Project title: Developing Nutrient Management Recommendations for Selected Horticulture Crops.

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DISCLAIMER

[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

- Under low soil mineral N (SNS Index 0) or modest (SNS Index 2 / 3) and Magnesium (Mg) (Index 1 / Index 2) indices, growth of *Betula pendula, Carpinus betulus* and *Crataegus monogyna* transplants and seedlings was not increased by additional fertiliser nitrogen (N).
- No difference in mean plant height was obtained when *Betula pendula, Carpinus betulus* and *Crataegus monogyna* were fertilised with standard or slow-release N fertilisers.
- Carbon reductions through reducing N fertiliser usage will help growers to meet net zero. Calculations have shown that reducing or eliminating the use of fertiliser containing 27% N can save between 240 – 270 kg CO_2e / ha (1 – 3 applications respectively).

Background

Field HNS growers typically apply single nutrients known as straights (e.g., ammonium nitrate) or compound fertilisers (containing mixes of nitrogen (N), phosphorus (P) and potassium (K) fertilisers or N and sulphur (S)), with limited use of slow / controlled release fertilisers in some crops. Some nurseries carry out regular soil analysis to find out what levels of P, K, and magnesium (Mg) are present in the soil to help determine the correct rate of fertiliser to apply. Soil sampling for soil mineral nitrogen (SMN) is less common than sampling for P, K & Mg however there has been increased interest in this approach following the rapid increase in fertiliser N prices in 2022. In the past, some nurseries have not historically carried out regular soil analysis and have instead applied the same rates of fertiliser every year, regardless of soil nutrient indices / crop need. Some of those that do carry out regular soil analysis sometimes struggle to interpret the results The situation is complicated by the fact that there are no readily accessible standard fertiliser recommendations for field, soil-grown HNS species for UK growers. The most recent recommendations were published in 1988 in the 5th Edition of RB209 (**MAFF, 1988**) Soil testing for P, K, Mg, and pH is now a legal requirement in England under the Farming Rules for Water (FRfW).

Because of the high value of field grown HNS in relation to the price of fertiliser (despite recent high N prices), the cost of the fertiliser and its application is not always considered. Many growers use historic application rates of fertiliser rather than analysis-based application rates, which can result in excessive use of nutrients. However, there is the potential for savings to be made which can contribute to improved profitability (refer to financial benefits).

Growers must also comply with legislation such as limits on the amount of N (a total N limit of 250 kg/ha) contained in organic materials such as manure or green compost that can be applied in Nitrate Vulnerable Zones (NVZs) to prevent the pollution of water. There are no N-max limits for manufactured nitrogen fertiliser applied to HNS in the NVZ rules. In England 55% of land is in a designated NVZ. Fertiliser production and use directly contributes to greenhouse gas emissions and hence climate change so efficient use of N fertilisers is vitally important for the horticulture sector transition to net zero. High levels of P should be avoided (above Index 3) as surface run off (particularly where soil erosion is a problem) can transport phosphates into water courses.

Maintaining an unnecessarily high P Index is considered bad practice as it increases the risk of P loss to water and further legislation such as the implementation of phosphate vulnerable zones. There are not currently any phosphate vulnerable zones in the UK, but in Northern Ireland phosphate regulations have been part of their nutrient action programme since January 2020, with restrictions on the maximum phosphate fertiliser applications allowed in certain situations.

A better understanding of the nutritional needs of field grown HNS species, and the optimum type of fertiliser for HNS could help to optimise crop nutrition. For example, fertilisers containing muriate of potash (potassium chloride) can scorch the foliage and result in slow establishment of some chloride-sensitive genera; potassium sulphate is a more suitable K source for ornamental crops (**Lindberg and Cregg, 2022**). The potash in muriate of potash (MOP) is fully available to plants. High rates of application should be avoided at crop establishment, particularly when placed next to the seed, as this can inhibit germination or damage the seedling. MOP is suitable for all arable crops and grassland. The chloride content can be a disadvantage in certain specialist horticultural crops. Sulphate of potash (SOP) is generally regarded as a relatively high-cost source of potash for application to soil in agriculture but is a very important source of this nutrient in horticulture, as it is suitable in situations where both potash and sulphur are required or where chloride is a concern. (The fertiliser directory materials guide)

Aim of the trial: To determine the impact of novel fertiliser application methods on plant nutrient status and evaluate crop nutrient assessment methods (soil electrical conductivity (EC), tissue analysis or leaf chlorophyll measurement) to provide data that correlate most closely to crop nutritional needs.

Year 3

Objective 1: To further evaluate / validate the soil and tissue analysis methods used in years one and two for correlation with crop nutritional needs on transplants of three commonly grown species from three vigour groups (high, medium, and low), using different straight or slow-release N). (**Transplant trial)**

Objective 2: Establish baseline nutritional information for two of the species of seedlings, from two vigour groups (as included in the transplant trial) using different straight or slow-release N). **(Seedling trial)**

Objective 3: To calculate potential reductions in carbon emissions associated with reduced N usage. **(Carbon emission from fertiliser use calculations)**

This work reported here is part of a wider project consisting of three work packages:

WP1. HNS (field and container) Literature review

WP2. Field tree production. To establish baseline information on nutrition for field-grown HNS trees by categorising the main plant families into vigour groups (e.g., Low; low – medium; medium - high), explore novel methods for applying fertilisers and determine the most suitable analyses (soil EC, tissue and/or leaf chlorophyll) to assess crop nutrient status (submitted as a separate report)

WP3. Container production. Optimisation of combined controlled release fertiliser (CRF) and liquid feed regimes for nursery stock liner production under protection

This is the final report for WP2. **The reports for WP1 and WP3 are submitted separately (see:** Developing nutrient management guidance for Hardy Nursery Stock | AHDB)**.**

Summary

During 2022 a field tree nutrition trial was carried out on field grown *Betula pendula* (high vigour)*, Carpinus betulus* (low vigour) and *Crataegus monogyna* (medium vigour) 1+1 transplants, post planting in their second year of growth using the host nursery's standard rate of fertiliser, see year 2 annual report for details of treatments.

The trial was repeated in 2023 to validate the results obtained in 2022 but the rates of Nitrogen were reduced to take account of slightly higher reserves in the soil.

Table 1. Field tree trial treatments, 2023.

Treatment and nutrient quantity	Product name / nutrient content	Nutrient component	Application rate (kg/ha)	
			Week 30	Week 34
1. Untreated	-	-	Untreated	Untreated
2. Straight 50 kg/ha N	Origin 27% N (27 - 0 - 0 + 10 SO_3)	NS Compound	186	-
3. Straight 100 kg/ha N	Origin 27% N (27:0:0 + 10 SO_3)	NS Compound	186	186
4. Straight (Floranid N31), 50 kg/ha N	Floranid N31 (31% N)	N	162	-

The field tree nutrition trial was set up in 2023 at Wyevale Nurseries, Transplant division, Ledbury, Herefordshire on three different species of transplants. Transplants were planted as one year old graded field grown seedlings of *Betula pendula, Carpinus betulus* and *Crataegus monogyna.* The one-year-old cold stored seedlings were planted on a standard system of four crop rows on a 1.2 m wide bed in loamy sand soil in late spring, plots were 3 m long. The aim of the work carried out was to determine if a straight and slow release of nitrogen impacted on plant nutrient status and growth and evaluate crop nutrient assessment methods (soil electrical conductivity (EC), tissue analysis or leaf chlorophyll measurement) to provide data that correlates most closely to crop nutritional needs. Floranid N31 was used as the slow-release N straight fertiliser, 3% of granules are coated with urea, the remaining 90% are coated in IBDU. The urea component requires microbial activity to release N as temperatures rise and the IBDU is broken down by the presence of water at 4°C and above, the product also contains a proportion of readily available N. This gives an activity Index of 98 – 99%; meaning that almost all the N can be taken up by the crop, preventing leeching – the product also has a low salt content. Standard straight fertilisers (e.g., Origin 27% N & 10 SO3) are much more prone to leaching following heavy rainfall.

Betula pendula were 60 – 80cm (high vigour), *Crataegus monogyna* were 40 – 60 cm (medium vigour) and *Carpinus betulus* (low vigour) were 20 – 40 cm transplants. These species were chosen as they are important species grown in large numbers, they also vary in vigour so were categorised into vigour groups.

Seedlings of *Carpinus betulus* and *Crataegus monogyna* which had been sown into seedbeds were also included within the trial to ascertain if trends in crop nutrition applied to both seedlings and transplants of the same species.

The fertilisers used are listed in **Table 1**. Leaf tissue analysis, measurements of the chlorophyll content of leaves (using an atLEAF hand-held device), soil EC, water content and temperature were carried out throughout the growing season. The height of selected transplants was also measured at the start of the trial and at the end of the growing season to determine differences in growth between treatments. Crop height is the main measure of crop performance for the grower.

The soil was loamy sand. Soil analysis was taken prior to fertiliser application (**Table 5**). Topsoil samples (0-15 cm) were taken for pH and extractable P, K and Mg, and soil mineral nitrogen samples were taken to 90 cm. The site of the transplant trial was SMN Index 3, P Index 4, K Index 3 and Mg Index 2. The site of the seedling trial was SMN Index 2, P Index 4, K Index 2+ and Mg Index 2.

There were no statistically significant differences ($P>0.05$) in mean height measurements between any of the treatments (including the untreated controls); three transplanted species measured in weeks 30, 34 and 37; two seedling species measured in weeks 34, 37 and 41.

Results from tissue analysis, compared with published figures, indicated that levels of some major and micronutrients were either low or high in all species / treatments combination throughout the growing season (**Tables 10 and 14**).

In summary, levels of N in *Betula* transplants From week 30 in T1 (untreated) and T4 (Floranid N31) were lower than the published figures, all treatments resulted in lower N levels in *Betula* transplants than published figures in weeks 34 and 37.

In *Carpinus* transplants levels of N in leaf tissue from T1 (untreated) were at the top end of the target range, all other treatments in weeks 34 and 37 contained higher levels of N than the published figures. In week 37 all treatments contained higher levels of N in leaf tissue than the published figures. In *Carpinus* seedlings all treatments in weeks 34 and 37 were higher in N than the published figures and T3 was higher than the published figures in week 41.

Throughout the trial all treatments applied to *Crataegus* transplants and seedlings resulted in higher levels of N in leaf tissue than the published figures.

This suggests that both *Crataegus* and *Carpinus* are efficient at taking up available nitrogen.

Table 2: Assessment of crop P and K offtake for transplants*

Species	Quantity (kg / ha) of P uptake (as P_2O_5)	Quantity (kg / ha) of K uptake (as K_2O)
Betula	62	94
Carpinus	45	67
Crataegus	23	61

*Crop offtakes should be considered to determine if any additional P & K is required to maintain levels at the target index.

As it is necessary to ascertain how much N has leached when making N application decisions, crop N offtake assessments have not been done: The SNS index for each field can be determined either by the Field Assessment Method using records of soil type, previous cropping and excess winter rainfall, or by the measurement method using measurement of Soil Mineral Nitrogen (SMN).

Table 3: Carbon calculations. GHG emissions based on fertiliser choice and number of applications, given in kg CO_2e / ha.

Fertiliser	Production	Supply	Applications		Use	Total
Floranid N31	175.8704	2.9671	1	13.7770	7.6471	200.2617
			2	27.5541		214.0387
			3	41.3311		227.8158
Origin 27% N + 10 SO_3	166.6802	2.3291	1	13.7770	59.2470	242.0333
			2	27.5541		255.8104
			3	41.3311		269.5874

Carbon reductions through reduced fertiliser usage can help growers to meet net zero; Floranid N31 has lower carbon emissions associated with it use than Origin 27%N + 10 SO_3, however Floranid N31 is a more expensive source of N so is not widely used by commercial growers. Savings based on the number of applications of the products used have been calculated **(Table 3).** If no N fertiliser was applied, compared to a standard application of 150 kg N applied as Origin 27%N + 10 SO_3 this would result in a reduction of 269 kg CO_2e.

Discussion

The fertiliser treatments had no effect on crop growth (assessed by height measurements) in *Betula, Carpinus* or *Crataegus* transplants or seedlings within these trials during 2023. Although the reserves of nitrogen were slightly higher in 2023 than 2022, no crop response in either the transplants or the seedlings was observed when comparing the final heights of treatments with untreated controls at the end of the growing season. Chlorophyll content has been correlated to Nitrogen content determined by tissue analysis **(Figures 1 – 3).** The measurement of soil EC and Volumetric water content help to pick up changes in nutrition and water content and are useful tools to monitor trends.

During the 2022 growing season the crop performed equally well where fertiliser NPK and no fertiliser was applied, despite the low soil nitrogen supply (SMN Index 0, P Index 3, K Index 2+), which indicates a low requirement for additional nitrogen. However, the potential for a crop response to additional fertiliser NPK may have been limited by the very dry and hot summer of 2022. Less irrigation was applied to the trial plots during 2022 compared with a typical growing season because of limited water supplies due to the drought.

The host grower reported a significant impact on growth during 2022 due to a combination of high temperatures inducing periods of crop dormancy during the growing season. Drought is also thought to have impacted crop growth compared with an average season.

This is the third year of nitrogen fertiliser response experiments on HNS. The first year (2019) tested the effect of broadcast application compared with band spread application of nitrogen fertiliser. Results from the first year showed no growth response to N, and it was suggested that this may have been because the species tested have a low requirement for N. This third fertiliser response experiment has also shown no response to N, despite low / modest soil nitrogen supply Index at both sites. This is an important result for growers and gives confidence in the consistent results within these trials indicating that *Betula, Carpinus* and *Crataegus* requirement for N may be lower than previously thought.

There was no correlation between chlorophyll content and growth in *Betula pendula, Carpinus betulus* or *Crataegus monogyna* at the soil N, P, K and Mg indices tested with and without fertilisers, in both the transplant and seedling trial

Conclusions

- No difference in growth (determined by height measurements) occurred within species between any of the three test subjects where no fertiliser was applied or where fertiliser was broadcast over plots in 2019, 2022 or 2023. This is an important result for growers and gives confidence in the consistent results within these trials over multiple growing seasons despite big differences in growing conditions having been experienced in the years that trials were undertaken.

- These trials indicate that the *Betula, Carpinus* and *Crataegus* requirement for N may be lower than previously thought. Growers should trial reducing N applications to these crops and compare resulting growth with their standard N application rate to determine where savings on N fertiliser (and associated carbon emissions) can be made.
- Good nutrient management is fundamental to economic and environmentally sustainable crop production by helping growers match inputs of nutrients (in fertiliser and organic materials) to crop demand; growers should scrutinise their N applications to field grown crops of *Betula, Carpinus* and *Crataegus*.
- Soil testing for pH, and extractable P, K and Mg to ensure that too low or excessively high soil indices do not occur. Growers should be aware that it is now a legal requirement for farmers in England under the Farming Rules for Water. Growers must test their soil at least every 5 years.
- Field grown HNS growers should aim to maintain soil at P Index 2, K Index 2 and Mg Index 2, which is consistent with target Index values for arable and fruit crops published in RB209.
- There is not a target SMN index for N as this nutrient is mobile and is prone to leaching; the SMN index is a means of quantifying how much N is available for crop uptake. This figure should be considered when planning N applications.
- It has been possible to correlate chlorophyll content to the nitrogen content as determined by tissue analysis, this demonstrates trends relating to chlorophyll content and the percentage of nitrogen in leaf tissue of three species.

Financial Benefits

The host nursery application of 180 kg/ha 27-0-0+10S, (27% N), fertiliser cost £323/ha. The slow-release form of N (Floranid N31) is roughly three times, more expensive per kilogram of N than the grower standard fertiliser costing £3.02 kg compared to straight N at £1.03 per kg. Floranid N31 is described by the manufacturer as providing a controlled release of N over a period of 3-4 months. Controlled/slow-release fertilisers can help reduce N losses to the environment and therefore ensure more of the N is available to the crop. The use of controlled release N fertiliser is likely to be most beneficial in wet years when there is risk of fertiliser N leaching below rooting depth following heavy rainfall. Despite 2023 being a wet summer there was no apparent benefit in terms of crop growth from using a slow-release form of nitrogen compared to a cheaper straight form of nitrogen.

There was no difference in growth between any of the treatments within any species including the untreated plots that received no fertiliser (where N and Mg was the only likely limiting factor) in 2022 (N was the only likely limiting factor in 2023). This implies these species have a low N requirement. *Betula* may not have a high N requirement for growth as it readily naturally colonises heathland and other habitats that are naturally low in N. These results indicate that there may be potential for growers to reduce N applications on these species (growers typically apply 150 kg N/ha) whilst maintaining crop growth.

A modest reduction of 50 kg N/ha to typical fertiliser N application rates would save growers £51.66/ha, whereas a 100 kg N/ha would save £103.33/ha, and a 150 kg N/ha would save £154.99/ha at current fertiliser prices of £350/tonne of Ammonium Nitrate (AHDB, 2024). Growers are advised to trial gradual reductions of 50 kg N/ha on a proportion of their crop (monitoring growth closely) for species not tested in this programme of work. A similar approach could be taken with *Betula, Carpinus* and *Crataegus* where desired in order to build confidence in this approach.

Action Points

- Test soil for pH, P, K and Mg at least every 5 years and ideally every 3 years. Aim to keep soil at P Index 2 and K Index 2-. There may be no need to apply additional fertiliser P and K above these target soil indices.
- Assess soil nitrogen supply (SNS) using guidance in AHDB Nutrient Management Guide. Consider sampling for soil mineral nitrogen (0-90 cm) to further improve N management.
- Review current N application rates to field grown HNS and consider whether reductions can be made.

SCIENCE SECTION

Introduction

Field HNS growers typically use straight or compound fertilisers, with limited use of slow / controlled release fertilisers in some crops. Some nurseries carry out regular soil analysis to find out what levels of phosphorus (P), potassium (K) and magnesium (Mg) are present in the soil (typically every three years) to help determine rates of fertiliser to apply, with sampling for soil mineral nitrogen (SMN) less commonly completed. Other nurseries do not currently carry out regular soil analysis and apply the same rates of fertiliser annually, regardless of soil nutrient indices / crop need. The situation is complicated by the fact that there are no readily accessible UK standard fertiliser recommendations for field grown HNS species making it difficult for growers to interpret soil analysis results and decide upon appropriate rates of N, P, K and Mg to apply. Because of the high value of field grown HNS in relation to broad acre arable crops the cost of fertiliser is relatively low compared with the value of the crop, which can result in excessive quantities being applied. The most recent recommendations were published in 1988 in the 5th Edition of RB209 (**MAFF, 1988**).

Soil testing for pH, and extractable P, K and Mg is now a legal requirement for farmers in England under the Farming Rules for Water (FRfW). Growers must test their soil at least every five years. Field grown HNS growers should aim to maintain soil at P Index 2 and K Index 2, which is consistent with target index values for arable and fruit crops published in RB209. Growers should avoid applying additional P fertiliser (manufactured or organic) to already high P Index soils as this increases the risk of P loss to water. This is particularly important on fields that are at high risk of soil erosion (generally lighter textured soils on sloping land) as field grown HNS provides limited soil cover which increases the risk of overland water flow and soil erosion following heavy rainfall.

A better understanding of field grown HNS species' nutritional needs could help to prevent vigorous species from being overfed, helping to control plant vigour while delivering increased profitability and environmental benefits through more sustainable fertiliser use. For less vigorous species, better optimisation of nutrition through novel approaches could minimise nutrient leaching and further optimise crop growth. There may be potential to shorten the production times of some species through targeted nutrient use or placement which could deliver several benefits for growers.

There is also a lack of understanding regarding selection of fertiliser type; fertilisers developed primarily for use in arable crops can contain muriate of potash (potassium chloride) which can scorch the foliage and may slow establishment of chloride-sensitive genera.

Reducing fertiliser use to help to meet Net Zero

The synthetic nitrogen fertiliser supply chain was responsible for estimated emissions of 1.13 GtCO2e in 2018, representing 10.6% of agricultural emissions and 2.1% of global greenhouse gas emissions. Reducing the use of synthetic nitrogen fertilisers will help the horticulture sector meet the UK's ambition of net zero by 2050.

Aim of project: To establish baseline information on nutrition for field-grown HNS trees, determine the impact of novel fertiliser application types on plant nutrient status, and evaluate crop nutrient assessment methods (tissue analysis or leaf chlorophyll measurement) for the provision of data that correlate most closely to crop nutritional needs.

Year 3 (2023)

Objective 1: To further evaluate / validate the soil and tissue analysis methods used in years one and two for correlation with crop nutritional needs on transplants of three commonly grown species from three vigour groups (high, medium, and low), using different straight or slow-release N). (**Transplant trial)**

Objective 2: Establish baseline nutritional information for two of the species of seedlings, from two vigour groups (as included in the transplant trial) using different straight or slow-release N). **(Seedling trial)**

Objective 3: To calculate potential reductions in carbon emissions associated with reduced N usage. **(Carbon emission from fertiliser use calculations)**

This project is comprised of three work packages:

WP1. HNS (field and container) Literature review

WP2. Field tree production. To establish baseline information on nutrition for field-grown HNS trees by categorising the main plant families into vigour groups (e.g., Low; low – medium; medium - high), explore novel methods for applying fertilisers and determine the most suitable analyses (soil EC, tissue and/or leaf chlorophyll) to assess crop nutrient status (submitted as a separate report)

WP3. Container production. Optimisation of combined controlled release fertiliser (CRF) and liquid feed regimes for nursery stock liner production under protection

This is the report for WP2. **The reports for WP1 and WP3 are submitted separately.**

Materials and methods

This field tree nutrition trial was set up in 2023 at Wyevale Nurseries, Transplant Division, Ledbury, Herefordshire on transplants of three species: *Betula pendula, Carpinus betulus* and

Crataegus monogyna, and seedlings of two species: *Carpinus betulus* and *Crataegus monogyna.* These species were chosen as they are important species grown in large numbers, they also vary in vigour so were categorised into vigour groups as follows; *Betula pendula* (high vigour)*, Carpinus betulus* (low vigour) and *Crataegus monogyna* (medium vigour)*.* Treatments within the seedling trial were the same as treatments applied to transplants.

Transplants were grown from seed drilled in 2022. They were lifted as seedlings, graded and cold stored prior to being planted out in week 21, 2023 in a field of loamy sand. Transplant size was as follows: *Betula pendula*, 60 – 80 cm; *Crataegus monogyna*,40 – 60 cm, and *Carpinus betulus*, 20 – 40 cm. Soil samples were taken in spring 2023, prior to fertiliser application, and sent to NRM laboratories for analysis (**Table 5**).

Seedlings were drilled in seedbeds in week 23 of 2023.

Treatments **(Table 4)** were applied in a randomised block design within species, with three treatments including an untreated control (no fertiliser applied, **Treatment 1**), a commercial standard (Origin 27% N and 10% SO3), straight nutrients to supply one application of 50 kg/ha N (**Treatment 2**) and two applications of 50 kg/ha N (**Treatment 3**). Straight nitrogen was also applied using a slow-release N source (Floranid N31, **Treatment 4**). Fertiliser was weighed out for each plot and was broadcast by hand over plots. All treatments were replicated four times. Plots measured 3 m x 1.2 m. P, K and Mg were not applied in line with soil analysis and recommendations for arable and fruit crops published in RB209.

Plant height. Ten representative transplants per plot were tagged (week 27) with coloured string. Height (cm) was measured at the start of the trial. Identifying selected plants in this way ensured that the same plants were measured at the end of the growing season to track growth within treatments during the trial.

Chlorophyll measurements were taken using the atLEAF handheld device, avoiding the main leaf rib, and samples for leaf tissue analysis were taken at each assessment date (taken in transplants in weeks 30, 34 & 37 and weeks 34, 37 and 41 in seedlings). Samples taken for leaf tissue analysis were taken from 2 inches / 5.08 cm below the growing point, selecting the youngest fully open leaf, combining leaves from across the plot to ensure sufficient plant material for analysis.

Soil measurements. Soil electrical conductivity (EC), volumetric water content (VMC) and temperature (°C) were measured using a Decagon Procheck with a gs3 Sensor (now available as Terros 12) in weeks 30, 34 & 37. These measurements were taken from the central row of each plot. The treatment list is shown below in **Table 4.**

Table 4. Field tree trial treatments, Year 3, 2023.

Treatment and nutrient quantity	Product name / nutrient content	Nutrient component	Application rate (kg/ha)	
			Week 30	**Week 34**
1. Untreated	-	-	Untreated	Untreated
2. Straight 50 kg/ha N	Origin 27% N (27 - 0 - 0 + 10 SO_3)	Nitrogen Sulphur (NS) Compound	186	
3. Straight 100 kg/ha N	Origin 27% N (27:0:0 + 10 SO_3)	Nitrogen Sulphur (NS) Compound	186	186
4. Straight (Floranid N31), 50 kg/ha N	Floranid N31 (31% N)	Nitrogen Sulphur (NS) Compound	162	-

Assessment of crop P and K offtake for transplants

Three representative bundles of 25 transplants were lifted and weighed for each of the three species included within the trial. A representative quantity of plant material was collected, and half was sent to NRM labs to determine the amount of phosphate and potash in the plant material. The remaining plant material was weighed prior to being placed in an oven for 48 hours at 80°C to determine the dry mass of the plant material in order to calculate crop offtake.

Objective 3 Carbon calculations

The following calculations (these are in line with the GHG protocol guidance and the 2019 refined methodology to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories) relate to savings in carbon dioxide that could be achievable through reductions in fertiliser use:

Boundaries: Analysis only reviewed GHG emissions related to N additions, including production, supply (delivery from factory), application (fertiliser spreader) and use (volatilisation and leaching). No attempt is made to estimate the impact of additions on assimilation of biomass / growth rate, as it is understood this is negligible.

Inputs: Two different N fertiliser sources were reviewed, including the number of applications at the same total volume applied. N sources considered:

Floranid N31, a slow-release urea form of N (IBDU), that releases over 8-12 weeks; applied at a total rate of 162 kg/ha, in 1, 2 or 3 applications. Cost £606.20 (162 kg). Produced by Compo in their factory in Krefeld, Germany.

Origin 27% N + 10 SO_3, ammonium nitrate; applied at a total rate of 186 kg/ha, in 1, 2 or 3 applications. Cost £84.82 (186 kg). Produced in Northern France.

Tractor mounted fertiliser spreader uses red diesel: 5 L/ha, per application.

Assumptions:

LCA of liquid isobutyraldehyde (IBA) or proportion used in production of IBDU not considered. Only emissions relating to production of urea accounted for. Emission profile during application of IBDU are calculated using IPCC methodology and adjusted to mirror relative volatilisation and leaching losses (**Rehberg**, **1980**).

- Northern France facility assumed to be in Paris (Fertilore) and driving distance to Royston (Origin HQ) is ~335 miles (diesel).
- Distance between Krefeld, Germany, and Compo registered office (DY13 8UW) is ~490 miles (diesel).
- Fertilisers assumed to be supplied in average laden 33 tonne artic, at 1.2335 kg CO_2e / mile. Quantity of each fertiliser used is taken as a proportion of the total supplied per trip.

Results

Transplant trial

Topsoil analysis (0-15 cm) for extractable Phosphorus (P), Potassium (K) and Magnesium (Mg) was completed prior to fertiliser application (**Table 5**). The soil was P Index 4 (above target Index of 2), K Index 3 (above target Index of 2) and Mg Index 2 (at target Index).

Soil samples were taken to 90 cm depth to determine soil mineral nitrogen levels which were found to be at Index 3 (**Table 6**).

Table 5. Soil analysis, available nutrients prior to fertiliser application.

Soil pH*	P Index	P (mg/l)	K Index	K (mg/l)	Mg Index	Mg (mg/l)	Organic matter (%)
7.2	4	53	3	251	2	60	1.9

* Soil pH was sufficiently high; lime only needs to be applied to maintain a soil pH between 6 – 6.5.

Table 6. Soil mineral nitrogen (SMN) analysis prior to planting and fertiliser application

Sampling depth	Nitrate-N kg/ha	Ammonium-N kg/ha	Soil mineral nitrogen kg/ha 30cm profile
0 – 30 cm	48.4	4.6	53.0
30 – 60 cm	30.9	3.3	34.2
60 – 90 cm	21.1	8.4	29.5
Total of all sample depths	100.4	16.3	116.7

Plant height

There were no significant differences in mean height measurements within species between treatments (**Tables 7 – 9**). Average mean heights across all treatments, within species indicates the following growth: *Betula,* 62.98 cm, *Carpinus,* 23.75 cm and *Crataegus* 13.25 cm between weeks 27 and 41.

Table 7. *Betula pendula*: average plant height and mean growth, 2023

Treatment No	Treatment	Initial height (cm)	Final height (cm)	Mean growth (cm)
1	Untreated	65.7	125.0	59.3
2	Straight N 50 kg/ha	64.5	130.2	65.8
3	Straight N 100 kg/ha	64.4	130.1	65.6
4	Straight N (Floranid N31) 50 kg/ha	67.7	129.0	61.2
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 8. *Carpinus betulus*: average plant height and mean growth, 2023

Treatment No	Treatment	Initial height (cm)	Final height (cm)	Mean growth (cm)
1	Untreated	37.54	62.7	25.2
2	Straight N 50 kg/ha	38.78	62.6	23.9
3	Straight N 100 kg/ha	37.77	57.0	19.2
4	Straight N (Floranid N31) 50 kg/ha	38.12	64.8	26.7
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 9. *Crataegus monogyna*: average plant height and mean growth, 2023

Treatment No	Treatment	Initial height (cm)	Final height (cm)	Mean growth (cm)
1	Untreated	59.26	75.2	15.9
2	Straight N 50 kg/ha	59.81	74.3	14.5
3	Straight N 100 kg/ha	57.87	66.0	8.1
4	Straight N (Floranid N31) 50 kg/ha	58.14	72.7	14.5
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Chlorophyll content

There were no significant differences in mean chlorophyll content in *Betula* at the first assessment in week 30, however all *Betula* treatments receiving nitrogen (Treatments 2, 3 and 4) had significantly higher mean chlorophyll content than the untreated control in week 37. The assessment in week 37 showed that chlorophyll levels were highest in *Betula* in Treatment 3, (**Appendix 6, Table 1**).

There were no significant differences in chlorophyll levels between treatments in *Carpinus* (**Appendix 6, Table 2**). or *Crataegus* (**Appendix 6, Table 3**).

Soil volumetric water content

There were no significant differences between mean soil volumetric water content in *Betula* treatments in any of the assessments (**Appendix 8, Table 1**).

For the *Carpinus* treatments, mean soil volumetric water content was significantly higher in Treatments 1, 2 and 4 than Treatment 3 in the week 34 assessment. There were no significant differences between treatments for *Carpinus* in weeks 30 and 37 (**Appendix 8, Table 2**).

There were no significant differences in mean soil volumetric water content in *Crataegus* for any assessments (**Appendix 8, Table 3).**

Soil EC

For *Betula*, EC was significantly higher in Treatment 4 than Treatment 1 (untreated) in week 30. There were no significant differences between treatments at the assessments in weeks 34 and 37 (**Appendix 10, Table 1).**

There were significant differences in mean soil EC in *Carpinus* at all the assessment dates; in week 30 EC in Treatment 4 was significantly higher than all other treatments. In week 34 the differences between treatments were not significant. In week 37 treatment 3 was significantly higher than all other treatments (**Appendix 10, Table 2).**

There were significant differences in mean soil EC in *Crataegus*. In week 34, EC was significantly higher in Treatment 1 (untreated) than all other treatments, and in week 37 EC was significantly higher in Treatment 3 than all other treatments. (**Appendix 10, Table 3).**

Soil temperature

There were no significant differences in mean soil temperature for *Betula* or *Crataegus.* For *Carpinus* the only significant differences were in the week 34 assessment, when the soil temperature was significantly lower in Treatment 3 than all other treatments. (**Appendix 12, Table 2**).

Plant tissue analysis

When comparing tissue analysis results **(Appendix 1 – 3)** with published figures **(Tables 15 – 17)** the published figures suggest that levels of nutrients in tissue analysis were either higher or lower than the guidelines in many species and assessment dates.

Table 10 Transplant summary table of tissue analysis where high or low levels were found compared with published figures (**Tables 15 – 17** and **Appendices 1 – 3** for raw tissue analysis data), unless plot numbers are listed in brackets all treatments within a species are in the category, they are listed under.

Species and week number	**Lower levels in leaf tissue than published figures**	**Higher levels in leaf tissue than published figures**
Betula transplants week 30*	Nitrogen (T1, T4), Potassium (T1), Magnesium, Copper, Iron, Zinc, Boron & Sulphur (T1, T4).	Calcium & Manganese.
Betula transplants week 34*	Nitrogen, Magnesium, Manganese, Copper, Iron, Zinc, Boron & Sulphur.	Calcium & Manganese.
Betula transplants week 37*	Nitrogen, Magnesium, Copper, Iron (T1, T3 & T4), Zinc, Boron & Sulphur (T2, T3 & T4).	Calcium, Manganese & Iron (T2).
Carpinus transplants week 30	Calcium, Magnesium, Copper, Boron & Sulphur.	Nitrogen (T2, T3 & T4), Phosphorus (T1 & T2) Potassium & Manganese.
Carpinus transplants week 34	Magnesium, Boron & Sulphur (T1, T2 & T4).	Nitrogen (T2, T3 & T4), Phosphorus, Potassium, Manganese & Iron (T2).
Carpinus transplants week 37	Magnesium, Calcium (T2, T3 & T4), Boron & Sulphur	Nitrogen, Phosphorus, Potassium, Manganese, Iron (T3 & T4) and Zinc.
Crataegus transplants week 30	Phosphorus (T4), Calcium, Magnesium, Copper, Zinc & Boron.	Nitrogen, Potassium Manganese & Sulphur.

Crataegus transplants week 34	Calcium, Magnesium Copper, Zinc (T2, T3 & T4) & Boron.	Nitrogen, Potassium, Manganese & Sulphur
Crataegus transplants week 37	Phosphorus (T1 & T3), Calcium, Magnesium, Copper, Zinc & Boron.	Nitrogen, Potassium, Manganese, Iron (T3) & Sulphur (T2).

* Published tissue analysis figures for *Betula pendula* (shown in black) are incomplete so figures for *Betula utilis* var*. jacquemontii* (in green) may provide useful guidance **(Mills and Jones, 1996).**

Seedling trial

Topsoil analysis (0-15 cm) for extractable Phosphorus (P), Potassium (K) and Magnesium (Mg) was done prior to fertiliser application (**Table 11).** The soil was P Index 4 (above target Index of 2), K Index 2+ (at target Index) and Mg Index 2 (at target Index).

Soil samples were also taken to 90 cm depth to determine soil mineral nitrogen levels which were found to be at Index 2 **(Table 12)**.

Table 11. Soil analysis, prior to fertiliser application.

Soil pH*	P Index	P mg/l available	K Index	K mg/l available	Mg Index	Mg mg/l available	Percentage organic matter
7.5	4	69	2+	225	2	67	1.8

* Soil pH was sufficiently high; lime only needs to be applied to maintain a soil pH between 6 – 6.5.

Table 12. Soil mineral nitrogen (SMN) analysis prior to planting and fertiliser application

Sampling depth	Nitrate-N kg/ha	Ammonium-N kg/ha	Soil mineral nitrogen kg/ha 30 cm profile
0 – 30 cm	42.0	2.1	44.1
30 – 60 cm	27.4	1.7	29.1
60 – 90 cm	26.6	1.1	27.7
Total of all sample depths	96.0	4.9	100.9

Plant height

There were no significant differences in mean plant height between treatments or species when measured (**Tables 7 - 9**) at the end of the growing season. When averaging mean heights across all treatments within a species, *Carpinus* seedlings grew by 19.34 cm and *Crataegus* seedlings grew by 33.7 cm between weeks 27 and 41.

Table 13. End of season heights for *Carpinus betulus* and *Crataegus monogyna* seedlings, 2023

Treatment No	Treatment	Final average plant height (cm)	
		Carpinus betulus	***Crataegus monogyna***
1	Untreated	16.86	29.9
2	Straight N 50 kg/ha	20.04	35.7
3	Straight N 100 kg/ha	20.78	37.2
4	Straight N (Floranid N31) 50 kg/ha	19.67	32.2
L.S.D.		(N/S)	(N/S)
p value		-	-

Chlorophyll content

There were no significant differences in mean chlorophyll content between treatments for either *Carpinus* or *Crataegus* (**Appendix 7, Tables 1 and 2**).

Soil volumetric water content

There were no significant differences between mean soil volumetric water content in *Carpinus* treatments in weeks 34 and 37 however there was a significant difference between mean soil volumetric water content in week 41 when treatment 3 was significantly lower than treatment 1 and 4 (**Appendix 9, Table 1**).

There were significant differences between mean soil volumetric water content for *Crataegus* in week 34 and week 37 with measurements for Treatment 1 significantly higher than all other treatments. However, there were no significant differences in soil volumetric water content in week 41 (**Appendix 9, Table 2**).

Soil EC

There were significant differences in mean soil EC in *Carpinus* week 34 when treatment 3 was significantly higher than treatment 1 (untreated) and 4. EC in treatment 3 remained significantly higher in week 37 than treatments 1 and 2 however there was no significant difference between treatments by the final assessment in week 41 (**Appendix 11, Table 1).**

Significant differences between mean soil EC in *Crataegus* occurred in weeks 37 and 41 when the soil EC in treatment 3 was significantly higher than for all other treatments (**Appendix 11, Table 2).**

Soil temperature

There were no significant differences in mean soil temperature in *Carpinus* or *Crataegus* during this trial. (**Appendix 13, Tables 1 & 2**).

When comparing tissue analysis results **(Appendix 4 – 5)** with published figures **(Tables 12 - 14)** the published figures suggest that levels of nutrients in tissue analysis were either higher or lower than the guidelines in many species and assessment dates:

Table 14 Seedling summary table of tissue analysis where high or low levels were found compared with published figures (**Tables 15 – 17** and **Appendices 4 - 5** for raw tissue analysis data), unless plot numbers are listed in brackets all treatments within a species are in the category, they are listed under

Species and week number	Lower levels in leaf tissue than published figures	Higher levels in leaf tissue than published figures
Carpinus seedlings week 34	Boron & Sulphur (T1 & T4).	Nitrogen, Phosphorus, Potassium, Manganese, Copper, Iron (T1, T3 & T4) & Zinc.
Carpinus seedlings week 37	Boron & Sulphur	Nitrogen, Phosphorus, Potassium, Manganese, Copper, Iron, Zinc.
Carpinus seedlings week 41	Magnesium (T3), Boron & Sulphur	Nitrogen (T3), Phosphorus, Potassium, Manganese, Copper (T1) Iron, and Zinc (T1, T2 & T4).
Crataegus seedlings week 34	Calcium, Magnesium, Copper, Zinc (T1, T3 & T4) & Boron (T2 & T3).	Nitrogen, Phosphorus, Potassium, Manganese & Sulphur (T2, T3 & T4).
Crataegus seedlings week 37	Calcium, Magnesium Copper, Zinc (T2, T3 & T4) & Boron.	Nitrogen, Phosphorus, Potassium, Manganese, Zinc (T1 & T2) & Sulphur (T2, T3 & T4)
Crataegus seedlings week 41	Calcium, Magnesium, Copper, Zinc (T2 & T3) & Boron (T2, T3 & T4).	Nitrogen, Phosphorus, Potassium, Manganese, Zinc (T1) & Sulphur (T3).

Chlorophyll content related to percentage Nitrogen in leaf tissue analysis.

The atLEAF meter reads the chlorophyll content of leaves. Data has been collated from all treatments and assessment dates to determine trends between chlorophyll readings from the species tested in relation to results from leaf tissue analysis.

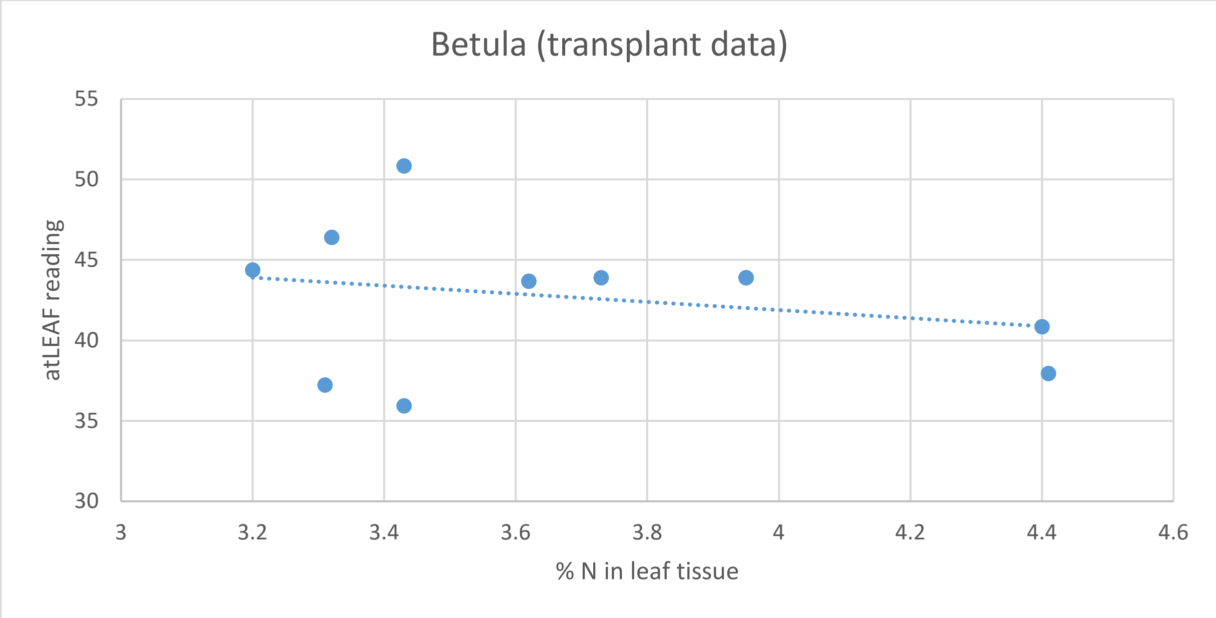

Figure 1. The relationship between atLEAF readings and percentage N in leaf tissue analysis in *Betula*.

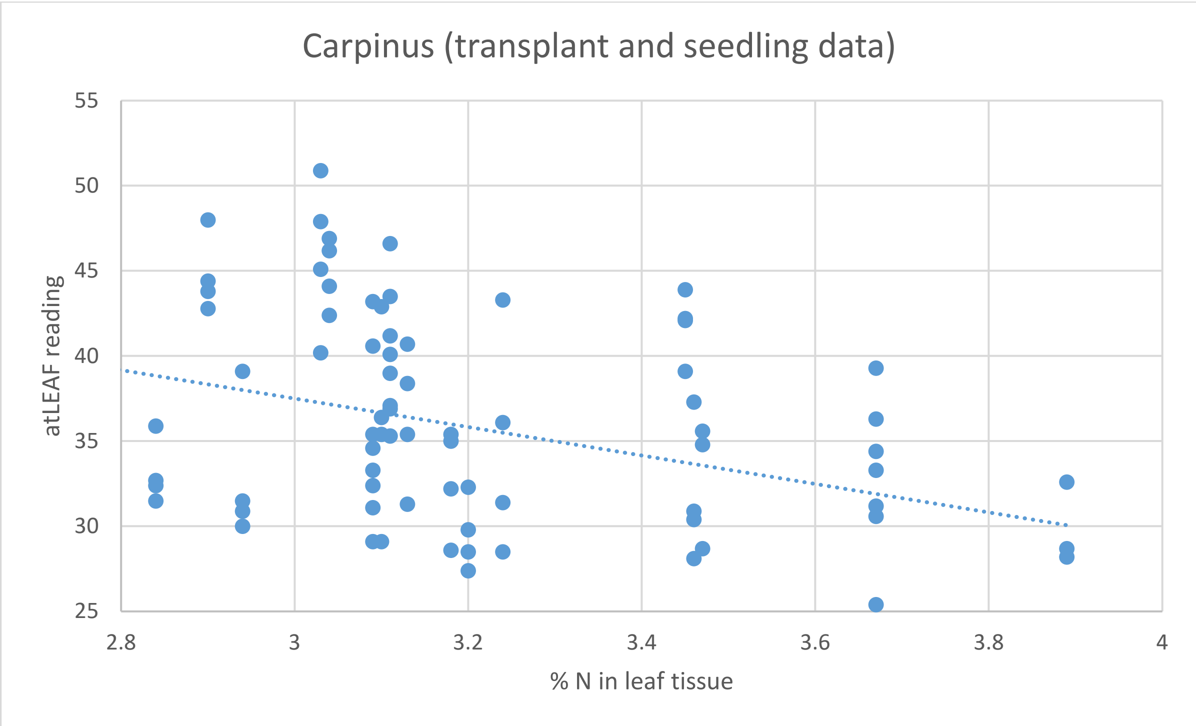

Figure 2. The relationship between atLEAF readings and percentage N in leaf tissue analysis in *Carpinus*.

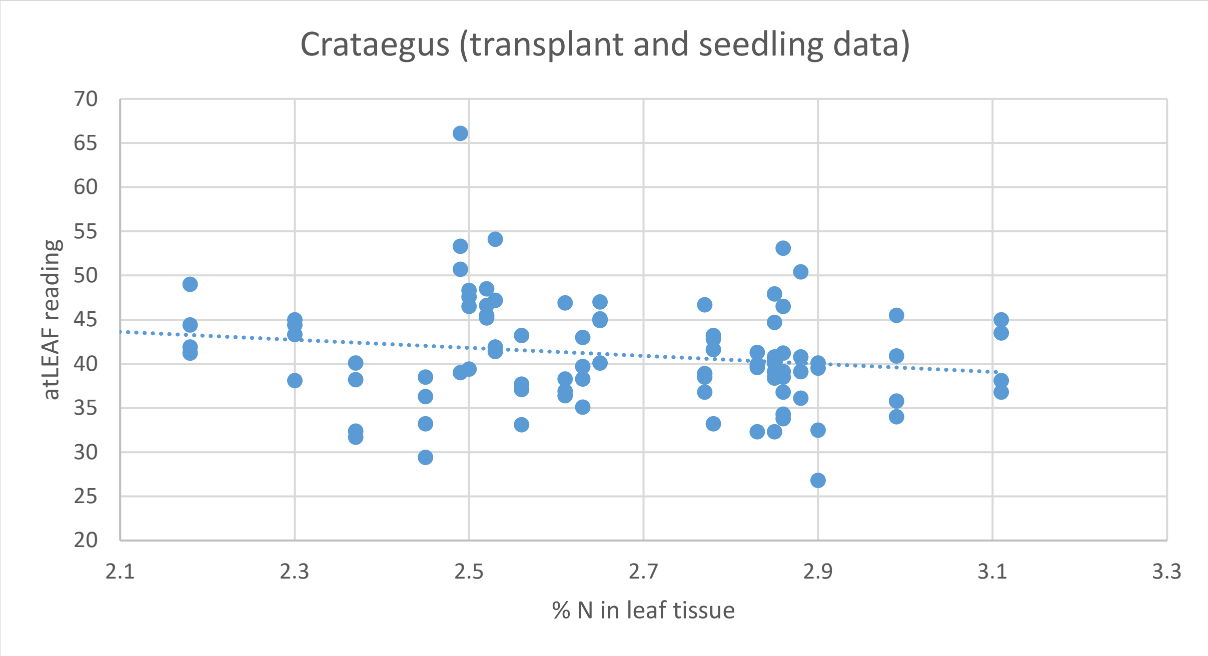

Figure 3. The relationship between atLEAF readings and percentage N in leaf tissue analysis in *Crataegus*.

The data from all species within the trial shows a trend that the higher the atLEAF reading the lower the percentage of N in leaf tissue was.

Discussion

None of the treatments resulted in any significant difference in the growth of transplants or seedlings (determined by height measurements) of the three species within this trial during the 2023 growing season (**Tables 7, 8, 9 and 13).** Trials carried out in previous years of this programme of research have indicated that the test species are not responsive to Nitrogen. 2023 was a very different growing season than 2022 when a severe drought and several heatwaves occurred. The fact that similar results were obtained in different growing seasons gives confidence in the results obtained as extreme heat is known to have a negative effect on plant growth (Teskey *et al.,* 2014).

The host grower previously stated that in a typical growing season he would expect second year (1+1) transplants of *Betula* and *Crataegus* to put on approximately 60cm of growth and 1+1 *Carpinus* transplants to put on approximately 50 cm of growth in their second growing season. When averaging mean heights across all treatments within a species in 2022, *Betula* grew by 32.65 cm, *Carpinus* grew by 17.68 cm and *Crataegus* grew by 9.46 cm. Whereas mean heights across all treatments within a species in 2023 resulted in 62.98 cm growth on *Betula,* 23.75 cm of growth on *Carpinus* and 13.25 cm of growth on *Crataegus.* Much of the summer of 2023 was wet and cool; and this is the most likely explanation as to why only the *Betula* put on the expected growth.

Despite another challenging growing season, once again the plants within the trial performed equally well where fertiliser and no fertilisers were applied. This result indicates that *Betula, Carpinus* and *Crataegus* are highly efficient at taking up the nutrients they require even when major nutrients such as Nitrogen (SNS Index 0) and Magnesium (Index 1) are available at what are considered low, but not atypical, levels. Although testing levels of soil mineral nitrogen gives a measure of available nitrogen it is important to consider other factors affecting nitrogen supply such as the mineralisable nitrogen which becomes available from mineralisation of soil organic matter and crop debris during the season. Soil organic matter was low at 1.8 - 1.9%, and therefore N mineralisation is likely to have been low during the season.

Generally, for most crops we would not expect to see a yield response to fertiliser P or K where the soil is at or above the target Index, and fertiliser is applied at the target Index to replace crop offtake only. Field grown HNS are not known to be particularly responsive to P or K, and therefore the standard guidance given in section 1 of the AHDB Nutrient Management Guide on maintaining soil indices, should be applicable to these crops.

Phosphorus can contribute to the pollution of water, particularly where soil erosion occurs; phosphates can enter water courses bound to soil particles lost through soil erosion. Government guidance recommends that rivers should not exceed annual mean phosphate concentrations of 0.1 mg per litre. Where high levels of phosphates do occur in water it contributes to algal blooms, the decomposition of which can reduce the oxygen content of water resulting it becoming unsuitable for some species; this is known as eutrophication. High soil P levels increase the risk of P loss to water, and additional P applications above the target Index of 2 should be avoided. It should be noted that field grown HNS crops provide very little soil cover and lack of soil cover increases the risk of overland flow and soil erosion following heavy rainfall events. This risk of erosion is further increased on light textured soils, soils low in organic matter, and in sloping fields. It is important that growers pay particular attention to soil and nutrient management to minimise losses to the environment.

Published tissue analysis figures for *Betula pendula* and *Carpinus betulus* (**Mills and Jones, 1996**) are the only guideline available as to optimum levels of nutrients within plant tissue. The figures are based on 30 years of tissue data analysis from a laboratory in the USA, however, do not necessarily represent maximum or minimum levels, the data set is incomplete for *Betula pendula* however the published figures for *Betula utilis* var*. jacquemontii* may provide some guidance as no other data is available. No tissue analysis data is available for *Crataegus monogyna* so data from *Crataegus phaenopyrum* (a similar species) was used for comparative purposes. These published figures are shown below in **Tables 15 - 17.** Although it is useful to compare against this published data, it should be noted that this data was published almost 30 years ago, and growers should be cautious about inferring nutrient deficiency in their own crops by comparison with this data. This published data provides a guide to typical values only.

Table 15. Published tissue analysis figures for *Betula pendula* (shown in black) are incomplete so figures for *Betula utilis* var*. jacquemontii* (in green) may provide some useful guidance (**Mills and Jones, 1996**).

Nutrient	Nutrient abbreviation	Amount	Unit of measurement*
Nitrogen	N	4.00 – 4.60	% Dry matter
Phosphorus	P	0.36 – 0.59	% Dry matter
Potassium	K	1.70 – 2.90	% Dry matter
Magnesium	Mg	0.26 – 0.38	% Dry matter
Calcium	Ca	0.20 – 0.31	% Dry matter
Sulphur	S	0.26	% Dry matter
Iron	Fe	183.00	Parts per million (ppm)
Copper	Cu	79.00	Parts per million (ppm)
Zinc	Zn	354.00	Parts per million (ppm)
Manganese	Mn	703.00	Parts per million (ppm)
Boron	B	82.00	Parts per million (ppm)

*ppm or mg/kg may be used however figures are the same for both units of measurement.

Table 16. Published tissue analysis figures for *Carpinus betulus* **(Mills and Jones, 1996).**

Nutrient	Nutrient abbreviation	Amount	Unit of measurement*
Nitrogen	N	2.14 – 2.84	% Dry matter
Phosphorus	P	0.14 – 0.20	% Dry matter
Potassium	K	0.68 – 0.92	% Dry matter
Magnesium	Mg	0.27 – 0.40	% Dry matter
Calcium	Ca	1.18 – 2.98	% Dry matter
Sulphur	S	0.19 – 0.21	% Dry matter
Iron	Fe	53 – 131	Parts per million (ppm)
Copper	Cu	3 – 8	Parts per million (ppm)
Zinc	Zn	18 – 32	Parts per million (ppm)
Manganese	Mn	233 – 2094	Parts per million (ppm)
Boron	B	23 – 203	Parts per million (ppm)
Molybdenum	Mo	0.12 – 2.51	Parts per million (ppm)

*ppm or mg/kg may be used however figures are the same for both units of measurement.

Table 17. Published tissue analysis figures for *Crataegus phaenopyrum;* no data is available for *Crataegus monogyna* (**Mills and Jones, 1996**).

Nutrient	Nutrient abbreviation	Amount	Unit of measurement*
Nitrogen	N	1.32 – 1.48	% Dry matter
Phosphorus	P	0.21 – 0.26	% Dry matter
Potassium	K	0.74 – 1.05	% Dry matter
Magnesium	Mg	0.29 – 0.33	% Dry matter
Calcium	Ca	1.38 – 2.24	% Dry matter
Sulphur	S	0.11 – 0.15	% Dry matter
Iron	Fe	40 – 158	Parts per million (ppm)
Copper	Cu	6 – 14	Parts per million (ppm)
Zinc	Zn	23 – 26	Parts per million (ppm)
Manganese	Mn	45 – 75	Parts per million (ppm)
Boron	B	14 – 21	Parts per million (ppm)
Molybdenum	Mo	0.05 – 1.14	Parts per million (ppm)

*ppm or mg/kg may be used however figures are the same for both units of measurement.

Using potassium sulphate is preferable to muriate of potash as a source of K as muriate of potash can contain too much chloride for some ornamental species, slowing crop establishment which can limit the crop's potential growth (**Lindberg, B. and Cregg, B., C., 2022**).

Micronutrients are not generally applied to field grown crops as it is assumed that sufficient quantities are available to plants in most soils. Low levels of micronutrients have the potential to limit crop growth and may need to be considered as it has previously been assumed that if no visible deficiency symptoms are seen sufficient quantities are available to plants.

There was no effect of fertiliser treatments on crop growth (assessed by height measurements) in *Betula, Carpinus* or *Crataegus* within this trial during the 2023 growing season. The fact that plants performed equally well regardless of whether nitrogen was applied or not NPK at SMN Index 3 (transplants) or SMN Index 2 (seedlings) indicates a low requirement for additional nitrogen.

This is the third year of fertiliser response experiments on HNS. The first year was in 2019 and tested the effect of broadcast compared to band spread application of nitrogen fertiliser. Results from the first year showed no growth response to N, and it was suggested that this may be as the species tested have a low requirement for N. The second fertiliser response experiment carried out during 2022 also showed no response to N, although the response to N may have been limited by the drought.

The third year's trials carried out in 2023 on both transplants and seedlings also showed no response to N fertiliser. The three years of no fertiliser N response despite low SNS Index in 2019, 2022 and a modest SNS Index in 2023 is an important result for growers and indicates that *Betula, Carpinus* and *Crataegus* requirement for N may be less than previously thought. The consistent results obtained in different growing seasons (notably a severe drought in 2022, and a wet summer in 2023) should build confidence in the results.

There was no correlation between chlorophyll content and growth in *Betula pendula, Carpinus betulus* or *Crataegus monogyna* at the soil N, P, K and Mg indices tested with and without fertilisers.

Chlorophyll content has been related to percentage Nitrogen in leaf tissue analysis, this shows a trend across all species included within the trial. The higher the chlorophyll reading the lower the percentage of N in leaf tissue in the species within this trial *(Betula, Carpinus* and *Crataegus)*. Correlation of the devices output to leaf tissue N level can be mapped over time for other species. Previous work in HDC project 193 found that the atLEAF device gave an indication of plant nutrient status at least 2 weeks prior to visual symptoms of nitrogen deficiency. No symptoms of N deficiency were observed within the trials carried out within this project.

Where the soil is at or below target soil Index (Index 2 for P & K) nutrient offtakes in the harvested crop must be replaced to maintain the target soil Index otherwise a reduction in productivity may be encountered.

Conclusions

- No difference in growth (determined by height measurements) occurred within species between any of the three test subjects where no fertiliser was applied or where fertiliser was broadcast over plots. This effect was noted over multiple years and at different crop growth stages (both seedling and transplant).
- No difference in growth (determined by height measurements) occurred within species between any of the three test subjects where no fertiliser was applied or where fertiliser

was broadcast over plots during summer 2023. However, the wet, cool weather during summer 2023 may have affected crop growth and limited the response to fertiliser.

- Good nutrient management is fundamental to economic and environmentally sustainable crop production by helping growers match inputs of nutrients (in fertiliser and organic materials) to crop demand.
- Soil testing for pH, and extractable P, K and Mg is now a legal requirement for farmers in England under the Farming Rules for Water. Growers must test their soil at least every 5 years.
- Field grown HNS growers should aim to maintain soil at P Index 2, K Index 2 and Mg Index 2, which is consistent with target Index values for arable and fruit crops published in RB209.
- The synthetic nitrogen fertiliser supply chain was responsible for estimated emissions of 1.13 GtCO2e in 2018 representing 10.6% of agricultural emissions and 2.1% of global greenhouse gas emissions.
- Reducing the use of synthetic nitrogen fertilisers is a simple and effective method of reducing carbon emissions associated with the production of field grown HNS, this approach will help the horticulture sector to reach net zero by 2050.
- The use of an atLEAF hand held chlorophyll meter is a reasonably priced (costing approximately £650) piece of robust equipment that can be used to detect trends within the nutritional status of the crop which can enable growers to amend fertiliser applications in advance of visual symptoms of nitrogen deficiency.

Knowledge and Technology Transfer

HTA Tree and Hedging group workshop 18/10/23 – Nutrient management of field grown ornamentals; developing nutrient management guidance for HNS.

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Appendix 1. Tissue analysis *Betula pendula* transplants, 2023

Table 1. Tissue analysis *Betula* Week 30

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	3.31	0.44	1.66	0.19	0.51	227	4.84	76.6	86.8	13.9	0.21
2. Straight N 50 kg/ha	4.40	0.44	1.73	0.18	0.41	200	6.12	78.9	80.6	12.3	0.26
3. Straight N 100 kg/ha	4.41	0.43	1.72	0.16	0.39	165	6.35	76.7	81.2	10.5	0.26
4. Straight N (Floranid N31) 50 kg/ha	3.96	0.44	1.77	0.18	0.44	206	5.52	76.2	83.6	12.4	0.24

Table 2. Tissue analysis *Betula* Week 34

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	3.31	0.41	1.95	0.25	0.59	354	7.89	78.4	161.0	9.12	0.20
2. Straight N 50 kg/ha	3.78	0.43	1.90	0.23	0.52	235	7.52	85.5	126.0	7.84	0.22
3. Straight N 100 kg/ha	3.95	0.40	1.73	0.21	0.52	182	7.10	82.9	106.0	6.94	0.23
4. Straight N (Floranid N31) 50 kg/ha	3.62	0.44	1.89	0.23	0.54	293	8.40	82.5	153.0	8.73	0.22

Table 3. Tissue analysis *Betula* Week 37

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	3.32	0.37	1.75	0.20	0.48	327	7.8	115.7	155.8	9.1	0.19
2. Straight N 50 kg/ha	3.50	0.37	1.79	0.21	0.52	239	6.8	206.9	114.5	8.7	0.20
3. Straight N 100 kg/ha	3.73	0.37	1.78	0.20	0.49	189	5.80	150.3	102.1	7.70	0.20
4. Straight N (Floranid N31) 50 kg/ha	3.43	0.41	1.83	0.21	0.47	280	7.50	135.2	134.1	10	0.20

Appendix 2. Tissue analysis *Carpinus betulus* transplants, 2023

Table 1. Tissue analysis *Carpinus* Week 30

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.84	0.22	1.00	0.22	0.98	201	2.56	81.6	20.6	12.8	0.16
2. Straight N 50 kg/ha	3.09	0.21	1.13	0.22	0.91	151	2.37	71.9	24.1	10.7	0.17
3. Straight N 100 kg/ha	2.94	0.20	0.98	0.21	1.02	168	2.93	73.1	21.9	11.10	0.16
4. Straight N (Floranid N31) 50 kg/ha	3.10	0.20	100	0.20	0.81	171	2.42	70.9	20.8	10.4	0.16

Table 2. Tissue analysis *Carpinus* Week 34

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.79	0.26	1.23	0.25	1.23	640	3.55	80.0	29.6	14.2	0.15
2. Straight N 50 kg/ha	3.18	0.23	1.33	0.23	1.27	313	3.73	255	31.6	12.8	0.18
3. Straight N 100 kg/ha	3.45	0.21	1.26	0.21	1.29	242	3.73	72.9	26.3	11.8	0.19
4. Straight N (Floranid N31) 50 kg/ha	3.13	0.23	1.29	0.23	1.18	414	3.57	82.3	26.8	13	0.17

Table 3. Tissue analysis *Carpinus*, Week 37

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.90	0.27	1.09	0.23	1.20	1048	5.11	122.0	41.0	14.4	0.16
2. Straight N 50 kg/ha	3.11	0.27	1.15	0.21	1.03	598	4.07	127	37.2	10.7	0.17
3. Straight N 100 kg/ha	3.03	0.26	1.17	0.21	1.09	611	4.25	235	38.8	10.6	0.16
4. Straight N (Floranid N31) 50 kg/ha	3.04	0.24	1.14	0.21	1.15	581	3.57	136	32.2	11.4	0.17

Appendix 3. Tissue analysis *Crataegus monogyna* transplants, 2023

Table 1. Tissue analysis *Crataegus* Week 30

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	3.11	0.26	1.70	0.24	1.20	90.6	4.17	78.7	20.1	11.1	0.21
2. Straight N 50 kg/ha	2.85	0.21	1.60	0.24	1.25	90.0	3.83	83.4	17.9	9.7	0.18
3. Straight N 100 kg/ha	2.99	0.21	1.55	0.22	1.20	85.9	3.54	82.1	17.3	9.9	0.19
4. Straight N (Floranid N31) 50 kg/ha	2.86	0.19	1.39	0.23	1.15	90.6	3.85	73.6	17.4	9.8	0.18

Table 2. Tissue analysis *Crataegus* Week 34

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.77	0.23	1.85	0.22	0.92	63.3	3.99	54.0	23.2	9.51	0.19
2. Straight N 50 kg/ha	2.78	0.23	1.75	0.20	0.87	62.0	4.03	51.7	22.4	8.56	0.18
3. Straight N 100 kg/ha	2.88	0.23	1.73	0.20	0.88	60.2	3.53	49.9	21.3	8.62	0.19
4. Straight N (Floranid N31) 50 kg/ha	2.84	0.24	1.71	0.22	0.83	64.9	3.65	51.5	20.9	8.72	0.19

Table 3. Tissue analysis *Crataegus* Week 37

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.50	0.20	1.84	0.25	0.85	76.0	4.0	134.9	18.1	6.9	0.15
2. Straight N 50 kg/ha	2.65	0.21	1.83	0.27	0.88	75.0	3.30	77.0	18.1	6.5	0.16
3. Straight N 100 kg/ha	2.49	0.20	1.79	0.24	0.90	78.0	4.60	403.9	18.4	5.9	0.15
4. Straight N (Floranid N31) 50 kg/ha	2.53	0.21	1.86	0.26	0.77	73.0	3.90	85.8	18.4	6.0	0.15

Appendix 4. Tissue analysis *Carpinus betulus* seedlings, 2023

Table 1. Tissue analysis *Carpinus* Week 34

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	3.89	0.34	1.32	0.35	1.51	254.0	10.10	218.0	39.1	21.5	0.17
2. Straight N 50 kg/ha	3.67	0.36	1.74	0.31	1.28	146.0	9.85	109.0	35.4	15.1	0.24
3. Straight N 100 kg/ha	3.47	0.34	1.38	0.29	1.23	165.0	9.07	141.0	34.9	13.1	0.20
4. Straight N (Floranid N31) 50 kg/ha	3.20	0.34	1.25	0.34	1.39	210.0	10.3	141.0	37.1	17.4	0.16

Table 2. Tissue analysis *Carpinus* Week 37

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	3.09	0.35	1.49	0.34	1.42	360.0	12.0	164.0	43.8	18.8	0.16
2. Straight N 50 kg/ha	3.28	0.33	1.57	0.33	1.43	281.0	10.4	191.0	41.9	14.6	0.17
3. Straight N 100 kg/ha	3.46	0.32	1.60	0.32	1.37	282.0	9.5	150.0	39.4	14.2	0.18
4. Straight N (Floranid N31) 50 kg/ha	3.24	0.33	1.49	0.33	1.40	368.0	11.8	187.0	41.0	18.1	0.16

Table 3. Tissue analysis *Carpinus* Week 41

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.60	0.41	1.89	0.28	1.37	425.0	8.47	247.0	46.0	22.5	0.14
2. Straight N 50 kg/ha	2.74	0.33	1.96	0.28	1.33	325.0	7.36	203.0	42.3	19.2	0.15
3. Straight N 100 kg/ha	3.11	0.27	1.98	0.25	1.33	285.0	6.76	235.0	31.6	16.5	0.16
4. Straight N (Floranid N31) 50 kg/ha	2.74	0.35	1.91	0.27	1.55	431.0	7.58	285.0	35.5	22.3	0.16

Appendix 5. Tissue analysis *Crataegus monogyna* seedlings, 2023

Table 1. Tissue analysis *Crataegus* Week 34

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.37	0.27	1.75	0.26	1.15	41.7	4.20	77.4	22.2	16.4	0.16
2. Straight N 50 kg/ha	2.85	0.29	1.81	0.26	1.11	42.5	5.37	74.8	23.4	12.2	0.21
3. Straight N 100 kg/ha	2.90	0.30	1.84	0.28	1.14	43.4	4.89	74.6	22.7	13.1	0.20
4. Straight N (Floranid N31) 50 kg/ha	2.56	0.28	1.85	0.27	1.05	42.1	4.11	68.4	22.2	15.1	0.17

Table 2. Tissue analysis *Crataegus* Week 37

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.45	0.31	1.87	0.29	1.15	68.0	7.20	83.7	29.4	12.4	0.16
2. Straight N 50 kg/ha	2.61	0.28	1.82	0.30	1.09	64.0	6.90	97.0	28.0	7.9	0.18
3. Straight N 100 kg/ha	2.83	0.28	1.91	0.31	1.05	62.0	6.60	80.8	25.4	7.9	0.19
4. Straight N (Floranid N31) 50 kg/ha	2.63	0.27	1.84	0.30	1.01	65.0	5.60	78.0	25.0	9.0	0.16

Table 3. Tissue analysis *Crataegus* Week 41

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	2.09	0.37	2.20	0.25	0.96	77.7	4.01	79.5	28.9	14.1	0.14
2. Straight N 50 kg/ha	2.18	0.28	2.10	0.24	0.91	78.9	3.79	72.2	22.4	10.8	0.15
3. Straight N 100 kg/ha	2.52	0.27	2.24	0.23	0.88	68.4	3.72	71.1	20.8	10.1	0.17
4. Straight N (Floranid N31) 50 kg/ha	2.30	0.30	2.18	0.23	0.86	73.2	3.96	65.5	24.0	11.8	0.15

Appendix 6. Chlorophyll content of transplants. Measurement of optical density difference at two wavelengths (660 & 940 nanometres)

Table 1. Average chlorophyll content (measured with handheld AtLEAF) for *Betula pendula* leaves during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	37.05	37.38	44.45
2	Straight N 50 kg/ha	40.85	43.90*	45.37
3	Straight N 100 kg/ha	40.10	44.68*	46.37
4	Straight N (Floranid N31) 50 kg/ha	36.52	43.90*	50.82
p value		(NS)	0.005	(NS)
L.S.D.		-	3.711	-

*Statistically significant

Table 2. Average chlorophyll content (measured with handheld atLEAF) for *Carpinus betulus* leaves during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	34.3	35.9	4.75
2	Straight N 50 kg/ha	35.6	32.8	41.83
3	Straight N 100 kg/ha	32.9	41.8	46.02
4	Straight N (Floranid N31) 50 kg/ha	36	36.5	44.90
p value		(NS)	(NS)	(NS)
L.S.D.		-	-	-

Table 3. Average chlorophyll content (measured with handheld atLEAF) for *Crataegus monogyna* leaves during 2023 by week number.

Treatment No	Treatment	Week 30	Week 34	Week 37
1	Untreated	46.65	49.65	53.0
2	Straight N 50 kg/ha	50.20	53.37	51.2
3	Straight N 100 kg/ha	48.50	50.50	55.1
4	Straight N (Floranid N31) 50 kg/ha	46.08	48.87	52.9
p value		(NS)	(NS)	(NS)
L.S.D.		-	-	-

Appendix 7. Chlorophyll content of seedlings. Measurement of optical density difference at two wavelengths (660 & 940 nanometres)

Table 1. Average chlorophyll content (measured with handheld atLEAF) for *Carpinus betulus* leaves during 2023 by week number.

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	32.00	34.4	40.6
2	Straight N 50 kg/ha	30.00	33.6	38.7
3	Straight N 100 kg/ha	31.62	31.7	38.1
4	Straight N (Floranid N31) 50 kg/ha	29.02	34.8	39.2
p value		(NS)	(NS)	(NS)
L.S.D.		-	-	-

Table 2. Average chlorophyll content (measured with handheld atLEAF) for *Crataegus monogyna* leaves during 2023 by week number.

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	35.6	34.35	42.70
2	Straight N 50 kg/ha	41.2	39.62	42.85
3	Straight N 100 kg/ha	34.7	38.27	44.12
4	Straight N (Floranid N31) 50 kg/ha	37.8	39.02	46.45
p value		(NS)	(NS)	(NS)
L.S.D.		-	-	-

Appendix 8. Soil volumetric water content (VMC) of transplants

Table 1. Average soil volumetric water content (VMC) % for *Betula pendula* plots during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	20.68	10.78	17.65
2	Straight N 50 kg/ha	20.18	9.53	17.45
3	Straight N 100 kg/ha	20.00	9.23	15.47
4	Straight N (Floranid N31) 50 kg/ha	21.25	9.78	18.24*
p value		(N/S)	(N/S)	(NS)
L.S.D.		-	-	-

*Statistically significant

Table 2. Average soil volumetric water content (VMC) for *Carpinus betulus* plots during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	22.37*	15.45*	21.78
2	Straight N 50 kg/ha	21.47	15.40*	21.28
3	Straight N 100 kg/ha	20.25	12.43	20.20
4	Straight N (Floranid N31) 50 kg/ha	21.35	16.15*	20.40
p value		0.19	0.03	(N/S)
L.S.D.		1.97	2.40	-

*Statistically significant

Table 3. Average soil volumetric water content (VMC) for *Crataegus monogyna* plots during 2023 by week number

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	19.77	11.15	18.70
2	Straight N 50 kg/ha	20.67	12.45	19.05
3	Straight N 100 kg/ha	20.00	11.87	17.55
4	Straight N (Floranid N31) 50 kg/ha	21.32	12.92	18.00
p value		(N/S)	(N/S)	(N/S)
L.S.D.		-	-	-

* Statistically significant

Appendix 9. Soil volumetric water content (VMC) of seedlings

Table 1. Average soil volumetric water content (VMC) for *Carpinus betulus* plots during 2023 by week number

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	17.77	19.10	17.50
2	Straight N 50 kg/ha	15.87	17.85	15.15
3	Straight N 100 kg/ha	18.12	16.35	13.17*
4	Straight N (Floranid N31) 50 kg/ha	16.25	17.02	16.40
p value		(N/S)	(N/S)	0.02
L.S.D.		-	-	2.58

***Statistically significant**

Table 2. Average soil volumetric water content (VMC) for *Crataegus monogyna* plots during 2023 by week number

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	14.40*	17.43*	13.85
2	Straight N 50 kg/ha	11.88	12.90	11.10
3	Straight N 100 kg/ha	11.88	13.95	10.78
4	Straight N (Floranid N31) 50 kg/ha	12.10	13.82	12.03
p value		<.001	0.03	-
L.S.D.		1.38	2.96	(N/S)

* Statistically significant

Appendix 10. Soil electronic conductivity (EC), transplants

Table 1. Average soil EC (μS/cm) for *Betula pendula* plots during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	2042	1955	2008
2	Grower standard	2142	1945	2012
3	Straight N, P, K, Mg.	2110	1975	2118
4	Straight N (Floranid N31), P, K, Mg.	2252*	1942	2035
p value		0.053	-	0.061
L.S.D.		144.1	(N/S)	(NS)

* Statistically significant

Table 2. Average Soil electronic conductivity (EC) in Microsiemens (μS/cm) for *Carpinus betulus* plots during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	2072	2018	2078
2	Grower standard	2150	2022	2072
3	Straight N, P, K, Mg.	2070	2190	2428*
4	Straight N (Floranid N31), P, K, Mg.	2348*	2060	2092
p value		0.002	-	0.006
L.S.D.		118.4	(NS)	191.5

* Statistically significant

Table 3. Average Soil electronic conductivity (EC) in Microsiemens (µS/cm) for *Crataegus monogyna* plots during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	2015	2125*	2025
2	Grower standard	2148	2002	2042
3	Straight N, P, K, Mg.	2322	2005	2208*
4	Straight N (Floranid N31), P, K, Mg.	2210	1990	2035
p value		-	0.006	0.027
L.S.D.		(N/S)	101.5	125.6

* Statistically significant

Appendix 11 – Soil electronic conductivity (EC) in Microsiemens (µS/cm) of Seedlings

Table 1. Average soil electronic conductivity (EC) in (µS/cm) for *Carpinus betulus,* 2023 by week number.

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	2085	2148	2135
2	Grower standard	2340	2160	2072
3	Straight N, P, K, Mg.	2355*	2395*	2095
4	Straight N (Floranid N31), P, K, Mg.	2148	2268	2115
p value		0.028	0.042	-
L.S.D.		197.2	180.3	(N/S)

*Statistically significant

Table 2. Average soil electronic conductivity (EC) (µS/cm) for *Crataegus monogyna,* 2023 by week number.

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	2010	2100	1995
2	Grower standard	2028	2068	1955
3	Straight N, P, K, Mg.	2028	2830*	2205*
4	Straight N (Floranid N31), P, K, Mg.	2100	2215	2075
p value		-	0.007	0.004
L.S.D.		(N/S)	409.3	116.5

*Statistically significant

Appendix 12. Soil temperature in transplants

Table 1. Average soil temperature (°C) for *Betula pendula* plots during 2023 by week number.

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	21.88	17.70	18.43
2	Grower standard	21.70	17.70	18.40
3	Straight N, P, K, Mg.	21.78	17.68	18.40
4	Straight N (Floranid N31), P, K, Mg.	21.80	17.63	18.40
p value		-	-	-
L.S.D.		(N/S)	(N/S)	(N/S)

Table 2. Average soil temperature (°C) for *Carpinus betulus* plots during 2023 by week number

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	21.88	15.45*	21.78
2	Grower standard	21.75	15.40*	21.28
3	Straight N, P, K, Mg.	21.83	12.43	20.20
4	Straight N (Floranid N31), P, K, Mg.	21.85	16.15*	20.40
p value		-	0.028	-
L.S.D.		(N/S)	2.40	(N/S)

Table 3. Average soil temperature (°C) for *Crataegus monogyna* plots during 2023 by week number

Treatment No.	Treatment	Week 30	Week 34	Week 37
1	Untreated	23.05	18.63	19.48
2	Grower standard	23.13	18.60	19.38
3	Straight N, P, K, Mg.	23.13	18.70	19.53
4	Straight N (Floranid N31), P, K, Mg.	23.03	18.70	19.45
p value		-	-	-
L.S.D.		(N/S)	(N/S)	(N/S)

Appendix 13. Soil temperature (°C), seedlings

Table 1. Average soil temperature (°C) for *Carpinus betulus* plots during 2023 by week number

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	23.8	21.1	19.2
2	Grower standard	23.8	21.0	19.2
3	Straight N, P, K, Mg.	23.8	21.0	19.1
4	Straight N (Floranid N31), P, K, Mg.	23.8	21.0	19.0
p value		-	-	-
L.S.D.		(N/S)	(N/S)	(N/S)

Table 2. Average soil temperature (°C) for *Crataegus monogyna* plots during 2023 by week number

Treatment No.	Treatment	Week 34	Week 37	Week 41
1	Untreated	24.6	22.1	18.7
2	Grower standard	24.6	22.0	18.8
3	Straight N, P, K, Mg.	25.0	22.1	18.8
4	Straight N (Floranid N31), P, K, Mg.	24.6	22.1	18.7
p value		-	-	-
L.S.D.		(N/S)	(N/S)	(N/S)

