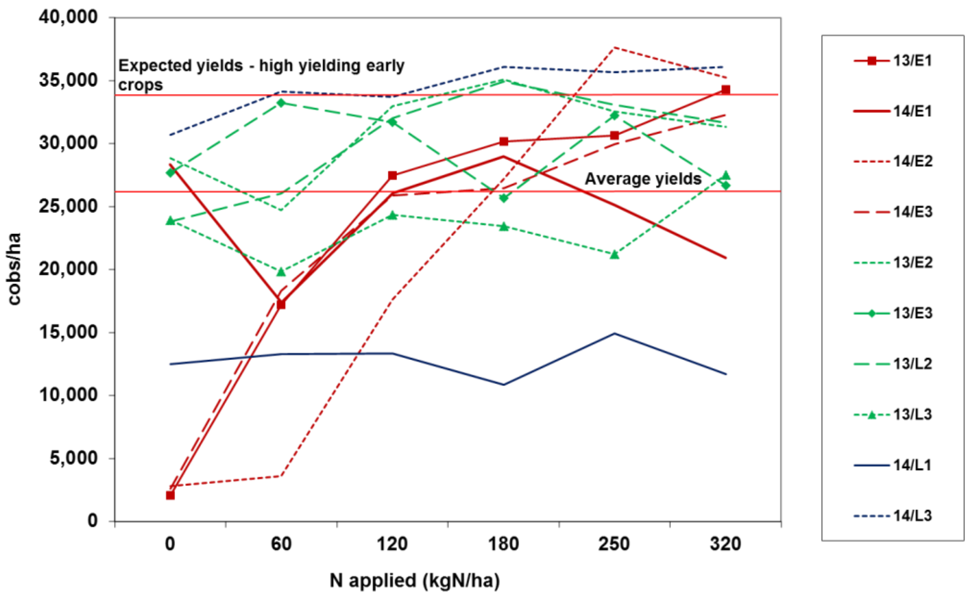

Figure 1a. Effect of the application of increasing rates of nitrogen on the number of marketable cobs in early and late drilled sweetcorn crops, Hants (solid line), Sussex (dotted line) and Isle of Wight (dashed line), 2013/14 (data shown are means of the three N timings treatments in each experiment).

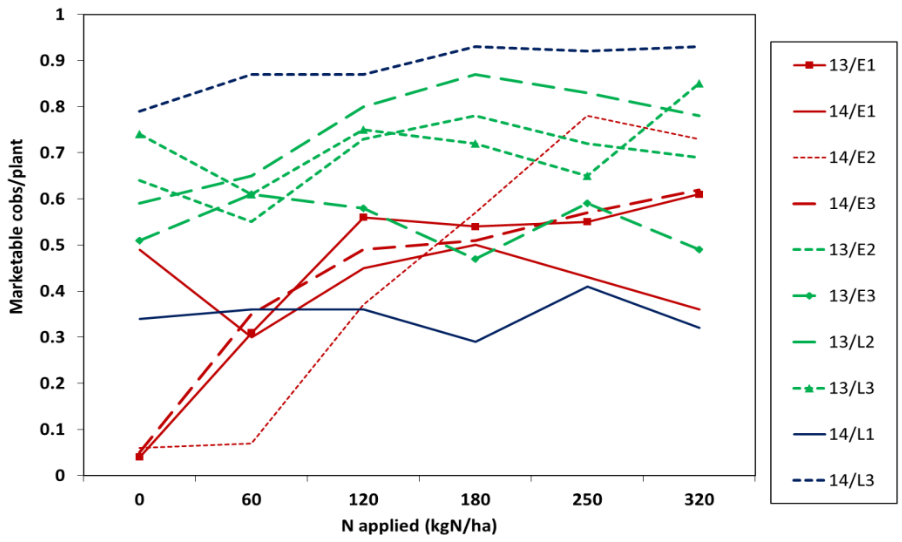

Figure 1b. Effect of the application of increasing rates of nitrogen on marketable cobs per plant (yield potential) in early and late drilled sweetcorn crops, Hants (solid line), Sussex (dotted line) and Isle of Wight (dashed line), 2013/14 (data shown are means of the three N timings treatments in each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