Nitrate Surveillance Monitoring Program

Annual Report April 2022 – March 2023

June 2023

Authors: RSK ADAS Ltd.

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Summary

While the UK is no longer part of the EU, monitoring activities have continued under GB retained law 1258/2011 since January 2021. The requirement to carry out monitoring for nitrate in lettuce, spinach and rocket is being met by the UK Nitrate Surveillance Programme. Results are presented for the period between 1 April 2022 and 31 March 2023.

The survey monitors compliance in UK and gathers data on occurrence levels in leafy green vegetables. This report covers the survey period 2022 to 2023. The current round of surveys commenced in 2020.

This surveillance has been undertaken since May 1996, except for 2019-20,and reported in earlier MAFF (now Defra)/FSA Food Surveillance Information Sheets. Monitoring of UK grown lettuce, spinach and rocket is currently led by RSK ADAS Ltd (ADAS) in partnership with NRM Laboratories.

The survey monitors compliance in UK and gathers data on occurrence levels in leafy green vegetables. The survey period covers the years 2022 to 2023. The survey commenced in 2020.

A total of 200 samples were collected within the sampling period, comprising of 120 lettuce, 18 rocket, 21 spinach samples. A further 41 samples categorised at 'Other Green Leafy Vegetables' was comprised of samples including chard, Chinese leaves, mizuna, kale, and pak choi. The lowest average nitrate concentration was recorded in summer-grown iceberg lettuce (1045.1 mg/kg). One iceberg sample exceeded the maximum nitrate concentration. The highest average nitrate concentrations were seen in 'other leafy green vegetables' (7701.3 mg/kg) and in summer-grown rocket (7235.7mg/kg).

The number of samples exceeding the maximum levels decreased this year to 6 samples – one sample of Iceberg, two samples of open-air non-iceberg lettuce sampled in the summer, two samples of rocket sampled in the summer and two samples of spinach. A further 14 samples were within 10% of the maximum level. Historical trends indicate that the average annual nitrate concentrations were again elevated for rocket and spinach, and the proportion of samples that exceeded the maximum level increased.

Consistent with previous years of this project, a strong correlation was found between nitrate concentration and sampling date, with samples collected later in the season showing greater concentrations, indicating potential interactions between nitrate accumulation and climate, particularly light levels, available soil moisture and any accumulation of nitrate in the soil. 2022-23 was warmer (particularly during the summer), with less rainfall and more hours of sunshine than in previous years.

Introduction

Nitrates (NO_3) are chemicals which are present in plants, soils and water. While background levels of nitrate will be present in the soil, additional nitrate will be applied either as inorganic fertiliser (e.g. calcium ammonium nitrate) or through the breakdown of soil organic material during crop production. Plants will take up nitrates from the soil for amino acid and protein synthesis, although a level of nitrate will be present in plant material at harvest.

Nitrate Surveillance

The survey monitors compliance in UK and gathers data on occurrence levels in leafy green vegetables. This report covers the survey period 2022 to 2023. The current round of surveys commenced in 2020.

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Study Objectives

The current study was undertaken to assess nitrate levels in domestic produce between May 2021 and March 2022 as part of an ongoing monitoring program. This program was undertaken to ensure a representative spread of sampling (including both geographically and seasonally) to ensure the following objectives were met.

1. To collect a total of 200 domestic samples of fresh produce (principally lettuce, rocket and spinach, but also including ‘other leafy green veg’).
2. To carry out the chemical determination of nitrate concentration in fresh tissue in accordance with the appropriate Directives.
3. To report results to the agency in an electronic format.
4. To ensure the grower has received a copy of the results relating to his/her sample.

Quality Assurance

The study was conducted in compliance with the requirements of the Food Standards Agency. Sampling methodology conforms to the rules set in EU retained law Regulation (EC) 1882/2006 and with the quality assurance procedures adopted previously for the 2002-2018 surveys.

ADAS has its own in-house Quality Management System (QMS) developed to meet the requirements of externally accredited standards applied to parts of the business. ADAS QMS ensures that all work is controlled by documented plans, project management methodology, and carried out by properly trained staff, using suitable equipment and facilities. Business processes and routine procedures are documented in Standard Operating Procedures (SOPs) authorised by management and subject to periodic review. In-built process improvement ensures that ADAS QMS continues to improve and evolve to cover new areas of activity and to be responsive to the changing needs of customers. Compliance with QMS is monitored through formal audit by the operationally independent Quality Management Group.

Audit schedules are designed to cover all key areas of activity. Study specific audits can also be carried out by prior agreement at contract stage. ISO 9001:2000 - ADAS is registered with DNV, including for: ‘Agricultural & horticultural consultancy including: soils, chemicals, productivity, food chain, farm business management and land management’.

Chemical analysis carried out by NRM Ltd meets the requirements of the Joint Code of Practice for Quality Assurance in Research, complies with EU retained law Regulation (EC) 1882/2006.

Methodology

Sampling Schedule

In March 2022 a sampling schedule was prepared by ADAS and agreed by the Food Standards Agency (FSA). The schedule was developed to ensure that samples were representative of the wider UK production. The schedule ensured that the sampling of fresh produce complied with the guidelines given in EU retained law Regulation (EC) 1882/2006 and met with the requirement to spread the sampling over representative geographical regions throughout the UK.

The sampling schedule covered the period from 4 April 2022 to the 28 March 2023 and involved the collection of lettuce, rocket, spinach and other leafy green vegetables from domestic sources. Geographic representation and seasonal growing trends were maintained and it was left to the discretion of the Sample Officer to ensure that appropriate numbers of samples from within each category were collected from a representative cross section of growers. A total of 200 samples were collected across the lettuce, rocket, spinach and other leafy green vegetable categories (**Table 1**). The range of samples included in the other leafy green vegetable category is given in **Table 2**.

Table 1: Summary figures for nitrate samples taken between 4 April 2022 and 28 March 2023

Crop Type	Count
Lettuce	120
Rocket	18
Spinach	21
Other Green Leafy Vegetables	41
Total	**200**

Table 2: Summary figures for nitrate samples taken between 4 April 2022 and 28 March 2023 – numbers of "Other Green Leafy Vegetables"

Crop Type	Count
Baby red leaf	2
Celery	2
Chard	10
Chinese leaves	6
Chinese mustard	1
Dandelion	1
Kale	3
Mizuna	3
Pak choi	1
Radicchio	1
Red baby leaf chard	1
Red chard	5
Red mizuna	3
Spring cabbage	1
Tatsoi	1
Total	**41**

Sample Collection

Sampling Strategy

Samples were collected by trained Sample Officers, in accordance with Standard Operating Procedure (SOP) ‘Field sampling and transportation of lettuce and spinach samples for the UK Nitrate Monitoring Programme’ (see Appendix) and EU retained law Regulation (EC) 1882/2006. Prior agreement was obtained from the grower before a sample was taken. A minimum of 10 heads of lettuce or 1.0 kg of spinach, rocket and other leafy green vegetables was randomly collected from various points within the lot. Where samples were collected from the field or glasshouse the sample points were, as far as possible, evenly distributed across the area by walking a ‘W’ pattern back and forth. Lot size did not exceed 2.0 ha and samples were not taken from the field edges. Plants were not collected from patches within the lot which appeared unrepresentative and material that was obviously damaged or diseased was avoided.

Sample Labelling and Documentation

The sampling schedule assigned a unique identification number to each sample, along with details of the Sample Officer, month of collection and region. All samples were anonymised. A copy of the schedule was sent to each Sample Officer and the laboratory to ensure that all parties were fully informed and prepared. Pre-printed labels were provided by NRM and sent directly to the Sample Officers. Samples were sealed and labelled by the Sampling Officer, immediately following collection. The Project Manager held a master copy of the schedule and tracked sample collection, analysis and reporting of results throughout the year. Crop husbandry details were collected by the Sample Officers to accompany each sample. Details included grower, date and time sample was collected, variety or type, location, lot size and fertiliser input.

Transportation of Samples to the Laboratory

Each sample was carefully placed into a clean polythene bag which was subsequently placed into polystyrene insulated box, provided by NRM. Ice packs were placed in the base of the box, as appropriate, to ensure the sample remained below 10^{o}C during transit. The containers provided were inert and offered adequate protection for samples against water loss, deterioration, contamination, damage, heat and significant changes in nitrate content during transportation to the laboratory. Samples were dispatched to the laboratory to arrive before 10.30am on the day after harvest. Samples from Scotland and Northern Ireland were placed in sealed plastic bags and transported in insulated containers at <10^{o}C, which arrived at the laboratory within two days of harvest.

Sample Preparation in the Laboratory

Laboratory preparations met the requirements of EU retained law Regulation (EC) 1882/2006. Basic checks were carried out to ensure that the temperature upon arrival was below 10^{o}C and that samples were intact and had not begun to degrade during transportation. Associated documentation was checked against the sample and each sample was assigned a unique NRM laboratory number, which was later reported alongside the unique identification number.

Samples were prepared in accordance with the requirements of EU retained law Regulation (EC) 1882/2006 and the quality assurance procedures meet the requirements of the Joint Code of Practice for Quality Assurance in Research and are in Compliance with the provisions of items 1 and 2 of Annex III to retained EU law Regulation (No 882/2004). The whole sample was homogenised using a protocol developed by NRM Ltd which has been demonstrated to produce suitably homogenous samples. Four representative sub-samples were taken, (A, B, C and D). Sub-sample A was used immediately for analysis. Sub-sample B was kept refrigerated in case of a requirement for repeat analysis when exceedance occurred. Sub-samples C and D were frozen and will be kept in storage for 12 months following the reporting of results.

Analytical Analysis

Analysis commenced immediately after preparation and initial analysis of all samples was completed within five days of sampling. Analysis was undertaken using a UKAS accredited method which fully meets the requirements of EU retained law Regulation (EC) 1882/2006. The method is accredited to BS EN ISO 17025: 2005 and has been since 2000. The method uses an extraction procedure which has been shown to be reliable and robust and involves freezing in liquid nitrogen prior to homogenisation. Detection is based on flow injection colorimetry and is currently used by NRM Ltd for analysis of all commercial samples.

The determination of nitrate-N is based on the formation of a diazo compound between nitrite and sulphanilamide. This compound is then coupled with N-1-napthylethylenediamine dihydrochloride to produce a red azo dye. The colour is measured at a light wavelength of 540 nm in a spectrophotometer. Nitrate is reduced quantitatively to nitrite by cadmium metal in the form of an open tubular cadmium reactor (OTCR). The nitrate content of the sample was calculated from the analysed nitrate-N value. Nitrite-N was monitored and was quantified if it was present. The measurement of Nitrite was not part of the accredited Nitrate method and was dealt with, when required, outside of the accredited system.

If any value was ≥ 90% of the maximum nitrate level (**Table 3**) for a particular product then this triggered a requirement for a repeat extraction and analysis of refrigerated Sample B to confirm the high value. This repeat confirmatory analysis was carried out within two days of the initial analysis and both results were reported on the same day.

Table 3. Maximum permitted level of nitrates in lettuce, spinach and rocket.

Product Type	Cultivation	Harvest Date	Maximum Permitted Level (NO_3 mg/kg)
Fresh spinach	Any	Any	3500
Preserved, deep-frozen or frozen spinach	Any	Any	2000
Fresh lettuce Non-iceberg type	Protected	1 October – 31 March	5000
Fresh lettuce Non-iceberg type	Protected	1 April – 30 September	4000
Fresh lettuce Non-iceberg type	Open Air	1 October – 31 March	4000
Fresh lettuce Non-iceberg type	Open Air	1 April – 30 September	3000
Fresh lettuce Iceberg type	Protected	Any	2500
Fresh lettuce Iceberg type	Open Air	Any	2000
Rocket	Any	1 October – 31 March	7000
Rocket	Any	1 April – 30 September	6000
Other Leafy Green Vegetables	Any	Any	n/a

Quality Control

All quality control (QC) information was recorded on the laboratory worksheets. Routinely an in-house reference material is included with every batch of samples at a frequency of at least one QC sample in every batch of twenty samples. A spiked sample may also be included at the same frequency if required. A reagent blank is prepared with each batch of samples. A mid-range standard is included at the end of each batch to ensure any drift over the run is within acceptable limits (+/- 5%). All QC results are plotted on Shewhart

Charts and monitored to ensure they conform to NRM's policy on Quality Control (i.e. precision, accuracy, 9 point bias, ascending or descending trends etc).

In-house reference materials are routinely used. These are prepared in-house from material obtained from growers or retailers. These materials are typical of produce entering the retail chain and therefore contain nitrate levels typical of those encountered in the marketplace. New materials are run alongside existing materials to obtain reference values for the new material.

The value obtained for the reagent blank must be less than 0.2 mg/l NO_3^-N. This equates to 8.9 mg/kg. One QC value at ± 2 standard deviations = Warning. Two consecutive QC values at ± 2 standard deviations = Action. One QC value at ± 3 standard deviations = Action.

A QC Failure Record is generated when an Internal QC falls outside the required criteria. This initiates a documented investigation into the cause of the failure under NRM's Non-Conforming Work policy. This typically results in the retained sample being re-extracted and re-analysed from the start.

New in-house reference materials and standard solutions are cross checked against the current reference material or standard solution prior to use. Documented evidence of this cross check is retained. Control materials are included in every batch at a frequency of at least one QC sample in every batch of twenty samples (5%). LOQ = 50 mg/kg, LOD = 6 mg/kg, Blanks = generally less than 2 mg/kg. Precision values over the relevant concentration range expressed as relative standard deviations; 4.4% at approx. 2000 mg/kg, 8.9% at approx. 450 mg/kg, 11.3% at approx. 100 mg/kg. IHRM: Currently Spinach, mean = 314 mg/kg, SD = 15.6 mg/kg, RSD = 5%.

Recovery was determined on five batches of triplicate samples spiked at three levels. Approx. 2000 mg/kg average recovery = 98%, range = 94% - 105%, approx. 450 mg/kg average recovery = 102%, range = 85% – 114%, approx. 100 mg/kg average recovery = 104%, range = 80% - 117%. Reporting limit = 50 mg/kg. Recovery: acceptable between 90% and 110%. Measurement uncertainty is estimated using precision and bias data.

Reporting of Results

Analysis commenced immediately after preparation and initial analysis of all samples was completed within five days of sampling. Where nitrate levels exceeded the limits the frozen sub-sample was re-analysed within two days of the initial analysis, in all cases. Results were received by ADAS within five days of sample receipt. Nitrate concentrations are expressed in milligrams of nitrate per kilogram of sample fresh weight (mg/kg).

Communication of Results to FSA

Results were reported to the FSA on a monthly basis. Individual data were reported in an Excel spreadsheet and filters were added to the column headings to enable the FSA to search for and group results, as appropriate. Monthly mean values and running totals of maximum, minimum and mean nitrate levels, grouped according to category, were tabulated (**Appendix 1** and **Appendix 2**).

Communication of Results to Growers and Wholesalers

A template letter was produced by the FSA and forwarded to ADAS for use when reporting results (**Appendix 3**). When the nitrate level of a sample was within the maximum permitted level, as described in retained law Regulation (EC) No 1881/2006, ADAS reported the results directly to the grower/wholesaler. A copy of the letter was also sent to the FSA. If the nitrate level in a sample exceeded the maximum permitted limit then, following confirmation of the result by NRM, ADAS informed the responsible person at the Agency before reporting the result to the grower/wholesaler (**Appendix 4**).

Long term sample storage in case of dispute

Sub-samples ‘C’ and ‘D’ (see above) from each sample have been frozen and will be stored by NRM for a period of 12 months after the reporting of results.

Results

Sample Overview by Region

A total of 200 domestic samples were collected between April 2022 and March 2023 (**Figure 1**). For England, 16 samples were collected from the North West, 5 from the North East, 48 from Central England, 26 samples from the East and East Anglia, 51 from South East England and 18 samples from the South West. 10 samples were collected from Wales, 16 samples from Scotland and 10 samples from Northern Ireland.

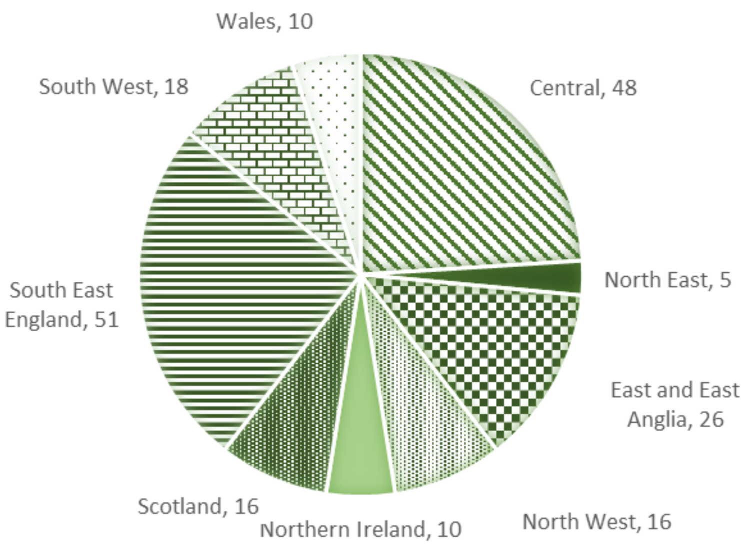

Figure 1. Total counts for samples collected from each region between April 2022 and March 2023.

Sample Overview by Category

A summary of samples collected by category is given in **Table 4**. The majority of samples were open air non-iceberg lettuce sampled in the summer (41) and protected non-iceberg lettuce sampled in the winter (37) and other leafy green vegetables (41). Overall, the majority of lettuce samples were of the non-iceberg type (94) with only 25 samples of iceberg-type lettuce collected. Four samples of open air non-iceberg lettuce were collected in the winter, and 12 protected non-iceberg lettuce sampled in the summer. 20 spinach samples and 18 rocket samples were collected in total. Of the rocket samples, 14 were protected and 4 were open air.

41 samples categorised as Other Green Leafy Vegetables were collected: baby red leaf (2), celery (2), chard (10), Chinese Leaves (6), Chinese mustard (1), dandelion (1), kale (3), mizuna (3), pak choi (1), radicchio (1), red baby leaf chard (1), red chard (5), red mizuna (3), spring cabbage (1) and tatsoi (1).

The distribution of samples between category type this season was largely comparable with past seasons. Of the lettuce, a larger proportion of iceberg lettuce (compared with non-iceberg) was sampled in 2022-23 compared with 2021-22 (21.7% vs. 11.8%). Considering the non-lettuce categories (spinach, rocket and other leafy greens) compared with lettuce (iceberg and non-iceberg), an increased proportion of non-lettuce categories was sampled in 2022-23 compared with 2021-22 (40% vs. 36%).

Table 4. Summary of sample counts per category, cultivation type and harvest period between April 2022 and March 2023..

Category	Cultivation	Harvest Period	Count
Lettuce – Non-Iceberg	Open air	Summer	41
Lettuce – Non-Iceberg	Open air	Winter	4
Lettuce – Non-Iceberg	Protected	Summer	12
Lettuce – Non-Iceberg	Protected	Winter	37
Lettuce – Iceberg	Open air	Summer	26
Spinach	n/a	n/a	21
Rocket	n/a	Summer	14
Rocket	n/a	Winter	4
Other Leafy Green Vegetables	n/a	n/a	41

Overview of Nitrate Concentrations

120 lettuce samples were collected, comprising of 26 open air summer iceberg samples, 49 protected non-iceberg types (12 summer, 37 winter) and 45 open air non-iceberg types (41 summer and 4 winter).

As expected, significant variation was seen in nitrate content for lettuce with levels varying according to season, product type and production method (**Figure 2**,**Table 5**). Levels were relatively low in open air iceberg-type lettuce, with both the lowest average nitrate concentration of all category types of 1045.1 mg/kg, and the most consistent across the season.

Non-iceberg types grown in the open air showed a broader range of nitrate concentrations, ranging from 369.6 mg/kg to 4273.9 mg/kg in the summer, and 915.1 – 1785.6 mg/kg in the winter. Average nitrate concentrations in open air non-iceberg types across the season was 1437.7 mg/kg.

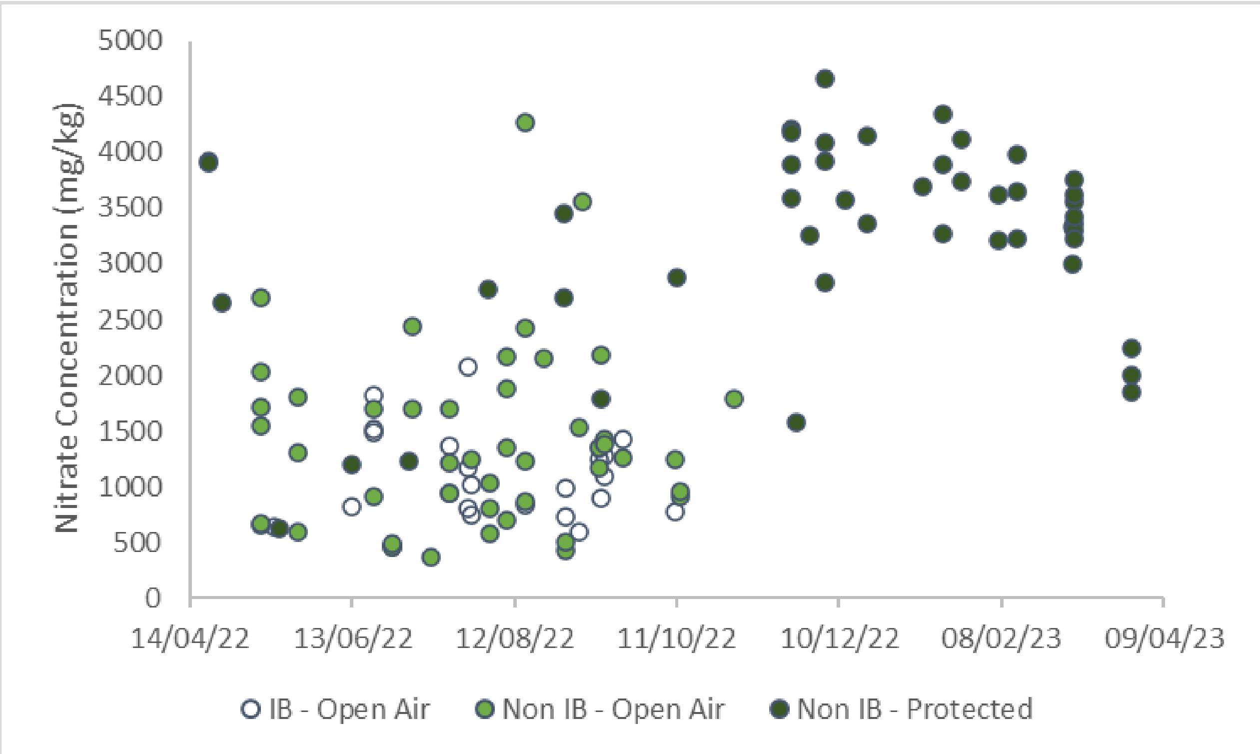

Figure 2. Seasonal nitrate concentrations for iceberg-type (IB) and non-iceberg type (Non-IB) lettuce grown under protection or in open air.

Two iceberg samples approached 10% of the maximum thresholds, and one sample exceeded the nitrate threshold (**Table 6**). Four non-iceberg samples were within 10% of the maximum threshold, three of which were summer protected and one winter protected. Two non-iceberg lettuce samples exceeded the nitrate threshold; these were open air samples collected in the summer.

For Other Green Leafy Veg, average nitrate concentrations were 2828.5 mg/kg, ranging from <50 mg/kg to 7701.3 mg/kg (**Figure 3, Table 5**). Levels were generally lowest in Chinese leaves (<50 mg/kg, average 544.7 mg/kg) and kale (357.7 mg/kg , average 509.2), although there was a single sample of radicchio (260.2 mg/kg) that was also low. The highest average nitrate concentrations was found in samples of red chard (7171 mg/kg, average 3829.7 mg/kg) and red mizuna (7142.0 mg/kg, average 6534.2 mg/kg). Levels were generally lower in the summer period, increasing in the winter.

Non-iceberg lettuce grown under protection showed the greatest nitrate concentration of 4664.8 mg/kg, which was recorded in a winter sample. The average nitrate concentration in protected non-iceberg type was 3251.3 mg/kg across the season. Concentrations in protected non-iceberg types were higher in the winter period, ranging from 1583.4 – 4664.8 mg/kg, compared with 617.0 – 4280.6 mg/kg in the summer.

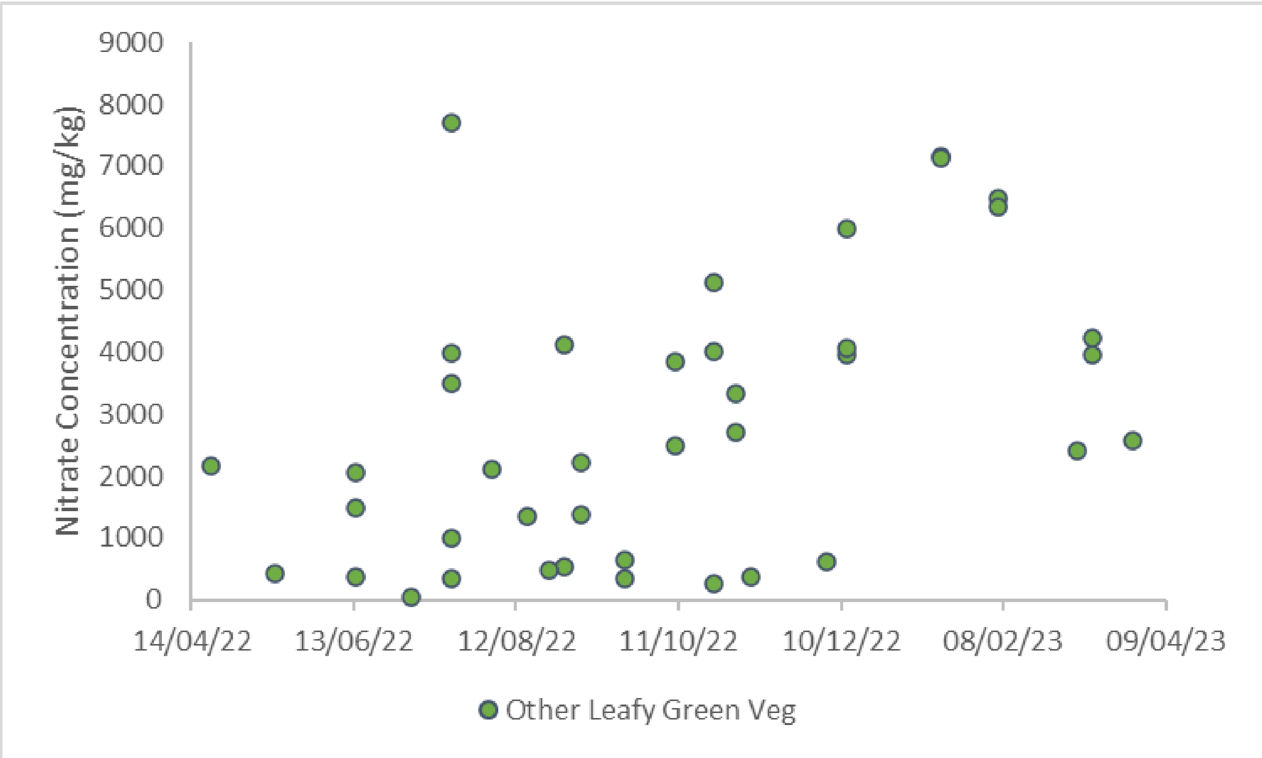

Figure 3. Seasonal nitrate concentrations for Other Green Leafy Veg.

For rocket, the average nitrate concentration across the season was 3809.6 mg/kg, ranging from 534.4 – 7235.7 mg/kg (**Figure 4, Table 5**). However, the limited number of samples collected in the winter (four) makes it difficult to compare changes in concentration across the season. Rocket samples accumulated greater maximum nitrate levels in the winter than all other categories except for 'other leafy greens'. Three rocket samples were within 10% of the maximum threshold (two summer and one winter), with two samples that exceeded the maximum threshold.

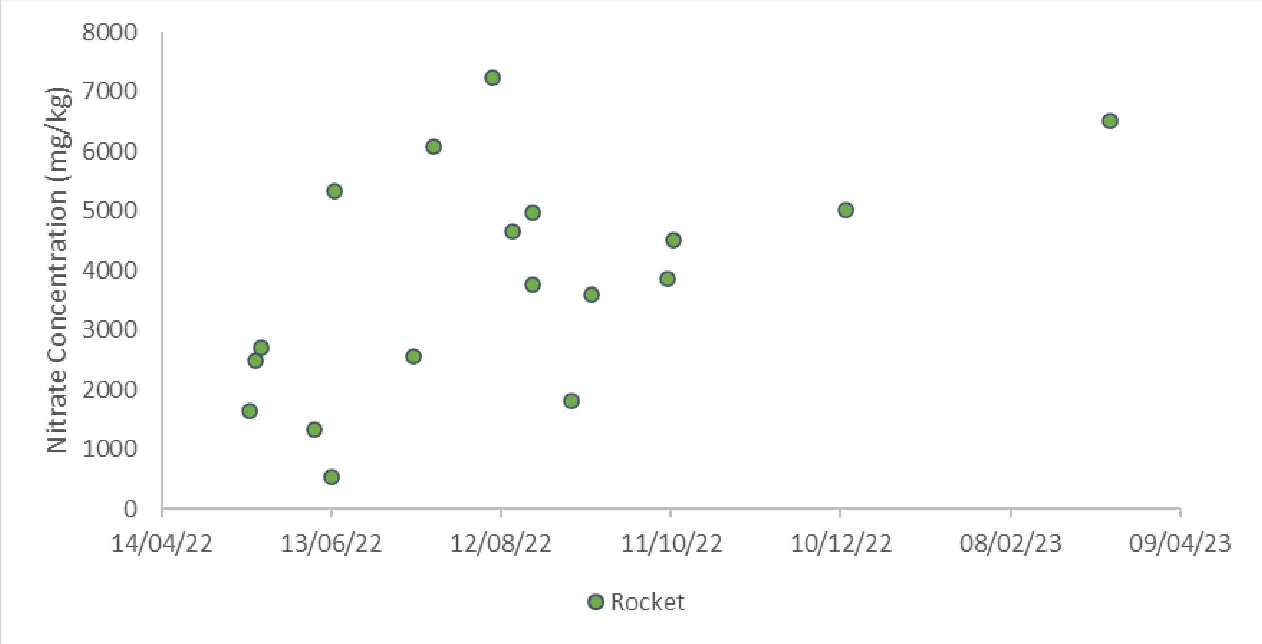

Figure 4. Seasonal nitrate concentrations for Rocket.

For spinach, the average nitrate concentration was 1651.6 mg/kg, with levels ranging from <50 – 3781.9 mg/kg across the season (**Figure 5**, **Table 5**). Similar to lettuce, nitrate concentrations were greater in the winter period compared with the summer.

Two spinach samples exceeded the maximum nitrate threshold, and one further sample came within 10% of the maximum threshold.

When compared against sample sizes, the greatest proportion of samples exceeding the threshold value for nitrate concentration were recorded for rocket sampled in the summer (2 of 14 samples, 14.3%) and Spinach (2 of 21 samples, 9.5%). Summary figures are given in **Table 6**.

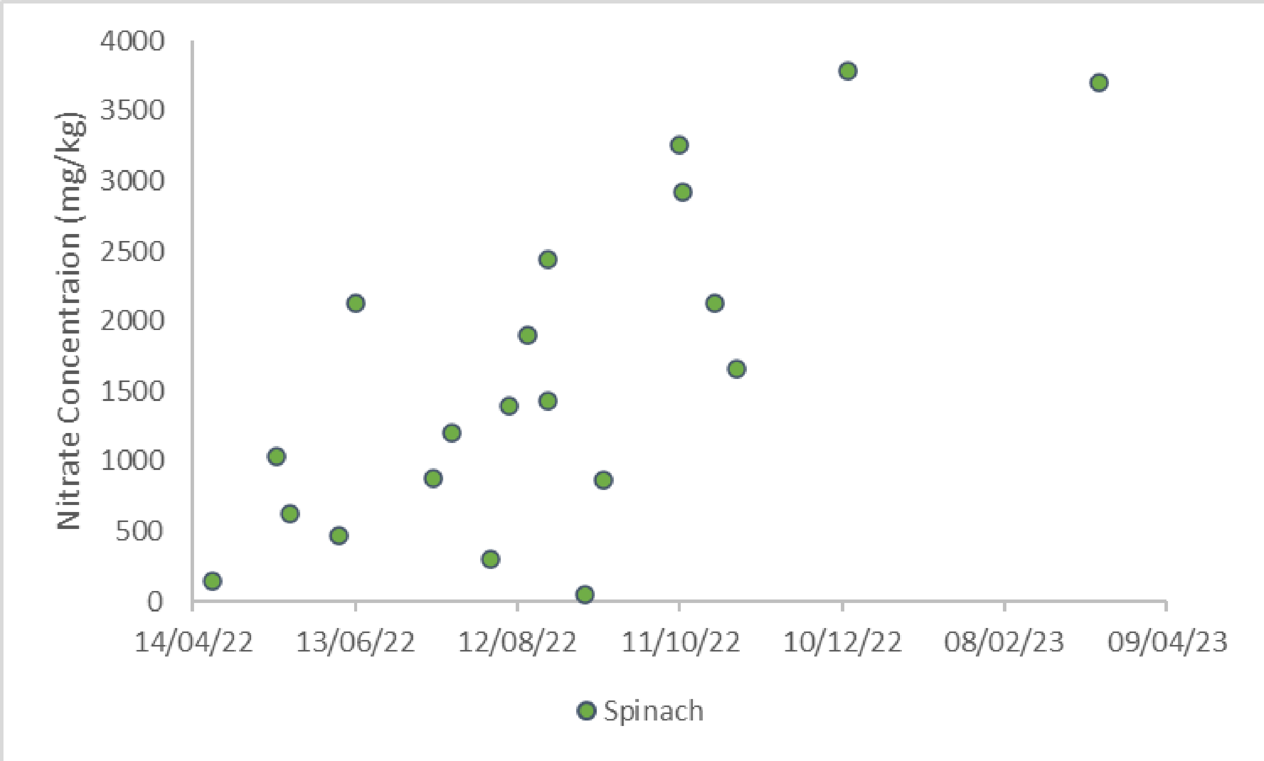

Figure 5. Seasonal nitrate concentrations for Spinach.

Table 5. Summary seasonal nitrate concentrations per category.

Category	Minimum Nitrate Concentration (mg/kg)	Average Nitrate Concentration (mg/kg)	Maximum Nitrate Concentration (mg/kg)
Iceberg	452	1045	2083
Non-Iceberg – Open (Summer)	370	1458	4274
Non-Iceberg – Open (Winter)	915	1229	1786
Non-Iceberg – Open (Season)	370	1438	4274
Non-Iceberg – Protected (Summer)	617	2646	4281
Non-Iceberg – Protected (Winter)	1584	3448	4665
Non-Iceberg – Protected (Season)	617	3251	4665
Other Leafy Green Vegetables	<50	2829	7701
Rocket (Summer)	534	3477	7236
Rocket (Winter)	3850	4974	6525
Rocket (Season)	534	3810	7236
Spinach	<50	1652	3782

Table 6. Summary figures for samples approaching 10% of, and exceeding, the maximum nitrate concentrations .

Product Type	Total Count	Count within 10% of Maximum	Count Above Maximum Level	Percentage of Samples Above Maximum Level (%)
Iceberg	26	2	1	3.8
Non-Iceberg – Open (Summer)	41	2	2	4.9
Non-Iceberg – Open (Winter)	4	0	0	0.0
Non-Ice – Protected (Summer)	12	3	0	0.0
Non-Ice – Protected (Winter)	37	1	0	0.0
Other Leafy Green Vegetables	41	n/a	n/a	n/a
Rocket (Summer)	14	2	2	14.3
Rocket (Winter)	4	1	0	0.0
Spinach	21	3	2	4.8
Total	200	14	6	3.0

Historical Trends

Average nitrate concentration in iceberg lettuce grown in the open air in 2022 (calendar year) was slightly above the 2021 mean for this category (1045 vs. 953 mg/kg - **Figure 6**), but is relatively consistent with previous years. The mean concentration in 2020 remains unrepresentative because of the different sampling strategy because of covid-19.

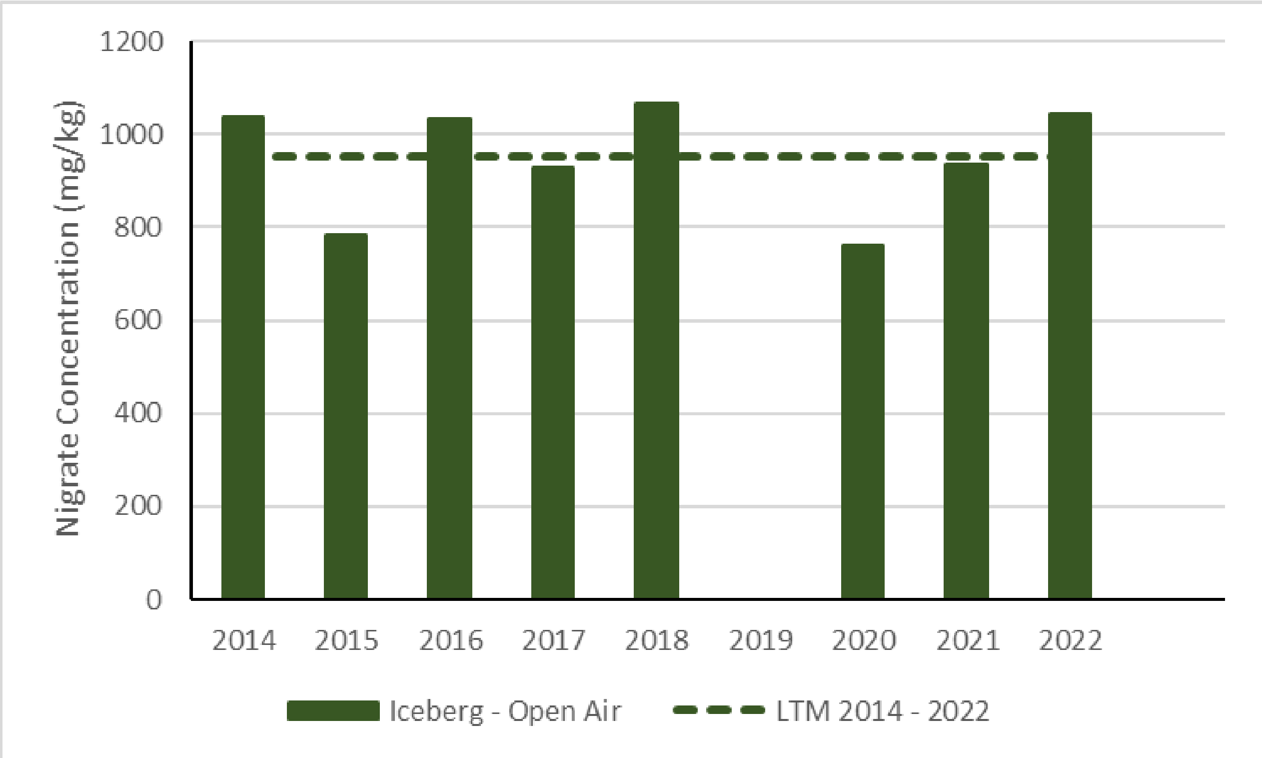

Figure 6. Comparison of annual average nitrate concentrations for outdoor iceberg-type lettuce compared with the long-term mean (LTM).

For non-iceberg types grown in the open air, summer samples in 2022 were above the long term mean (1455.7 vs. 1278 mg/kg), whilst winter samples were significantly below the long term mean (1228.5 vs. 1649 mg/kg - **Figure 7**). As in 2020, this is different to the general trend, where higher nitrate concentrations are generally seen in the winter compared to the summer.

In 2022 the difference between summer and winter samples of open air non-iceberg types was substantial (1455.7 vs. 1228.5 mg/kg), and is an average across four samples that were collected. A comparison of environmental conditions in 2022-23 compared with previous years indicates that the year was warmer (particularly during the summer), drier and with more hours of sunshine (**Appendix 5**).

Elevated nitrate levels in the winter, particularly in protected samples are likely as a result of lower light levels. Research indicates that lettuce may accumulate nitrate at higher concentrations at lower light levels to aid the plants ability to modulate internal osmotic balance (Blom-Zandstra *et al*., 1985). While light levels are likely to be a primary driver of this, there is also potential interaction with cultivation system. Protected crops are likely to be exposed to a more consistent external solute concentration (and one which may internally be kept low to drive growth), and with increased rates of transpiration due to supplementary heat provision, which will increase nitrate uptake compared with more inconsistent conditions in open fields.

The accumulation of nitrate to act as an osmoticum will occur to enable plants to maintain favourable internal water volumes and solute concentrations during growth, including buffering environmental changes. A range of osmotica will be used for this including other salts and neutral solutes, and this could be exploited by cultural methods to reduce nitrate accumulation. The increase in nitrate accumulation in low light conditions is likely to counter the reduced availability of sugars due to declines in photosynthesis (Behr *et al*., 1992). Therefore, increasing light levels through supplementary lighting, increasing the proportion of ammonium used to provide total nitrogen or the harvesting of more mature plants (solute concentrations decline with age) (Burns *et al*., 2008) may help to reduce levels nitrate accumulation. More innovative approaches could include the application of alternative osmoticum to the roots – a study in which glycine betaine was applied through a fertigation solution led to significant reductions in nitrate accumulation in lettuce (Jokinen *et al*., 2022). Glycine betaine is already used commercially as a supplementary osmoticum to promote frost resistance in apple when applied as a foliar spray, and so its use could be extended into leafy salad production. These approaches remain experimental, however, and some studies have reported that similar interventions have not had a positive effect (e.g. McCall & Willumsen, 1999) but it would be beneficial to explore the potential positive impacts of these approaches in commercial-scale trials.

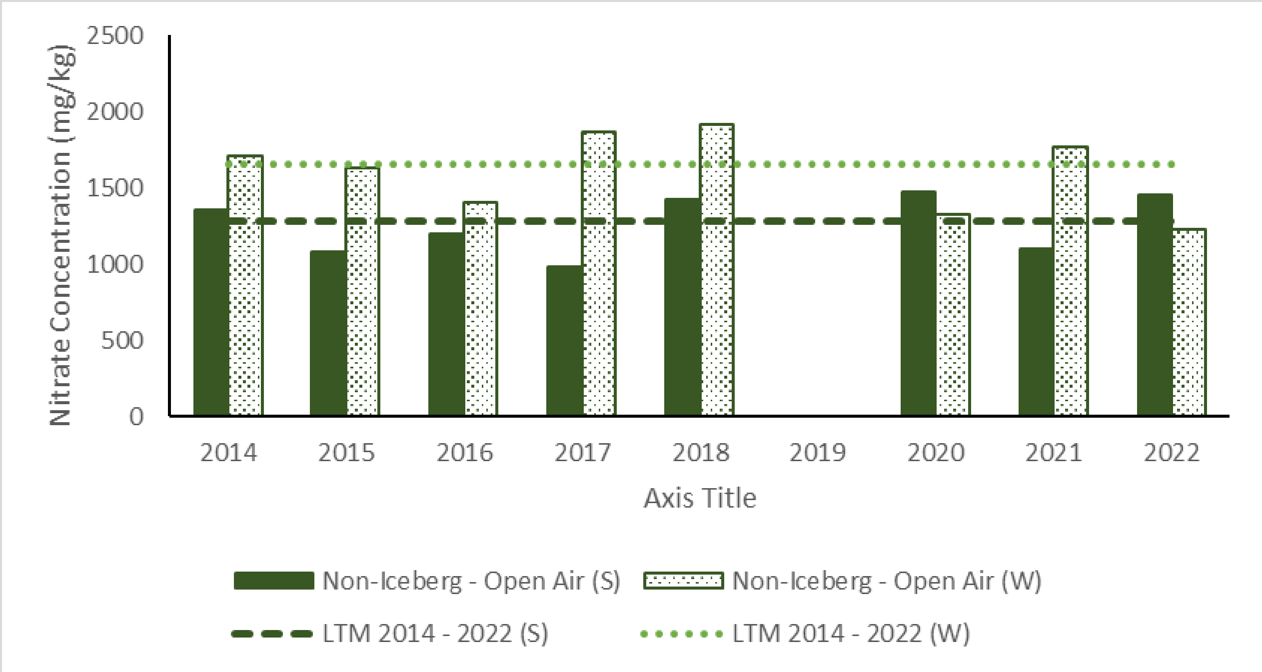

Figure 7. Comparison of annual average nitrate concentrations for outdoor non iceberg-type summer (S) and winter (W) grown lettuce compared with the long-term mean (LTM).

For protected non-iceberg types, both summer and winter samples were marginally below long term means (**Figure 8**). The summer average in 2022 was 2646.1 mg/kg compared with a long term mean of 2758 mg/kg. Winter averages were 3305.7 and 3364.6 mg/kg in 2022 and 2023 respectively compared with a long term mean of 3495 mg/kg. Winter levels have been relatively consistent since 2020, although with a declining trend. Summer levels have readjusted compared with 2021, which were markedly lower than the long term average, and in 2022 were only marginally below the long term summer average.

However, given that winter levels have also declined, this reduction may be a result of more consistent growing (protected) environments in the winter months leading to increased control of nutrient uptake and management.

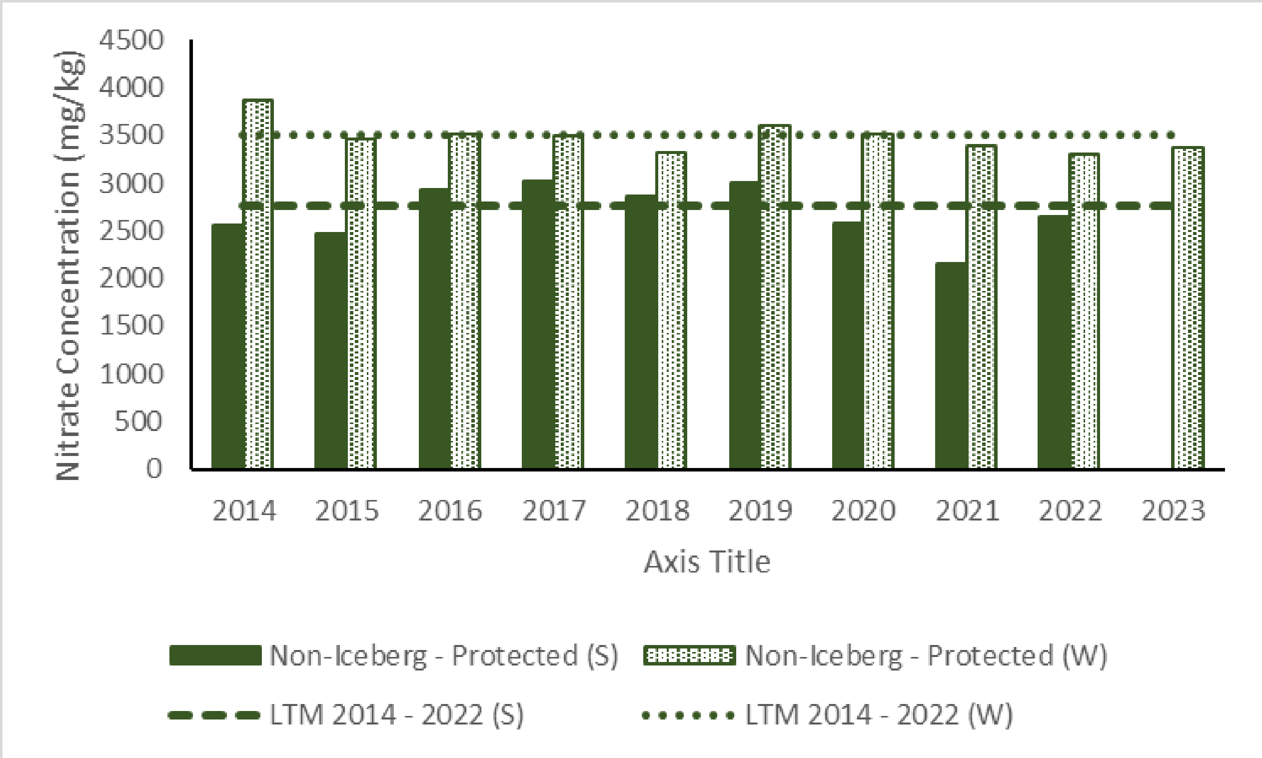

Figure 8. Comparison of annual average nitrate concentrations for protected non iceberg-type summer (S) and winter (W) grown lettuce compared with the long-term mean (LTM).

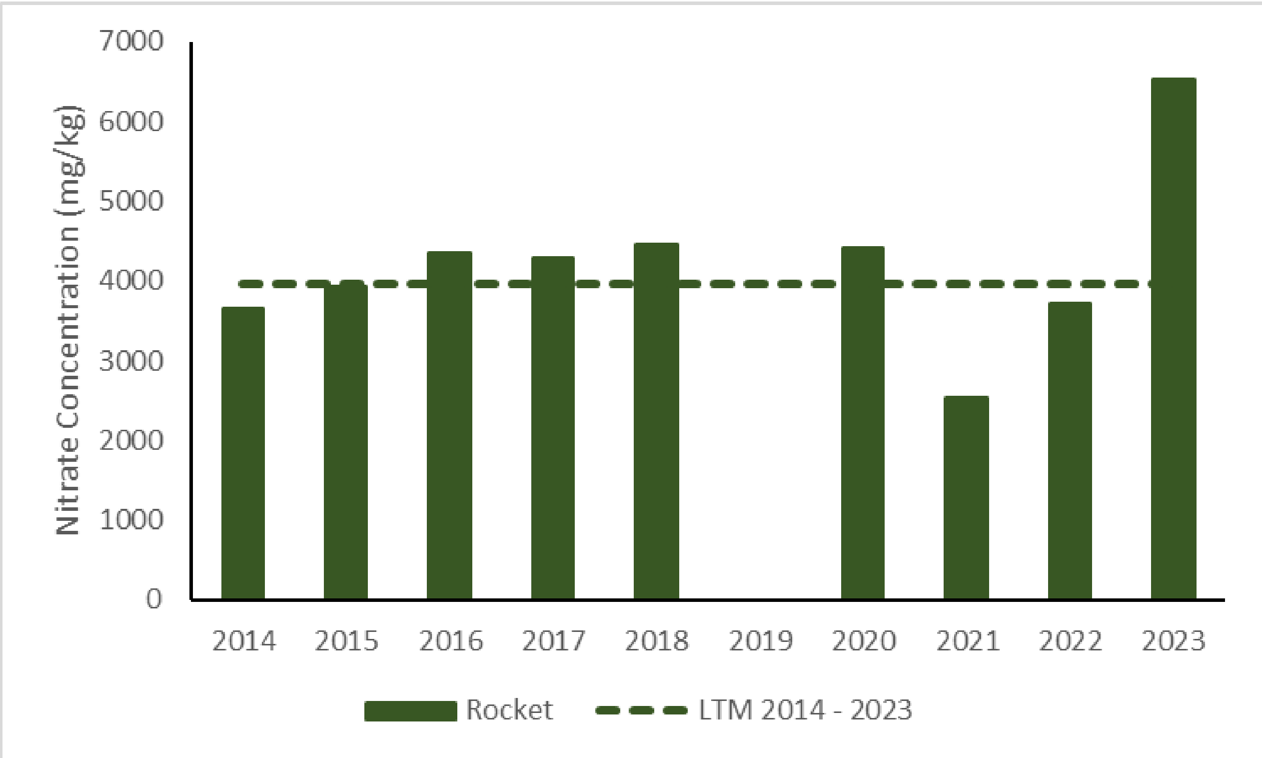

Figure 9. Comparison of annual average nitrate concentrations for rocket compared with the long-term mean (LTM).

Average nitrate concentration in rocket was marginally lower than the long term mean in 2022 (3715.6 vs. 3969 mg/kg, **Figure 9**), and higher than average in 2023 (6524.5 vs 3969 mg/kg). Average nitrate level in spinach samples collected in 2023 were greater than the long term mean (3707.6 vs. 1761 mg/kg, **Figure 10**). However, it should be noted that for both rocket and spinach the 2023 average was based on a small number of samples collected before the end of March 2023. This average will be adjusted in the June 2024 report, at which time samples for the whole of 2023 will be incorporated into the data.

Long term means for other leafy green vegetables are not presented given variable sample group composition between years.

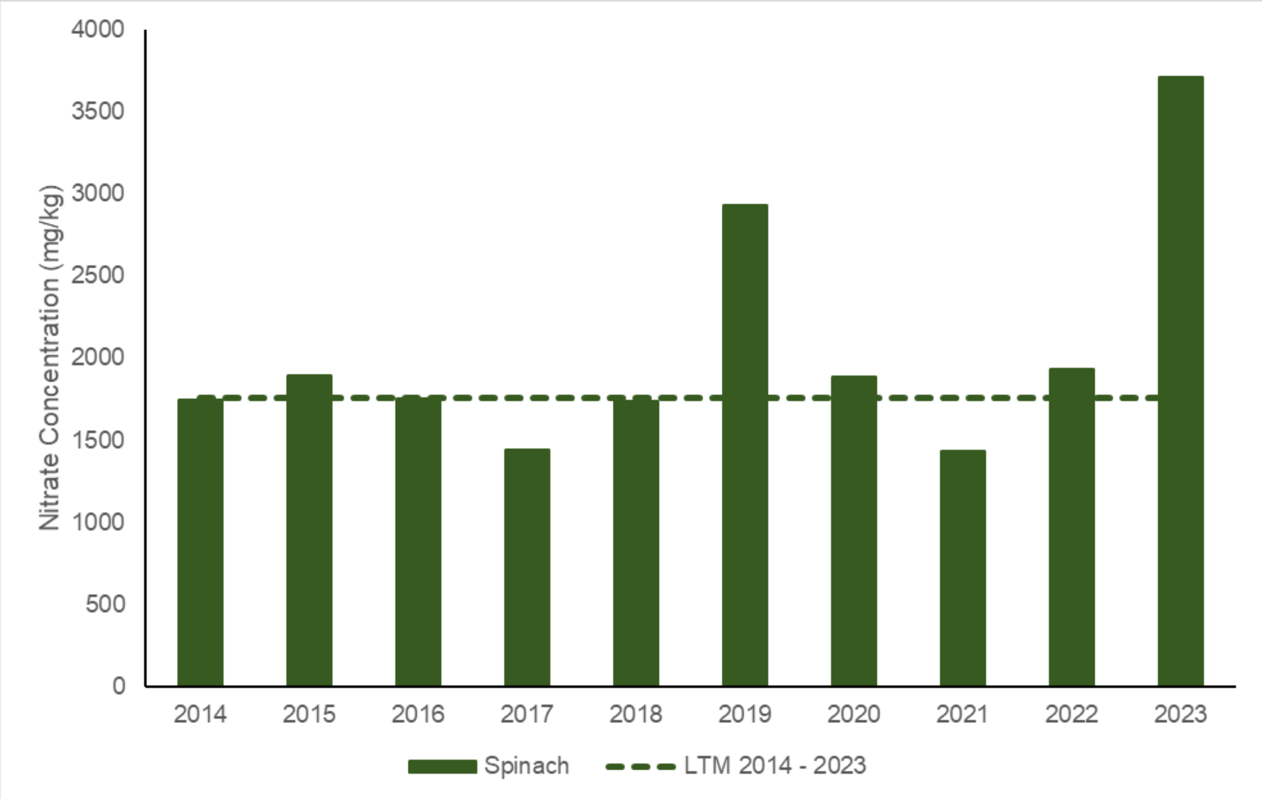

Figure 10. Comparison of annual average nitrate concentrations for spinach compared with the long-term mean (LTM).

Samples Exceeding Regulation Limits

Six out of 217 samples (2.8%) collected in 2022 (January – December) exceeded the maximum level (NB. this value spans two report periods). The six exceedances were represented by one open air iceberg sample, two open air non-iceberg samples (summer), two rocket samples (summer) and one spinach sample. A further 17 samples were within 10% of the maximum level in this period.

This figure is lower than 2020 (3.2%) and corresponds with the long term trend of a decline in the proportions of samples exceeding maximum levels(**Figure 11**). Average percentages between 2002 – 2011 were 8.3% compared with 3.4% between 2012 – 2022.

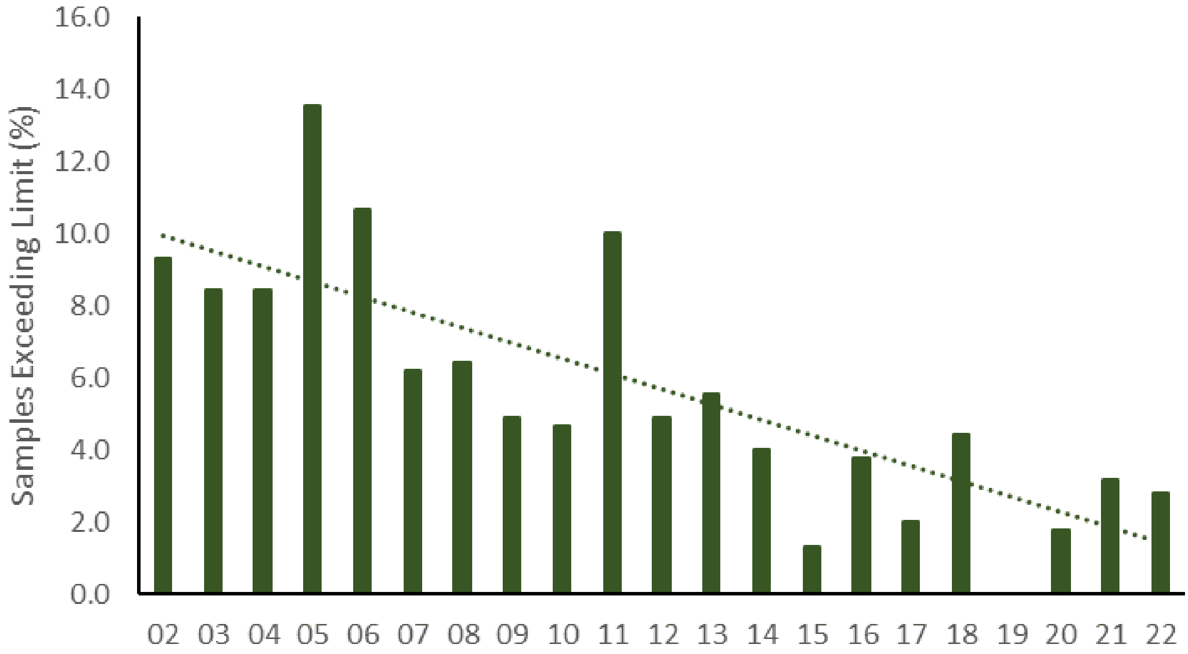

Figure 11. Annual percentages of UK samples collected between 2002 – 2022 which exceeded the maximum level. Samples collected between Jan – March 2023 are not included. NB. Data for 2019 is not available.

When considered on a per-category basis, until 2022 there had been no samples of open-air iceberg lettuce exceeding maximum levels since 2014 (**Figure 12**). A small but consistent proportion of open-air non-iceberg type lettuce (summer) has exceeded maximum levels since 2020, and increased from no samples in 2015-2017 (**Figure 13**). The proportion of protected non-iceberg type samples exceeding the maximum levels in winter samples has remained at 0% since 2015. However, there have been relatively consistent exceedances in summer-sampled non-iceberg samples since 2014, with the greatest exceedances in 2021 (11% of samples) since 2014; this figure has since declined to 8.3% in 2022 (**Figure 14**). There had been no exceedances in rocket since 2018 (**Figure 15**), until 2022 (10.5%). Exceedance in spinach in 2022 had increased markedly compared with 2021 (increased from 3.8% to 12.5%, **Figure 16**).

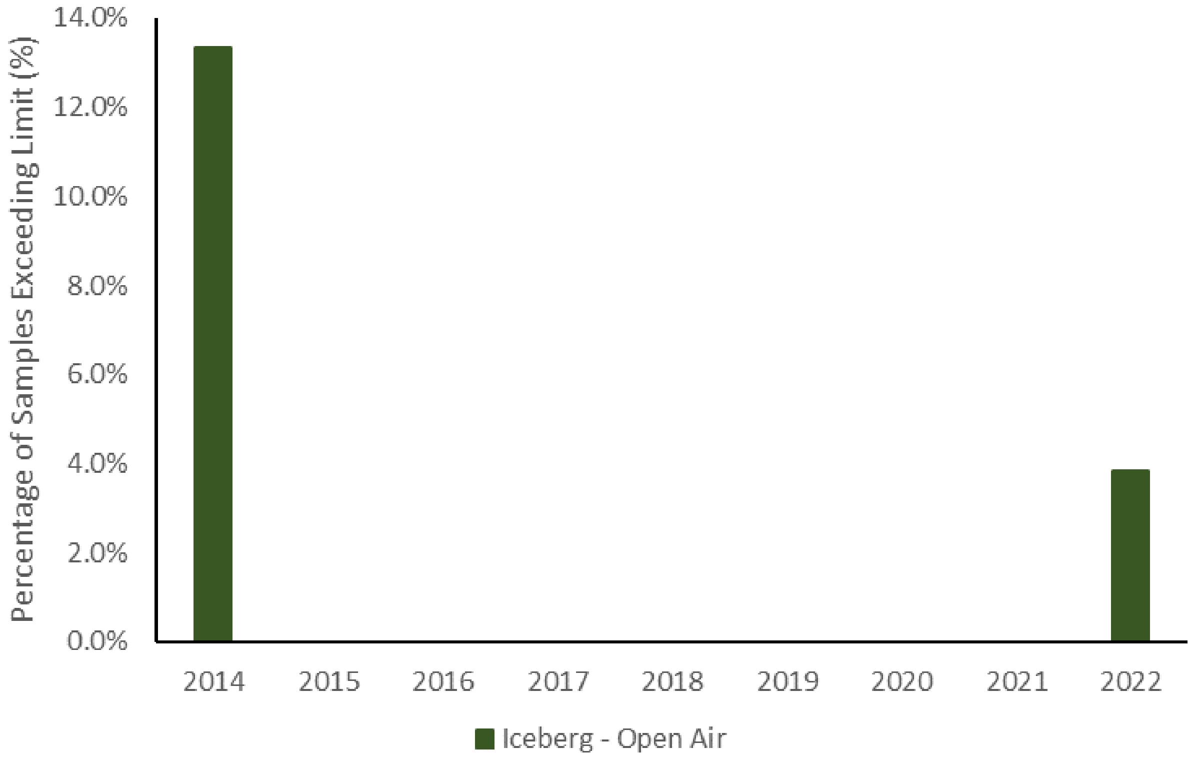

Figure 12. Proportion of open air iceberg lettuce exceeding maximum levels since 2014.

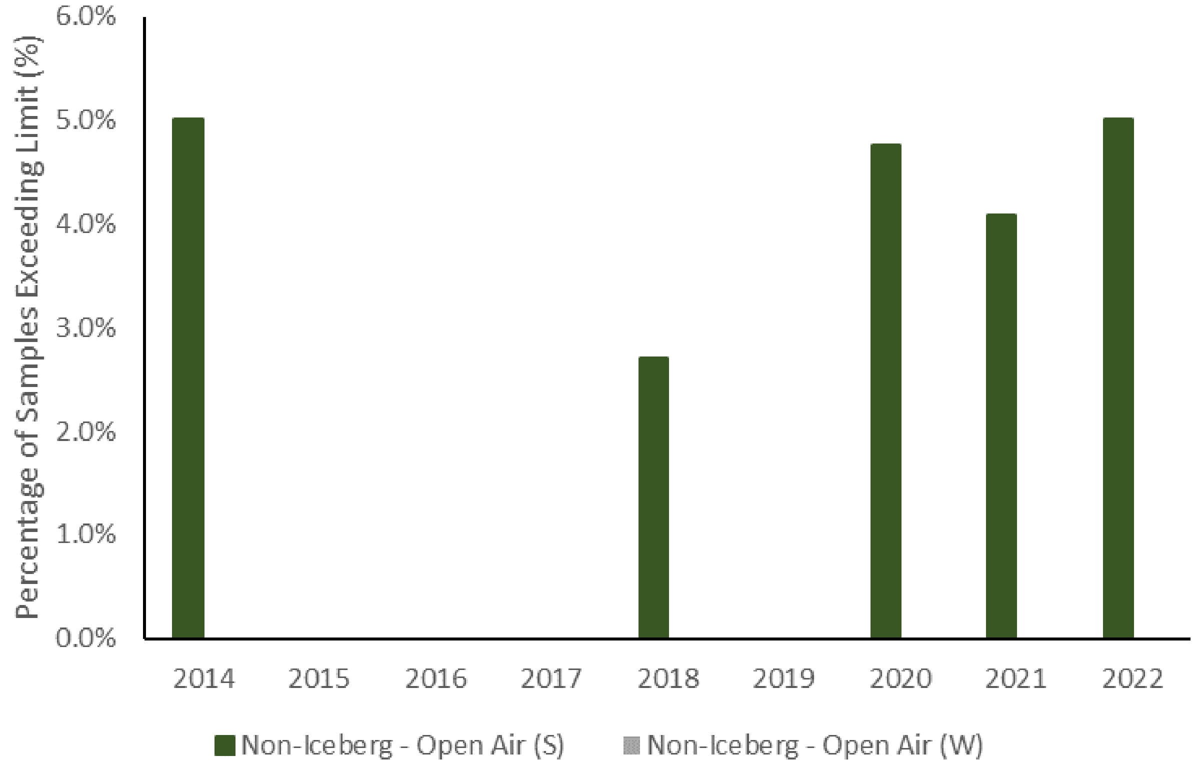

Figure 13. Proportion of open air non-iceberg lettuce exceeding maximum levels since 2014.

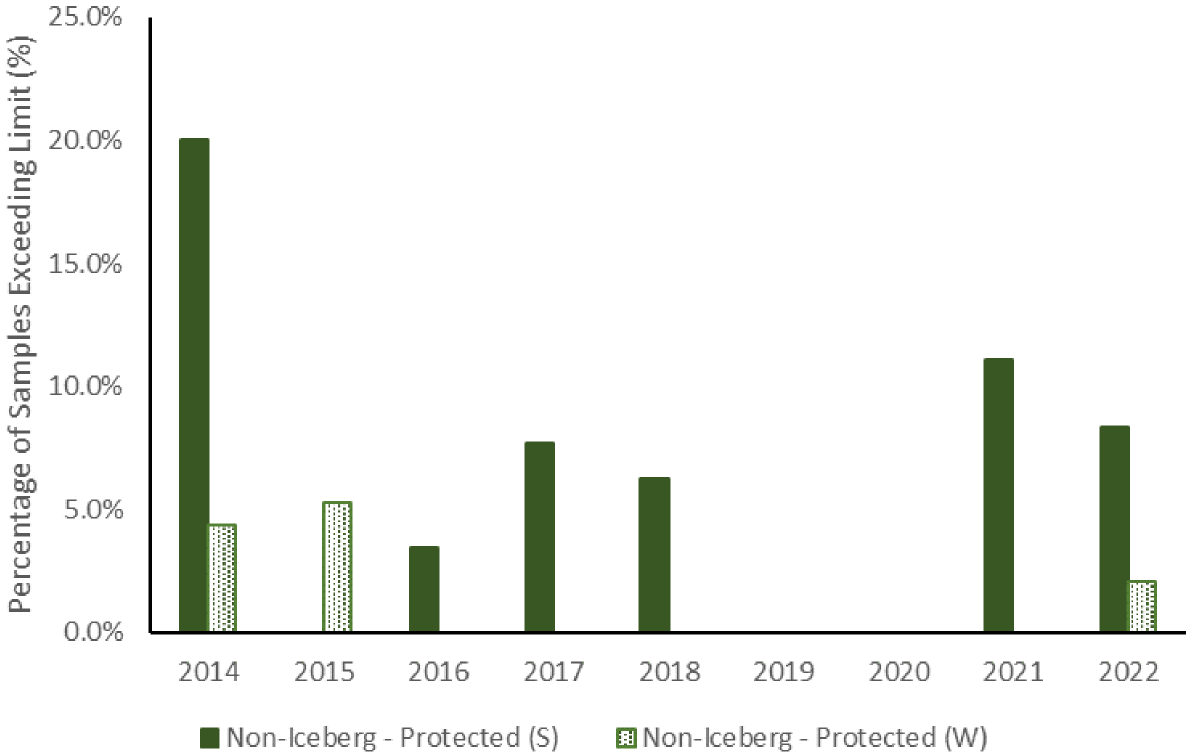

Figure 14. Proportion of protected non-iceberg lettuce exceeding maximum levels since 2014.

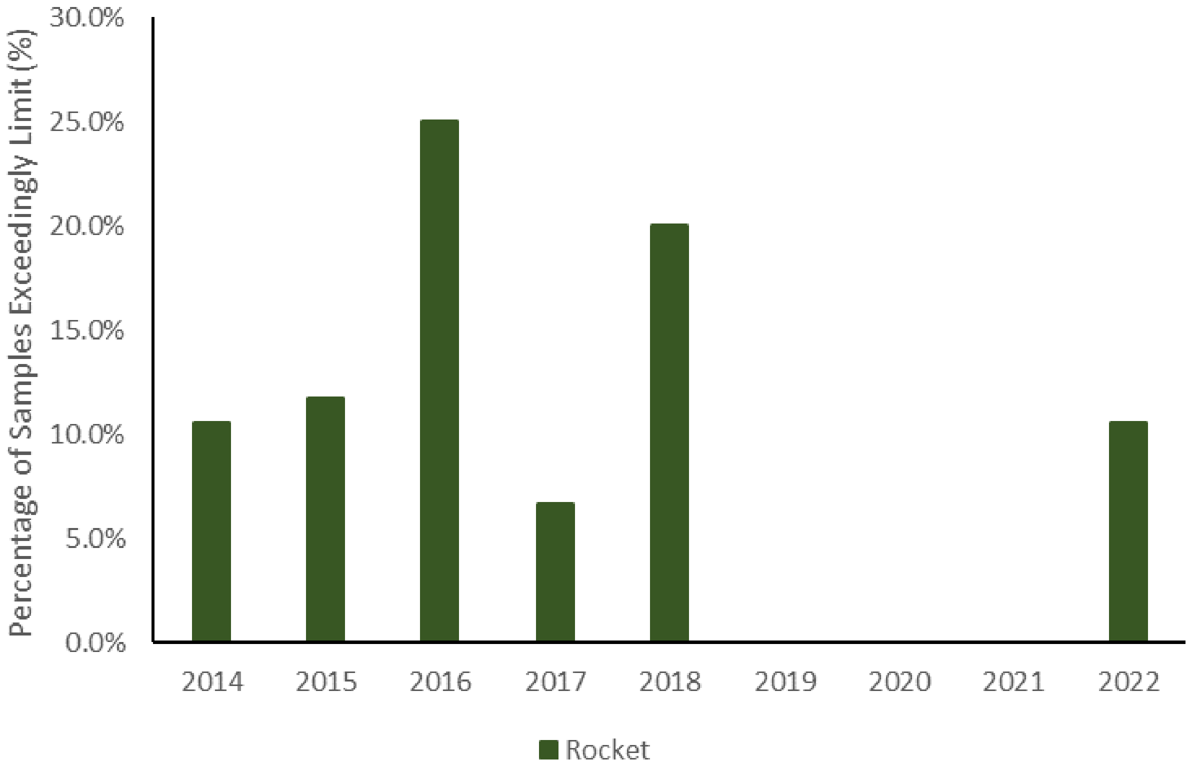

Figure 15. Proportion of rocket exceeding maximum levels since 2014.

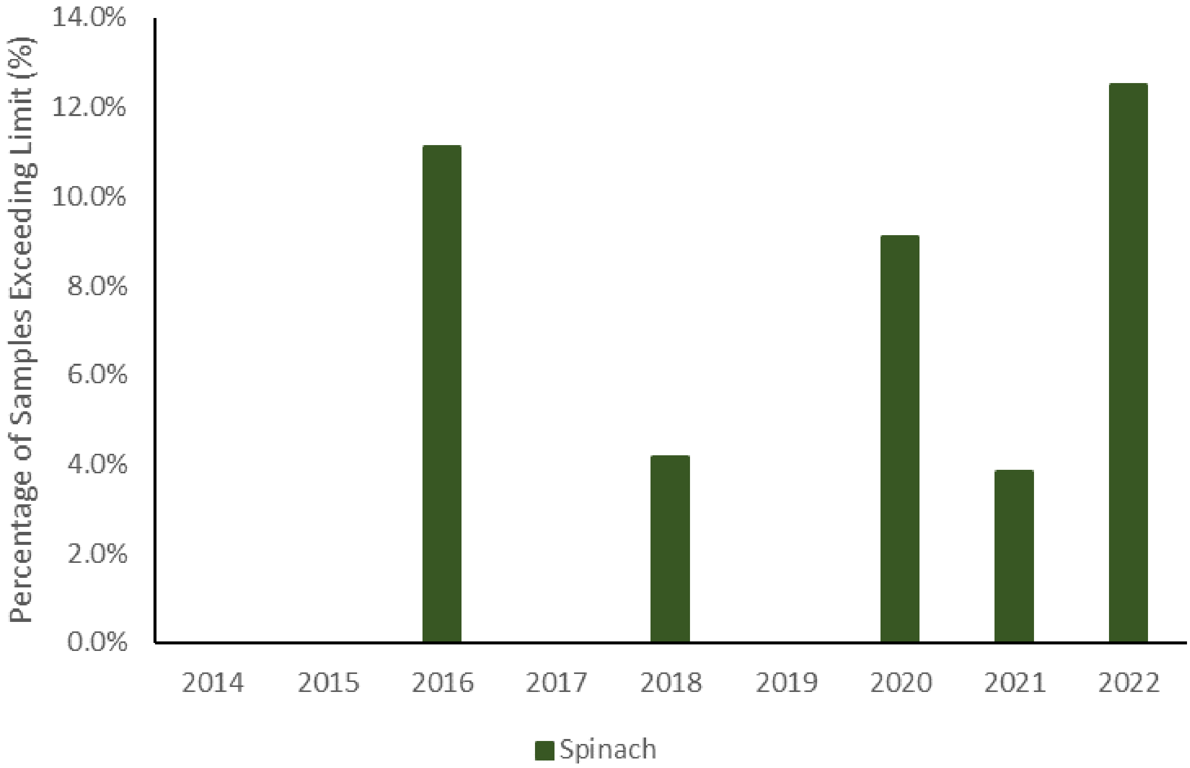

Figure 16. Proportion of spinach exceeding maximum levels since 2014.

Discussion

Evaluation of 2022 Results

The samples collected in the 2022/23 period continue to follow trends illustrated in previous years. Notably, nitrate levels remain low in leafy salad products, with the proportion of samples exceeding the corresponding maximum level remaining below 5% since 2014. The proportion of samples exceeding maximum levels has varied between crop types since 2014: open air iceberg was at 0% for every year until 2022, while nitrate levels in rocket tend to be the highest, but were at 0% from 2019 until 2022. In general, nitrate levels in non-iceberg types and spinach are marginally higher than iceberg, and protected non-iceberg types generally show higher concentrations compared with open air iceberg and open air non-iceberg types. These results continue to show trends which indicate that risk factors for elevated nitrate concentrations are associated with variety, season and production method.

The dry spring of 2022 impacted establishment of brassicas, and the hot summer temperatures and drought impacted production and yield, particularly in non-irrigated crops. There were also reports, though, of early sowings of baby leaf salad affected by the hot summer despite supplementary irrigation. Later sowings fared better with milder conditions leading to some higher yields. Lettuce and other outdoor salad crops were similarly affected, leading to high planting losses. In some areas growers had difficulty irrigating crops towards the end of the summer and into the early autumn, with a combination of low reservoir levels and having to move water to the neediest crops where possible.

Previous reports have commented on the seasonal fluctuations in nitrate accumulation evident in the data collected, and research correlating low light levels in the mid-term before harvest, specifically 5 and 7-10 days before harvest with nitrate accumulation (**Burns, 2000; Weightman *et al.*, 2006**). Generally only the most valuable protected lettuce / leafy green salad crops are lit during the winter, but more are heated, if only to provide frost protection. Broad information on weather conditions – temperature, rainfall and hours of sunshine – has been introduced into the report this year (**Appendix 5**) - using open access data published by the Met Office. This does make it possible to compare conditions year on year, enabling high level commentary, but it doesn't allow for more detailed exploration of interactions between nitrate concentration, lettuce type, planting date, crop husbandry, agricultural practices, fertiliser input, edaphic factors and environmental factors including climate change scenarios.

Future Perspectives

Nitrate levels in leafy salads are likely to fluctuate from year to year because of the influence of prevailing environmental conditions and cultural management of the crop. The data in this report indicate that nitrate levels in both rocket and ‘other leafy greens’, the latter reaching 7,000 – 8,000 mg/kg in some instances (**Figure 3**), are consistently higher than both iceberg and non-iceberg type lettuce, and spinach. Planted areas of iceberg and non-iceberg type lettuce (protected and outdoor) and baby leaf salad have declined in recent years (**Defra, 2023**), but statistics for non-standard leafy green salad types are not reported individually. Consumption of mixed bagged salads continues to be popular, and one of the advantages of these lines is that growers may substitute different species of leafy greens subject to availability, and these are likely to accumulate different levels of nitrates. As previously considered, the variable composition of mixed bagged salad may mean that there could be more exceedances in the future, particularly if new crops are introduced into the mix. It would be useful to be able to obtain more detailed weather data and analyse this alongside sampling results.

Other factors previously reported continue to impact on horticulture production, including high fertiliser and energy prices, and although both have seen a reduction in recent months they remain a concern to growers. In a move to reduce their carbon footprint, growers are looking to low carbon fertilisers as well as reducing their energy consumption where they can without impacting crop quality, but which will affect the physiological balance, potentially including nitrate accumulation.

References

Burns, I. (2000). Development of a decision support system for nitrogen fertiliser application in glasshouse lettuce (LINK). Final LINK project report to HDC. Copyright, Horticulture Research International, Wellesbourne, Warwick, CV35 9EF.

Defra (2023) Horticulture statistics – 2022. Retrieved 07/06/2023 from:.

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Weightman, R. M., Dyer, C., Buxton, J. and Farrington, D. S. (2006). Effects of light level, time of harvest and position within field on variability of tissue nitrate concentration in commercial crops of lettuce (*Lactuca sativa*) and endive (*Cichorium endiva*). Food Additives and Contaminants, 23 (5); 462-469.

Appendix

Appendix 1. Summary Sample Figures by Month

Apr-22			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	4000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	5	2474.6	3921.4	3420.8	0	5	2474.6	3921.4	3420.8	0
	Lettuce grown in the open air	3000	0	-	-	-	0	0	-	-	-	0
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	0				0	0				0
Spinach	*Fresh*	3500	2	143.4	2390.6	1267.0	0	2	143.4	2390.6	1267.0	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September	6000	0	-	-	-	0	0	-	-	-	0
Other leafy green veg		n/a	2	2165.2	2617.2	2391.2	0	2	2165.2	2617.2	2391.2	0
		Total	**9**				**0**	**9**				**0**

May-22			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	4000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	1	617	617	617	0	6	617	3921.4	2922.0	0
	Lettuce grown in the open air	3000	8	589	2694.3	1545.6	0	8	589	2694.3	1545.6	0
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	2	633.3	649.9	641.6	0	2	633.3	649.9	641.6	0
Spinach	*Fresh*	3500	2	629.5	1030.9	830.2	0	4	143.4	2390.6	1048.6	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September	6000	3	1647.2	2709.7	2281.1	0	3	1647.2	2709.7	2281.1	0
Other leafy green veg		n/a	1	434.5	434.5	434.5	0	3	434.4	2617.2	1739.0	0
		Total	**17**				**0**	**26**				**0**

Jun-22			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	4000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	1	1202.6	1202.6	1202.6	0	7	617.0	3921.4	2676.4	0
	Lettuce grown in the open air	3000	4	451.9	1702.8	890.7	0	12	451.9	2694.3	1327.3	0
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	6	451.8	1817.6	1095.2	0	8	451.8	1817.6	981.8	0
Spinach	*Fresh*	3500	2	463.8	2127.0	1295.4	0	6	143.4	2390.6	1130.9	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September	6000	3	534.4	5326.3	2394.8	0	6	534.4	5326.3	2338.0	0
Other leafy green veg		n/a	3	384.7	2054.6	1305.2	0	6	384.7	2617.2	1522.1	0
		Total	**19**				**0**	**45**				**0**

Jul-22			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	4000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	1	1228.7	1228.7	1228.7	0	8	617.0	3921.4	2495.4	0
	Lettuce grown in the open air	3000	8	369.6	2442.3	1274.0	0	20	369.6	2694.3	1306.0	0
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	7	751.2	2082.7	1161.6	1	15	451.8	2082.7	1065.7	1
Spinach	*Fresh*	3500	2	675.3	1202.1	1038.7	0	8	143.4	2390.6	1107.8	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September	6000	2	2561.5	6077.3	4319.4	1	8	534.4	6077.3	2833.3	1
Other leafy green veg		n/a	6	<50	7701.3	2763.9	0	12	<50	7701.3	2143.0	0
		Total	**26**				**2**	**71**				**2**

August 2022			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	4000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	3	2700.0	3454.2	2974.5	0	11	617.0	3921.4	2626.1	0
	Lettuce grown in the open air	3000	14	428.2	4273.9	1571.9	1	34	369.6	4273.9	1415.1	1
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	3	736.1	979.3	851.6	0	18	451.8	2082.7	1030.0	1
Spinach	*Fresh*	3500	5	295	2438.9	1489.5	0	13	143.4	2438.9	1254.6	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September	6000	4	3763.6	7235.7	5155.7	1	12	534.4	7235.7	3607.5	2
Other leafy green veg		n/a	5	490.1	4118.4	1718.3	0	17	<50	7701.3	2018.1	0
		Total	**34**				**2**	**105**				**4**

Sep-22			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	4000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	1	1791.5	1791.5	1791.5	0	12	617.0	3921.4	2556.5	0
	Lettuce grown in the open air	3000	7	1161.5	3562.4	1666.7	1	41	369.6	4273.9	1458.1	2
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	7	591.9	1418.8	1122.6	0	25	451.8	2082.7	1055.9	1
Spinach	*Fresh*	3500	2	<50	871.1	460.6	0	15	<50	2438.9	1148.7	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	0	-	-	-	0
	Harvested 01 April - 30 September	6000	2	1803.8	3583.6	2693.7	0	14	534.4	7235.7	3476.9	2
Other leafy green veg		n/a	4	357.7	2227.4	1154.7	0	21	<50	7701.3	1853.6	0
		Total	**23**				**1**	**128**				**5**

Oct-22			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	1	2873.9	2873.9	2873.9	0	1	2873.9	2873.9	2873.9	0
	Lettuce grown in the open air	4000	3	915.1	1249.3	1042.8	0	3	915.1	1249.3	1042.8	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	0	-	-	-	0	12	617	3921.4	2556.5	0
	Lettuce grown in the open air	3000	0	-	-	-	0	41	369.6	4273.9	1458.1	2
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	1	773.4	773.4	773.4	0	26	451.8	2082.7	1045.1	1
Spinach	*Fresh*	3500	3	2122.2	3263	2768.5	0	18	<50	3263.0	1418.7	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	2	3849.6	4501.3	4175.5	0	2	3849.6	4501.3	4175.5	0
	Harvested 01 April - 30 September	6000	0	-	-	-	0	14	534.4	7235.7	3476.9	2
Other leafy green veg		n/a	5	260.2	5114.4	3142.0	0	26	<50	7701.3	2101.4	0
		Total	**15**				**0**	**143**				**5**

Nov-22			**Sampling month**					**RUNNING TOTAL**				
UK grown samples		**Max. permitted ($mg\ NO_3/kg$)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	6	1583.4	4207.4	3449.4	0	7	1583.4	4207.4	3367.2	0
	Lettuce grown in the open air	4000	1	1785.6	1785.6	1785.6	0	4	915.1	1785.6	1228.5	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	0	-	-	-	0	12	617	3921.4	2556.5	0
	Lettuce grown in the open air	3000	0	-	-	-	0	41	369.6	4273.9	1458.1	2
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	0	-	-	-	0	26	451.8	2082.7	1045.1	1
Spinach	*Fresh*	3500	1	1656.8	1656.8	1656.8	0	19	<50	3263.0	1431.2	0
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	2	3849.6	4501.3	4175.5	0
	Harvested 01 April - 30 September	6000	0	-	-	-	0	14	534.4	7235.7	3476.9	2
Other leafy green veg		n/a	3	378.1	3335.0	2137.9	0	29	<50	7701.3	2105.2	0
		Total	**11**				**0**	**154**				**5**

Dec-22			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	7	2833.5	4664.8	3800.7	0	14	1583.4	4664.8	3583.9	0
	Lettuce grown in the open air	4000	0	-	-	-	0	4	915.1	1785.6	1228.5	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	0	-	-	-	0	12	617.0	3921.4	2556.5	0
	Lettuce grown in the open air	3000	0	-	-	-	0	41	369.6	4273.9	1458.1	2
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	0	-	-	-	0	26	451.8	2082.7	1045.1	1
Spinach	*Fresh*	3500	1	3781.9	3781.9	3781.9	1	20	<50	3781.9	1548.8	1
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	1	5021.2	5021.2	5021.2	0	3	3849.6	5021.2	4457.4	0
	Harvested 01 April - 30 September	6000	0	-	-	-	0	14	534.4	7235.7	3476.9	2
Other leafy green veg		n/a	4	621.8	5985.7	3660.8	0	33	<50	7701.3	2293.7	0
		Total	**13**				**1**	**167**				**6**

Jan-23			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	6	3264.7	4339.4	3842.3	0	20	1583.4	4664.8	3661.4	0
	Lettuce grown in the open air	4000	0	-	-	-	0	4	915.1	1785.6	1228.5	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	0	-	-	-	0	12	617	3921.4	2556.5	0
	Lettuce grown in the open air	3000	0	-	-	-	0	41	369.6	4273.9	1458.1	2
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	0	-	-	-	0	26	451.8	2082.7	1045.1	1
Spinach	*Fresh*	3500	0	-	-	-	0	20	<50	3781.9	1548.8	1
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	3	3849.6	5021.2	4457.4	0
	Harvested 01 April - 30 September	6000	0	-	-	-	0	14	534.4	7235.7	3476.9	2
Other leafy green veg		n/a	2	7142	7171	7156.5	0	35	<50	7701.3	2571.6	0
		Total	**8**				**0**	**175**				**6**

Feb-23			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted (mg NO_3/kg)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	5	3211.8	3987.2	3538.7	0	25	1583.4	4664.8	3636.9	0
	Lettuce grown in the open air	4000	0	-	-	-	0	4	915.1	1785.6	1228.5	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	0	-	-	-	0	12	617	3921.4	2556.5	0
	Lettuce grown in the open air	3000	0	-	-	-	0	41	369.6	4273.9	1458.1	2
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	0	-	-	-	0	26	451.8	2082.7	1045.1	1
Spinach	*Fresh*	3500	0	-	-	-	0	20	<50	3781.9	1548.8	1
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	0	-	-	-	0	3	3849.6	5021.2	4457.4	0
	Harvested 01 April - 30 September	6000	0	-	-	-	0	14	534.4	7235.7	3476.9	2
Other leafy green veg		n/a	2	6331.5	6474.5	6403.2	0	37	<50	7701.3	2778.7	0
		Total	**7**				**0**	**182**				**6**

Mar-23			Sampling month					RUNNING TOTAL				
UK grown samples		**Max. permitted ($mg\ NO_3/kg$)**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**	**No. samples**	**Min. NO_3/kg**	**Max. NO_3/kg**	**Mean NO_3/kg**	**No. samples exceeding max.**
Lettuce non-iceberg type	*Harvested 01 October - 31 March*											
	Lettuce grown under cover	5000	12	1844.7	3754.3	3053.2	0	37	1583.4	4664.8	3447.6	0
	Lettuce grown in the open air	4000	0	-	-	-	0	4	915.1	1785.6	1228.5	0
	Harvested 01 April - 30 September											
	Lettuce grown under cover	4000	0	-	-	-	0	12	617	3921.4	2556.5	0
	Lettuce grown in the open air	3000	0	-	-	-	0	41	369.6	4273.9	1458.1	2
Iceberg type lettuce	Lettuce grown under cover	2500	0	-	-	-	0	0	-	-	-	0
	Lettuce grown in the open air	2000	0	-	-	-	0	26	451.8	2082.7	1045.1	1
Spinach	*Fresh*	3500	1	3707.6	3707.6	3707.6	1	21	<50	3781.9	1651.6	2
	Preserved, deep frozen or frozen spinach	2000	0	-	-	-	0	0	-	-	-	0
Rocket	*Harvested 01 October - 31 March*	7000	1	6524.5	6524.5	6524.5	0	4	-	-	-	0
	Harvested 01 April - 30 September	6000	0	-	-	-	0	14	534.4	7235.7	3476.9	2
Other leafy green veg		n/a	4	2418.6	4217.4	3289.5	0	41	<50	7701.3	2828.5	0
		Total	**18**				**1**	**200**				**7**

Appendix 2. Standard Operating Procedure for collecting samples

Field sampling and transportation of lettuce and spinach samples for the UK Nitrate Monitoring Programme.

Introduction

EC Regulation No. 1881/2006 requires Member States to monitor nitrate levels in lettuce and spinach. This document specifies the procedure to be followed for taking and transporting samples of lettuce and spinach to the laboratory in connection with the UK Monitoring Programme for nitrate.

Principle: Representative sampling of lettuce, or spinach, from the field in accordance with EU retained law Regulation (EC) 1882/2006. Transfer to suitable containers and transport to the laboratory under appropriate conditions. Complete and despatch the sample pro-forma to the laboratory.

Reference documents

EU retained law Regulation (EC) 1882/2006/ of 20 Dec 2006 establishing Community methods of sampling for the official control of nitrate in lettuce. Official Journal of the European Communities. No. L364/25.

Materials and equipment

- Vegetable knife.
- Suitable insulated box for sample transportation.
- Ice packs. Sampling record pro-forma.

Procedures

1. Sampling and data logging

As far as possible samples should be taken at various places distributed throughout the lot. Avoid taking samples that are extensively spoiled. Also avoid taking samples from areas which appear to be unrepresentative of the field, and avoid taking samples from the extreme edges of the field

Take samples from a pattern similar to that on a "5-spot" die, or by walking a "W" pattern across the field, collecting a minimum of 10 heads of lettuce (or 10 spinach samples) to give a combined total minimum weight of 1 kg. Plants must be cut at ground level. Trim off outer leaves to ensure the lettuce plant resembles a marketable product. Samples must not be cut or broken to produce the laboratory samples.

Complete the "Sampling Record - UK Produce" pro-forma (Annex 1) and transfer this to a plastic bag to prevent damage in transit.

2. Transportation to the laboratory.

Place each set of (minimum) 10 vegetables in a clean, inert container offering adequate protection from contamination and damage in transit. Ensure that suitable ice packs are included with the sample to ensure that the sample temperature is maintained below 10 ^{0}C during transportation to the laboratory. Include the completed pro-forma. Arrange despatch to the laboratory without delay.

Transportation should ensure that samples arrive at the laboratory before 10.30am on the day after harvest.

Appendix 3. Mean temperature, rainfall and sunshine

Data extracted from Met Office (2023).

Mean temperature (°C)

Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
2014	5.4	6	7.4	9.9	12.1	15	17.5	15	14.8	12.2	8.3	5
2015	4.3	3.9	6.2	8.9	10.7	13.9	15.8	15.9	12.5	10.7	9.2	9.4
2016	5.2	4.7	5.6	7.3	12.1	14.8	16.6	16.8	15.8	10.6	5.6	5.9
2017	3.7	5.9	8.4	8.8	12.9	15.9	16.5	15.6	13.4	12.1	6.6	4.6
2018	5.1	2.6	4.6	9.5	12.9	15.8	18.8	16.7	13.6	10.5	7.9	6.5
2019	3.8	6.5	7.7	8.8	11	14.2	17.5	17	14.1	10	6.1	5.6
2020	6.2	6.2	6.4	10.2	12.4	15	15.7	17.4	13.9	10.3	8.4	4.8
2021	2.9	4.8	7	6.2	9.9	15.3	17.5	15.8	15.8	11.8	7.3	6.1
2022	4.6	6.5	7.5	8.8	12.8	14.8	18.1	18.3	14.3	12.7	8.9	3.5

Mean rainfall (mm)

Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
2014	160	123.4	49.1	53.1	95.7	46.3	51.6	107.4	15	102.8	104.4	74.6
2015	91.5	52.5	48.4	25.8	79.6	35.3	79.2	92.3	50.9	60.3	117.5	133.6
2016	124.2	72.5	78.3	62.4	51.3	95.4	39.8	64.3	62.5	36.4	100.2	35.6
2017	62.8	61.8	69.9	17.6	57.2	82.1	90.8	72.4	91.3	53.9	67.5	98.1
2018	90.4	48.7	103.1	78.3	45	14.6	36	66.4	59.4	64.8	89.7	98.9
2019	37.7	47.7	88.1	35.3	42.3	107.3	70.5	83.7	113.6	127.9	119.6	105.5
2020	74.2	160.9	50.7	28.8	9.6	91.2	66.2	114.7	47.8	144.3	64.2	137.1
2021	128.4	75.4	50.4	11	113.9	49.7	80	48.3	59.9	129.1	39.9	91.2
2022	32.2	99.8	43.2	25	52.3	46.1	23.6	35.9	78.6	107.3	143	91.3

Duration of bright sunshine (hrs)

Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
2014	54.8	87.2	140.8	146.1	173	203.1	245	188.2	131.9	92.8	54.3	72.5
2015	69.3	82.8	127.9	220.6	182.4	221.4	186.2	156.5	168.8	91.6	36.8	35
2016	47.3	93.4	123.1	168.7	208.3	129.9	190.4	209.9	135.4	111.1	81.1	52.3
2017	61.8	54.3	123.4	181.6	198.3	188.3	181.7	177.9	118.5	84.6	83.3	55.1
2018	55.7	101.6	79.6	123.5	254.1	242.1	269.3	169.4	154	130.4	68.1	43.9
2019	56.8	120.1	128.2	180.4	202.1	164.4	201.1	205.1	164.3	86.6	48.7	57.6
2020	56	79.3	156.5	236.7	299.4	181.9	166	160.8	165.4	68.1	60.7	45.5
2021	41.9	74.4	112.5	228.4	167.2	193.6	200.7	131.4	140.8	95.5	70.6	29.9
2022	82.5	85	169.3	187.6	171.6	222.2	216.3	238	127	129.8	58.1	59.7

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