Factsheet 16/14

Field Vegetables

Nitrogen recommendations for optimizing yield and quality of baby leaf lettuce

Richard Weightman, ADAS

This factsheet, an output of HDC project FV 418, provides results of nitrogen response experiments focusing on baby leaf lettuce (*Lactuca sativa*). The project aimed to provide recommendations for nitrogen fertilizer use for this crop which is grown and harvested as young leaves for the bagged salad market. Average crop nitrogen offtake of baby leaf lettuce was estimated at 65 kg N/ha which should be used as a baseline guide for determining crop N requirement. If background soil mineral nitrogen prior to drilling is greater than 60 kg N/ha (0-30 cm depth), then further N applications are unlikely to be necessary, and can result in high tissue nitrate concentration and reduced yields.

Action points

- Baby leaf lettuce crops (Figure 1) can be at risk from exceeding the limits set for tissue nitrate concentration which is set at 3,000 mg NO_3^-/kg for outdoor lettuce. The risk is particularly high for late season crops, when soil mineral nitrogen (SMN) builds up in the rotation.
- There was an average crop requirement of only 65 kg N/ha in baby leaf lettuce crops, which is approximately half that required in wild rocket. This therefore implies that the recommended amounts of nitrogen (N) in baby leaf lettuce crops should be lower than those defined in HDC Factsheet 08/13.
- Based on such a low N requirement, in most cases, even with a low soil N supply e.g. soil nitrogen supply (SNS) index zero (<20 kg N/ha, 0-30 cm) at drilling, the crop is only likely to need a maximum of 60 kg N/ha applied as fertilizer N.
- With SMN levels above 60 kg N/ha (0-30 cm) at drilling, it is likely that no further N will be required by baby leaf lettuce crops.
- Growers are advised to measure SMN to 30 cm when crops follow intensive vegetable or salads and/or when crops are sown late.
- Recommendations may be adjusted upwards or downwards if the grower has their own different estimates of yields and N uptake for crops in their soils, and can therefore justify a different N requirement. However, if recommendations are lifted, then the increased risk of high tissue nitrate concentration (TNC) should be taken into account.

1. N response experiment in a baby leaf lettuce crop

Background and the nitrate problem

The popularity of more convenient salads such as bagged products containing a range of baby leaf lettuce and leaves of other species continues to increase. As with other salad leaves, the fast growing short-season crops of baby leaf lettuce have a tendency to accumulate nitrate in their tissues. Nitrate is viewed as a contaminant of leafy vegetables, and limits for its control are set in EU legislation at 3,000 mgNO_3^-/kg for summer-grown non-iceberg outdoor lettuce types. In northern Europe including the UK where the growing season is short and the weather is often dull during crop growth, nitrate levels tend to be higher than in southern European states. Recent work in the UK funded by HDC has examined the N responses of baby leaf rocket and spinach, and led to development of N recommendations for optimising yield, and minimising tissue nitrate concentration (TNC) in baby leaf salad crops (HDC Factsheet 08/13). In addition to its effects on TNC, the recent studies showed that over-supplying baby leaf rocket and spinach crops with fertiliser N can actually cause a reduction in yield, when the crop has adequate supplies of N from the soil.

The aim of the work in HDC project FV 418, which was carried out in 2013, was to gather robust and independent data on TNC in commercial baby leaf lettuce crops, and determine the yield response to nitrogen fertilizer, taking into account varietal types (red vs green), SMN prior to drilling, soil type and the previous cropping history. As well as measuring the yield response (crop fresh weight), TNC, leaf greenness and total N offtake was also measured in order to better estimate crop N requirement (a pre-requisite for an N recommendation).

Nitrogen response studies

Five sites in a single year were chosen for the N response studies to represent the geographical spread of UK baby leaf lettuce growers in Wiltshire, Dorset, Kent and Shropshire providing 6 individual N responses for red (one Red Cos and two Red Batavia) and green baby leaf (Green Cos and Green Batavia) and Green Tango lettuce varieties (Table 1). Experiments were carried out through the summer into early autumn, representing the full duration of the UK growing season and covering both first and second crops. Topsoil (pH, P, K, Mg) and SMN samples at 0-30 cm depth were taken prior to drilling and prior to application of fertiliser N at each site using a standard 12 point W-shaped sampling pattern and soil samples were bulked to provide an analysis for the whole trial for background SMN.

Table 1. Previous cropping, site details and sowing and harvest dates of four N response experiments on individual baby leaf lettuce varieties, and one variety x N rate experiment on commercial growers' premises in 2013.

Site code, location and soil type	Variety	Sowing & harvest dates 2013	SMN kg/ha (0-30cm) immediately prior to drilling	Previous crop(s) in 2012 season*	N applied to 2012 crop(s) (kg N/ha)	Previous crop(s) in experimental season (2013)	N applied to previous crop(s) in 2013 (kg N/ha)
Single variety N response experiments							
13/1 Wilts Sandy loam	Green Cos	7 May- 13 June	30	Wholehead Lettuce	220	(first crop)	N/A
13/2 Dorset Sandy loam	Red Batavia	23 May- 2 July	27	BBL, BBS, BBL, BBB	140 90	(first crop)	N/A
13/3 Kent Brick Earth	Green Tango	1 July- 8 Aug	166	BBS, Wholehead Lettuce	135 120	(first crop)	N/A
13/4 Shrops Sandy loam	Red Batavia	17 July- 27 Aug	116	Wild Rocket BBL	96 96	Babyleaf Lettuce	96
Variety x N response study							
13/5 Wilts Sandy loam	Green Batavia & Red Cos	7 Aug- 10 Sept	265	Wholehead Lettuce	220	Babyleaf Lettuce	100

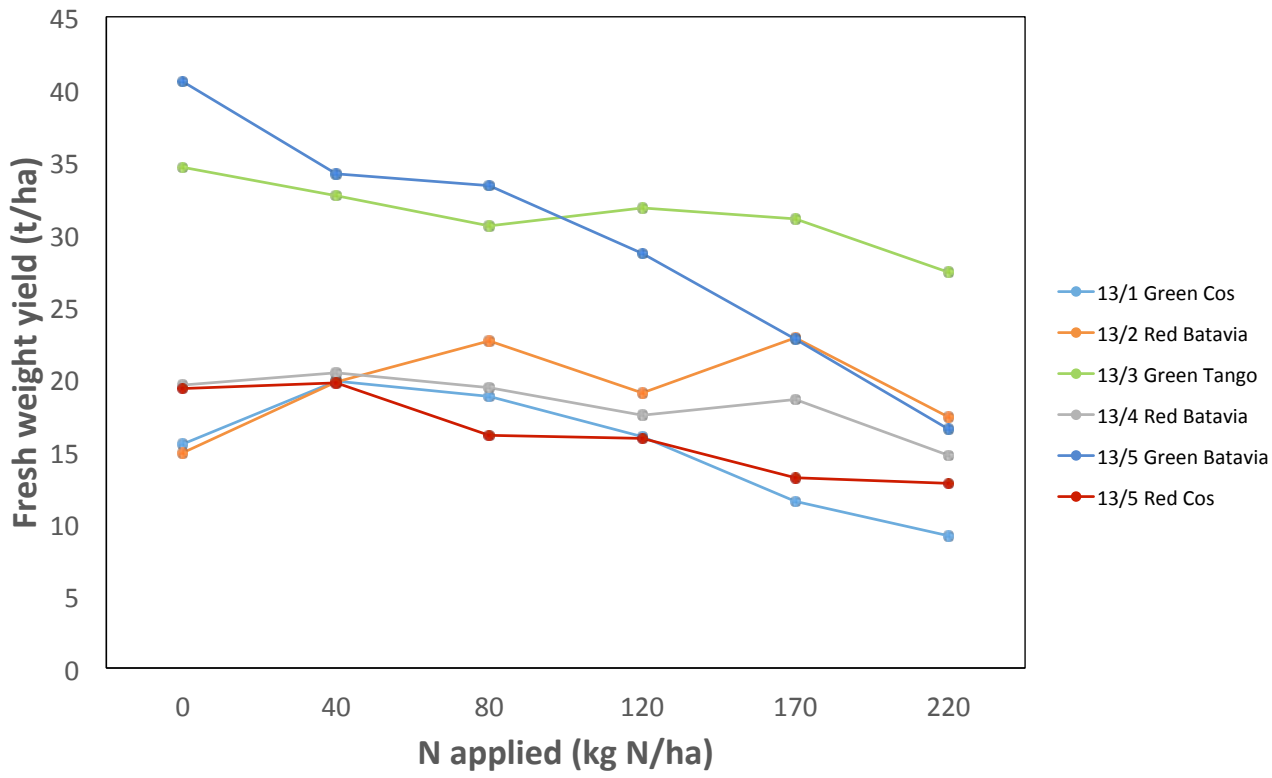
Notes
*, Abbreviations: BBL, baby leaf lettuce; BBS, baby leaf spinach; BBB, baby leaf brassicas.

Significant yield responses to applied N were only seen at two locations (Sites 13/1 and 13/2) where initial background SMN was at or below 30 kg N/ha (0-30 cm depth) prior to applying N treatments (Figure 2). At these two sites, further applications of N above 40 kg/ha (Site 13/1) or 80 kg N/ha (Site 13/2) had no significant effect on yield.

In the remaining four response data sets (Sites 13/3, 13/4 & 13/5) where initial the SMN was 116 – 265 kg N/ha, yield declined with addition of fertiliser N (Figure 2). Higher fertiliser nitrogen treatments applied at sites 3 and 5 where the initial SMN was > 100 kg N/ha caused a yield decrease to occur.

The main reason for the yield decrease appeared to be lower plant density (resulting from poorer emergence). These results clearly indicate that growers and agronomists need to take into account SMN when deciding on fertilizer N recommendations.

Significant effects of N applied on leaf greenness (measured by a SPAD meter) were seen only seen at sites 1 and 2, where yield responses were also recorded and initial SMN was low (<30 kg N/ha, 0-30 cm). The data suggest that for sites with high initial SMN, reducing application rates of N should not affect the quality of the crop in terms of colour.



2. Effects of applied N fertiliser on fresh weight yield in five experiments at four commercial production sites in 2013

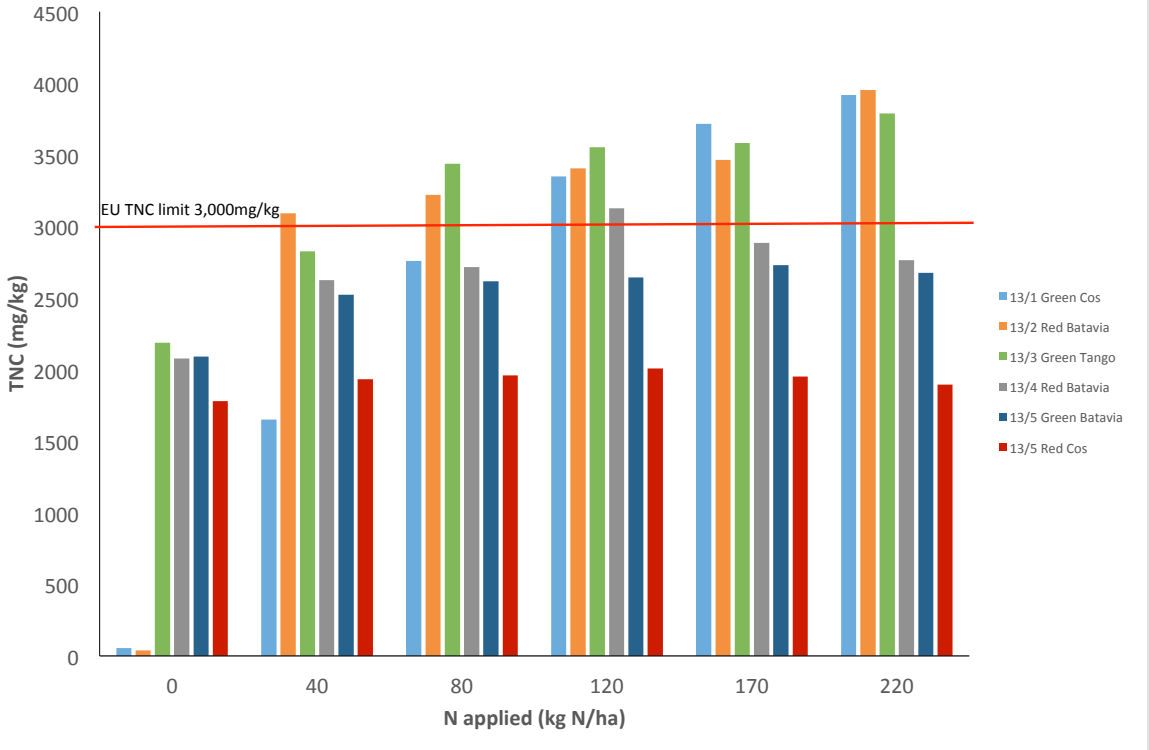
Tissue nitrate concentration

The 3,000 mg NO_3^-/kg limit for TNC was exceeded at a number of the sites, when the amounts of N applied was reached as follows:

- 40 kg N/ha applied at Site 13/2,
- 80 kg N/ha at Site 13/3,
- 120 kg N/ha at Sites 13/1 & 13/4.

Of the two sites which showed a significant yield response to applied N, Site 13/2 had the additional problem that at 40 and 80 kg N/ha applied, its TNC levels were 3,090 and 3,221 mg/kg respectively. In this case fertilizer N was not beneficial given the exceedance of the legal limit.

The only site therefore at which an N application for yield could be recommended, and at which the crop would also stay below the limit for TNC, would be Site 13/1 (with 40 kg N/ha).



3. Effect of applied fertiliser nitrogen on tissue nitrate concentration (TNC) in baby leaf lettuce at five sites in 2013. Red line shows 3,000 mg NO_3^-/kg limit for TNC

Differences between red and green baby leaf lettuce types

Based on the fresh weight yields in a single season at the recommended N rates for yield and TNC (recommended N rates, 40 kg/ha for Site 13/1, and zero for the remaining Sites), the average yield for the red types at 21 t/ha was ca. 66% of that of the green types at 30 t/ha (excluding Green Tango which is considered separately). In spite of the yield difference between crops the N offtake values were similar, at 65 kg/ha N.

TNC levels were similar overall between colour types: Red; 2,549 & 2,633 mg/kg and green; 2,344 & 2,938 mg NO_3^-/kg, at 40 and 80 kg N/ha respectively of applied N fertiliser averaged across the six data sets. However at one site (13/5) where Green and Red varieties were grown side by side (Figure 4) in the same experiment, the Red Cos had significantly lower TNC overall than the Green Batavia type (1,921 vs 2,547 mg NO_3^-/kg).

4. Green Batavia and Red Cos grown side by side, Wilts, in 2013

N recommendations

The harvested yields of baby leaf lettuce were similar to those of wild rocket, but in most cases that total N concentration in the baby leaf lettuce was lower, meaning that the N uptake was less than in wild rocket. A major finding is that with the exception of the Green Tango 'multi-leaf' type there was an average crop requirement for N of only 65 kg N/ha meaning that recommended amounts of N for baby leaf lettuce are likely to be lower than those for wild rocket types reported in HDC Factsheet 08/13.

When determining fertiliser N application rates, the data show that it is essential to take into account the potential soil N supply which depends on soil type, over winter rainfall and previous cropping. Growers should also take into account applications of N to preceding crops within the current season, as well as mineralisation of N from soil organic matter between soils warming in spring and actual drilling of the crop. Soil mineral nitrogen measurements can be used to asses soil N supply.

The Fertiliser Manual uses the SNS index system to define soil N supply. Its assessment is described for field vegetables in Factsheet 09/12. For first-sown crops, SNS can be assessed using the field assessment method (FAM) based on previous cropping, soil type and excess winter rainfall, or measurement of SMN prior to drilling. However for crops sown later in the rotation (within the same season) the FAM is not reliable and SMN must be measured.

Table 2 shows typical recommendations for baby leaf lettuce (excluding Green Tango). The SNS index in the Fertiliser Manual is based on SMN to 90 cm depth. For baby leaf lettuce, SNS Index can be based on SMN content to a rooting depth, of 30 cm.

If growers have evidence that rooting depth is less than 30 cm (e.g. 20 or 15 cm), then more fertilizer N might be required. If SMN was to be measured to a shallower depth (possibly in conjunction with topsoil sampling), the recommendations in Table 2 would still be valid, but if the assessment of rooting depth was underestimated, there is a high risk that TNC might be exceeded even with as little as 40 kg N/ha fertilizer applied.

Baby leaf lettuce crops grown in the summer of 2013 were at risk from exceeding the limits set for TNC in outdoor lettuce of 3,000 mg NO_3^-/kg with as little as 40 kg/ha fertilizer N. As found in previous HDC-funded work on wild rocket and baby leaf spinach, the risk was particularly high for the late season crops, when SMN builds up in the rotation due to soils warming, plus mineralization of N from soil organic matter, and residues from previous crops in the current and past seasons.

As in the rocket work, recommendations may be varied if the grower has their own different estimates of yields and N uptake for crops in their land, and can therefore justify a different N requirement, provided that the increased risk of having high TNC in the produce is taken into account.

Table 2. Nitrogen Recommendations[a] (kg N/ha) to maximize gross yield of the baby leaf lettuce crop, based on SNS indices from RB209 and SMN measured to 30 cm depth.

SNS Index	0	1	2	3	4	5	6
SMN (kg N/ha) to 30 cm[d]	<20	20-27	28-33	34-40	41-53	54-80	>80
N recommended (kg N/ha)[b,c]	60	50	40	30	10	0	0

[a] The recommendations in the table are based on crops of baby leaf lettuce with N offtakes of 65 kg N/ha, and fresh weight yields of between 21 t/ha (red) and 30 t/ha (green). Mineralisation of soil organic matter is estimated to be 11 kg N/ha. Soil N recovery is 100% and fertiliser recovery = 60% (Based on Fertiliser Manual RB209; for details see box 4 in factsheet 09/12).

[b] Recommendations may need to be revised down if there is a risk of exceeding the limits for TNC e.g. for late season crops under dull conditions,

[c] Recommendations for baby leaf lettuce may need to be varied if yields are consistently lower or higher than the typical yield given above, bearing in mind that larger applications of fertilizer may increase the risk of a high TNC.

[d] Underestimation of rooting depth can lead to the risk of high TNC.

Green Tango - note on 'multi-leaf' types

Varieties grown as 'multi-leaf' types are not strictly baby leaf types and therefore are considered separately: Based on the results from the single site studied in 2013, the Green Tango delivered 69 t/ha of fresh produce (although only a fraction was harvested) and achieved this with a total N uptake of 140 kgN/ha.

Whilst its N requirement appears to be higher than other 'true' baby leaf varieties, Green Tango was well satisfied by the initial soil mineral N at this site which was 265 kg/ha to 30 cm. No fertiliser N would be recommended for the crop. Such 'multi-leaf' types could use the wild rocket recommendations given in HDC Factsheet 08/13.

Further information

- HDC Project FV418. Baby leaf lettuce: N response studies to maximise yield and manage nitrate levels.
- HDC Factsheet 09/12 Soil nitrogen supply for field vegetables.
- HDC Factsheet 08/13 Nitrogen Recommendations for optimising yield and minimizing nitrate levels in baby leaf salad crops. Fertiliser manual RB209 (8th Edition) Defra 2010.
- Noxious or nutritious? Progress in controlling nitrate as a contaminant in leafy crop species. Food Energy and Security, Vol 2: 141–156. DOI: 10.1002/fes3.28

Acknowledgements

The following are gratefully acknowledged: Angela Huckle (ADAS) for management of the experiments described and associated data analysis, and Clive Rahn (Plant Nutrition Consulting) for comments and advice during the preparation of this factsheet.

£8.75
where sold

HDC is a division of the Agriculture and Horticulture Development Board (AHDB).

AHDB Agriculture & Horticulture DEVELOPMENT BOARD

HDC **Horticultural Development Company**

Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T: 024 7669 2051
E: hdc@hdc.org.uk
Twitter: @HDCtweets

www.hdc.org.uk