Project title:	Developing Nutrient Management Recommendations for Selected Horticulture Crops.
Project number:	HNS 200.
Project leader:	Jill England, RSK ADAS Ltd.
Report:	Annual report, June 2023.
Previous report:	N/A
Key staff:	Jill England David Talbot Elysia Bartel John Adlam Susie Holmes
Location of project:	Wyevale Nurseries Transplants Division, Herefordshire. RSK ADAS Ltd., Boxworth, Cambridge
Industry Representative:	James Moffatt, James Coles & Sons (Nurseries) Ltd., Leicester
Date project commenced:	1 April 2019

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.

David Talbot

Senior Horticulture Consultant

ADAS]

Signature .... David P. Talbot .... Date ....21 June 2023................

Dr Jill England

Technical Director, Head of Horticulture

ADAS

Signature .... Date ....21 June 2023................

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GROWER SUMMARY

Headline

- Under low soil mineral N (SNS Index 0) and Magnesium (Mg) (Index 1) indices, growth of *Betula pendula, Carpinus betulus* and *Crataegus monogyna* 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.

Background

Field HNS growers typically use single nutrients known as straights (e.g., ammonium nitrate) or compound fertilisers (containing mixes of nitrogen (N), phosphorus (P) and potassium (K) fertilisers or nitrogen (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 soil to help determine rates 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 Nmax 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 usage directly contributes to greenhouse gas emissions and hence climate change so efficient use of N fertilisers is vitally important in the horticulture sectors 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 are now part of their nutrient action programme – since January 2020, there are 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 ornamental chloride-sensitive genera; potassium sulphate is a more suitable K source for ornamental crops (Lindberg, B. and Cregg, B., C., 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. Although sulphate of potash (SOP) is generally regarded as a relatively high cost source of potash for application to soil in agriculture, but a very important source of nutrient in horticulture, 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 2

Objective 1: To further evaluate / validate the soil and tissue analysis methods used in year one for correlation with crop nutritional needs on up to three commonly grown species from three vigour groups (high, medium, and low)

Objective 2: Establish baseline nutritional information for specific crops (i.e., seedlings, vigour groups).

Objective 3: To compare crop nutrient status as a result of different fertiliser delivery systems (i.e., straight or compound fertilisers, slow-release N).

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.**

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, Treatment 2, Table 1.

Table 1. 2022 Field tree trial year two treatments, quantities of products applied in kg/ha. Quantities of nutrients supplied to each treatment in kg /ha hectare are shown as footnotes below this table.

Treatment number	Product (name)	Nutrient content	Application 1 June, Rate (kg/ha)	Application 2 July, Rate (kg/ha)	Application 3 August, Rate (kg/ha)
1. Untreated	-	-	Untreated	Untreated	Untreated
2. Grower standard[1]	Origin 27% N (27 - 0 - 0 + 10 SO3)	NS Compound	90	90	
	Potash Plus (0 – 0 – 37 – 23 SO3 – 8 Mg0 – 8 Ca)	MOP, KCL, Polysulphate, Ca + Mg	125	-	-
3. Straight N, P, K, Mg[2]	Origin 27% N (27 - 0 - 0 + 10 SO3)	NS Compound	186	186	186
	Tripple super phosphate (0 - 46 - 0)	TSP	55		
	Sulphate of Potash (0-0-51+18 S03)	SOP	148		
	Kieserite (16% Mg)	Mg0	313		
4. Straight N (Floranid N31), P, K, Mg[3]	Floranid N31 (31% N)	N	323	162	
	Tripple super phosphate (0 - 46 - 0)	TSP	55		
	Sulphate of Potash (0 - 0 -51+18 S03)	SOP	148		
	Kieserite (16% Mg)	Mg	313		

Actual nutrient content applied in kg/ha by treatment:

[1]The grower standard treatment supplied two applications of 24.3 kg/ha N. In addition, the following quantities of nutrients were supplied at application 1: 46.3 kg/ha K, 37.8 kg/ha SO3,10 kg/ha Mg & 10 kg/ha Ca. 9 kg/ha SO3 was applied at application 2.

[2]Treatment 3 supplied three applications of 50.2 kg/ha N. In addition, the following quantities of nutrients were supplied at application 1: 25.3 kg/ha P, 75.5 kg/ha K + 45.2 kg/ha SO3, and 50.1 kg/ha Mg. 18.6 kg/ha SO3 was applied at application 2 and 3.

[3]Treatment 4 supplied 100.1 and 50.2 kg/ha N at applications 1 & 2 respectively. In addition, the following quantities of nutrients were supplied at application 1: 25.3 kg/ha P, 75.5 kg/ha K, 26.6 kg/ha SO3, and 50.1 kg/ha Mg.

2022 Field Tree Trial

This field tree nutrition trial was set up in 2022 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 slow-release forms 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 index. 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.

The fertiliser 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 young trees 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 (see **Table 3, Science section).** 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 was SMN Index 0, P Index 3, K Index 2+ and Mg Index 1; P, K and Mg levels were below the target levels in RB209 5th edition.

There were no statistically significant differences (*P*>0.05) in mean height measurements between treatments (including the untreated controls) in all three species when measured in weeks 30, 34 and 37.

There were no statistically significant differences (*P*>0.05) in mean chlorophyll content between treatments or species measured by the atLEAF 30 at any of the assessment dates.

There were no statistically significant differences (*P*>0.05) in leaf tissue analysis results between treatments within species. 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 (see **Table 5**)

Discussion

There was no effect of fertiliser treatments on crop growth (assessed by height measurements) in *Betula, Carpinus* or *Crataegus* within this trial during the 2022 growing season. The fact that plants performed equally well where fertiliser NPK and no fertiliser was applied despite the low SNS (P index 3, K index 2+) 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 to a typical growing season due to a limited supply of water in the reservoir and the need to prioritise irrigation for crops with the highest irrigation need (e.g., first year seedlings). It is estimated that around 40% less irrigation was applied to trial (and much of the commercial crop on the nursery) compared to an average season, due to limited water resources. Monitoring the soils moisture content showed the soil to be consistently dry at the three assessment dates when soil volumetric water content was measured (see **Appendix 5**). 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 on crop growth compared to an average season.

This is the second 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. This second fertiliser response experiment has also shown no response to N, and although the response to N may have been limited by the drought, the two years of no fertiliser N response despite low SNS index at both sites is an important result for growers and indicates that *Betula, Carpinus* and *Crataegus* requirement for N may be less 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.

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. However, the hot and dry weather during summer 2022 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.

Financial Benefits

The host nursery application of 180 kg/ha 27-0-0+10S, (27% N), P, K, Mg and Ca fertiliser cost £323/ha. The slow-release form of N (Floranid N31) is more expensive per kilogram of N than the grower standard fertiliser. 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.

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). Although this implies these species have a low N requirement, the hot dry conditions of 2022 may have limited growth and response to fertiliser. *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 30 kg N/ha to typical fertiliser N application rates would save growers £34/ha at current fertiliser prices of £390/tonne of Ammonium Nitrate (AHDB, 2023).

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 soil (typically every three years) to help determine rates of fertiliser to apply. Soil sampling for soil mineral nitrogen (SMN) is less commonly done than sampling for P, K & Mg. 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 standard fertiliser recommendations for field grown HNS species that are readily accessible to UK growers. This may be another reason why some nurseries do not routinely carry out soil analysis as it can be difficult for them to interpret the results and decide upon appropriate rates of N, P, K and Mg to apply, even where soil analysis is carried out to determine reserves of these nutrient in the soil. Because of the high value of field grown HNS in relation to broad acre arable crops the cost of fertiliser is relatively low compared to the value of the crop, which can result in excessive quantities being applied.

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 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 higher P Index soils as this increases the risk of P loss to water. This is particularly important on fields which are at high risk of soil erosion (generally lighter textured soils on sloping land) as field grown HNS provide limited soil cover which increases the risk of overland flow and soil erosion following heavy rainfall.

A better understanding of field grown HNS species' nutritional needs could help to prevent vigorous species being overfed, helping to control their vigour whilst delivering increased profitability and environmental benefits through more sustainable fertiliser usage. 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 some ornamental chloride-sensitive genera.

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 2 (2022)

Objective 1: To further evaluate / validate the soil and tissue analysis methods used in year one for correlation with crop nutritional needs on up to three commonly grown species from three vigour groups (high, medium, and low)

Objective 2: Establish baseline nutritional information for specific crops (i.e., seedlings, vigour groups).

Objective 3: To compare crop nutrient status as a result of different fertiliser delivery systems (i.e., straight or compound fertilisers, slow-release N).

This project is comprised of three work packages:

WP1. HNS (field and container) Literature review

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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 2022 at Wyevale Nurseries, Transplant division, Ledbury, Herefordshire on transplants of three species: *Betula pendula, 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). Transplants were planted in the field; *Betula pendula* were 60 – 80cm, *Crataegus monogyna* were 40 – 60 cm and *Carpinus betulus* were 20 – 40 cm. Transplants had been grown from seed drilled in 2021, seedlings were lifted, graded and cold stored prior to being planted out in week 21 2022 in a field of loamy sand. Soil analysis was taken in spring 2022, prior to fertiliser application and sent to NRM laboratories for analysis, results are shown below in **Table 3**

A randomised block design within species was used with three treatments including an untreated control, a commercial standard (Origin 27% N and 10 SO3), straight nutrients to supply three applications of 50 kg/ha N. P, K and Mg were applied in line with soil analysis and recommendations from RB209 5th edition in conjunction with N at the first application. Straight nitrogen was also applied using a slow-release N source (Floranid N31). Fertiliser was weighed out for each plot and was broadcast by hand over plots. An untreated control had no fertiliser applied. All treatments were replicated four times. Plots measured 3 m x 1.2 m.

Ten representative transplants per plot were tagged (week 25) with either a cable tie or coloured string), they were 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 in centimetres within treatments during the trial.

Chlorophyll measurements using the atLEAF handheld device, avoiding the main leaf rib, and samples for leaf tissue analysis were taken at each assessment date (taken in weeks 30, 34 & 37). Samples taken for leaf tissue analysis were taken from 2 inches / 5.08cm below the growing point, selecting the youngest fully open leaf, combining leaves from across the plot to ensure sufficient plant material for analysis. Measurements of soil electrical conductivity (EC), soil volumetric water content (VMC) and soil temperature (°C) were taken with 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 2.**

Table 2. .2022 Field tree trial year two treatments, quantities of products applied in kg/ha. Quantities of nutrients supplied to each treatment in kg /ha hectare are shown as footnotes below this table.

Treatment number	Product (name)	Nutrient content	Application 1 June, Rate (kg/ha)	Application 2 July, Rate (kg/ha)	Application 3 August, Rate (kg/ha)
1. Untreated	-	-	Untreated	Untreated	Untreated
2. Grower standard[1]	Origin 27% N (27 - 0 - 0 + 10 SO3)	NS Compound	90	90	
	Potash Plus (0 – 0 – 37 – 23 SO3 – 8 Mg0 – 8 Ca)	MOP, KCL, Polysulphate, Ca + Mg	125	-	-
3. Straight N, P, K, Mg[2]	Origin 27% N (27 - 0 - 0 + 10 SO3)	NS Compound	186	186	186
	Tripple super phosphate (0 - 46 - 0)	TSP	55		
	Sulphate of Potash (0-0-51+18 S03)	SOP	148		
	Kieserite (16% Mg)	Mg0	313		
4. Straight N (Floranid N31), P, K, Mg[3]	Floranid N31 (31% N)	N	323	162	
	Tripple super phosphate (0 - 46 - 0)	TSP	55		
	Sulphate of Potash (0 - 0 -51+18 S03)	SOP	148		
	Kieserite (16% Mg)	Mg	313		

Actual nutrient content applied in kg/ha by treatment:

[1]The grower standard treatment supplied two applications of 24.3 kg/ha N. In addition, the following quantities of nutrients were supplied at application 1: 46.3 kg/ha K, 37.8 kg/ha SO3,10 kg/ha Mg & 10 kg/ha Ca. 9 kg/ha SO3 was applied at application 2.

[2]Treatment 3 supplied three applications of 50.2 kg/ha N. In addition, the following quantities of nutrients were supplied at application 1: 25.3 kg/ha P, 75.5 kg/ha K + 45.2 kg/ha SO3, and 50.1 kg/ha Mg. 18.6 kg/ha SO3 was applied at application 2 and 3.

[3]Treatment 4 supplied 100.1 and 50.2 kg/ha N at applications 1 & 2 respectively. In addition, the following quantities of nutrients were supplied at application 1: 25.3 kg/ha P, 75.5 kg/ha K, 26.6 kg/ha SO3, and 50.1 kg/ha Mg.

Data was analysed by ANOVA using Genstat 18.2; significant differences from the untreated control were determined by using least significant difference (LSD)

Results

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

Table 3. Soil analysis, prior to planting and 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
6.7	3	42	2+	185	1	46	1.9

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

Table 4. 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	19	5.28	24
30 – 60 cm	10.52	5.16	16
60 – 90 cm	14.48	5.84	20
Total of all sample depths	44	16.3	60

There were no significant differences in mean height measurements within species between treatments when measured in weeks 30, 34 and 37 (**Tables 7 - 9**). When averaging mean heights across all treatments within a species, *Betula* grew by 32.65 cm, *Carpinus* grew by 17.68 cm and *Crataegus* grew by 9.46cm between weeks 25 and 48.

Height measurements in centimetres (cm)

Table 6. Average heights for *Betula pendula* and mean growth in cm during 2022.

Treatment. Number.	Treatment.	Start of trial	End of growing season total	Mean growth in cm
1	Untreated	65.7	98.6	32.88
2	Grower standard	64.5	94.9	30.46
3	Straight N, P, K, Mg.	64.4	98.5	34.09
4	Straight N (Floranid N31), P, K, Mg.	67.7	100.9	33.17
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 7. Average heights for *Carpinus betulus* and mean growth in cm during 2022.

Treatment. Number.	Treatment.	Start of trial	End of growing season total	Mean growth in cm
1	Untreated	37.54	55.42	17.88
2	Grower standard	38.74	56.09	17.32
3	Straight N, P, K, Mg.	37.77	55.91	18.14
4	Straight N (Floranid N31), P, K, Mg.	38.12	55.50	17.37
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 8. Average heights for *Crataegus monogyna* and mean growth in cm during 2022.

Treatment. Number.	Treatment.	Start of trial	End of growing season total	Mean growth in cm
1	Untreated	58.21	67.60	9.39
2	Grower standard	58.73	68.62	9.90
3	Straight N, P, K, Mg.	56.87	66.37	9.51
4	Straight N (Floranid N31), P, K, Mg.	58.05	67.09	9.04
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

There were no significant differences in mean chlorophyll content within species between untreated controls and fertilised treatments at any point during the trial (See **Appendix 4, Tables 1-3**).

There were no significant differences within species between treatments in mean soil volumetric water content (see **Appendix 5, Tables 1 – 3)** or mean soil temperatures (see **Appendix 7, Tables 1 – 3)** between treatments.

There were no significant differences in mean soil EC until week 34 when soil EC was significantly higher in fertilised plots of *Betula* and *Carpinus* (treatments 2, 3 and 4) compared to the untreated controls. There was no significant difference in soil EC between treatments (including the untreated) at the next and final assessment in week 37 (see **Appendix 6, Tables 1 – 3**).

When comparing tissue analysis results **(Appendix 1 – 3)** with published figures **(Tables 10 - 12)** the published figures suggest the following:

Table 9 Summary table of tissue analysis where high or low levels were found compared with published figures (see Tables 10 – 12 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 week 30*	Nitrogen, Phosphorus (T2, T3 & T4), Potassium Manganese, Copper, Iron, Zinc, Boron & Sulphur.	Calcium.
Betula week 34*	Nitrogen, Phosphorus, Potassium, Magnesium, Manganese, Copper, Iron, Zinc, Boron & Sulphur.	Calcium.
Betula week 37*	Nitrogen (T2), Phosphorus (T1, T3, T4), Potassium, Manganese, Copper, Iron (T2 & T3), Zinc, Boron & Sulphur (T2).	Nitrogen (T3 & T4), Calcium, Iron (T1 & T4) and Sulphur (T1, T3 & T4).

Carpinus week 30	Calcium (T2, T3 & T4), Magnesium, Manganese (T3), Boron & Sulphur.	Potassium.
Carpinus week 34	Calcium, Magnesium, Boron & Sulphur.	Potassium & Iron (T2 & T3).
Carpinus week 37	Magnesium, Sulphur & Boron.	Nitrogen (T2, T3, T4) Phosphorus (T4) & Potassium.
Crataegus week 30	Phosphorus, Calcium, Copper, Zinc & Boron.	Nitrogen, Potassium Manganese & Sulphur (T1 & T2 only).
Crataegus 34	Phosphorus, Calcium, Copper, Zinc & Boron.	Nitrogen, Potassium & Manganese.
Crataegus 37	Phosphorus, Calcium, Magnesium, Copper, Zinc & Boron.	Nitrogen, Potassium, Manganese & Sulphur (T1, T3 & T4).

* 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).**.

Discussion

None of the treatments resulted in any significant difference in the growth (determined by height measurements) of the three species within this trial during the 2022 growing season (See **Appendix 8, Figures 1 – 12)**

A severe drought occurred during the spring and summer of 2022, accompanied by a succession of extreme heatwaves. Extreme heat events can impact negatively on growth; as the leaf level photosynthesis is reduced, stress increases and the growth rate of remaining leaves decreases. Heat stress can decrease plant growth, carbon gain and can shift biomass allocation. When drought stress accompanies heat waves, the negative effects of heat stress are exacerbated. Higher temperatures increase atmospheric vapour pressure deficit which increases evaporation, resulting in more rapid soil drying and increased drought severity (Teskey *et al.,* 2014).

The host grower also confirmed that high temperatures can induce a temporary dormancy in many species of young broad-leaved trees which is becoming an increasing problem in the production of transplants. The host grower 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, *Betula* grew by 32.65 cm, *Carpinus* grew by 17.68 cm and *Crataegus* grew by 9.46cm between weeks 25 and 48.

Less irrigation was applied to the trial plots during 2022 compared to a typical growing season due to a limited supply of water in the reservoir and the need to prioritise irrigation for crops with the highest irrigation need (e.g., first year seedlings). It is estimated that around 40% less irrigation was applied to trial (and much of the commercial crop on the nursery) compared to an average season, due to limited water resources. Monitoring the soils moisture content showed the soil to be consistently dry at the three assessment dates when soil volumetric water content was measured (see **Appendix 5**)

Despite a challenging growing season, 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 1.9%, 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 10 - 12.** 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 10. 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 11. 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 12. 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 – 1.58	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.

Conclusions

No difference in growth (determined by height measurements) occurred within species between *Betula pendula, Carpinus Betula* and *Crataegus monogyna* in any of the treatments. This included the untreated plots that received no fertiliser. This indicates that these species are either highly effective at taking N up or have a lower N requirement than is widely assumed.

Previous trials work within this project indicated that *Betula* may not have a high N requirement for growth as this species readily colonises heathland and other habitats that are naturally low in N. There may be potential to further reduce N applications to this species whilst maintaining the desired crop growth.

The extreme heat experienced at times during 2022 combined with periods of drought undoubtably limited the growth of the species within this trial. Had the weather been less extreme there is a possibility that greater differences between treatments may have been found.

Unnecessary applications of some nutrients are potential environmentally damaging whilst also increasing production costs. Therefore, there is potential for savings on fertiliser use and associated application costs through the use of regular soil analysis to accurately determine soil reserves of major nutrients.

Further work is required to determine the optimum nutrition of a range of species of important field grown hardy nursery stock crops including the importance of micronutrient availability. A better understanding of hardy nursery stock nutrient offtake at harvest would help growers to quantify field grown hardy nursery stock nutritional needs.

Although this trial has indicated that these species can perform well when some major nutrients are at low levels, regular (before planting or every three years) soil analysis to determine soil nutrient levels and tailoring fertiliser applications to crop need based on the soil analysis is still recommended.

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.

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Appendices

Appendix 1 – Tissue Analysis ***Betula pendula***

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	3.81	0.36	1.69	0.27	0.72	203	6.6	92.4	120.6	19.6	0.24
2. Grower standard	3.78	0.34	1.64	0.26	0.66	164	5.6	92.1	105.7	17.6	0.23
3. Straight N, P, K, Mg	3.88	0.31	1.61	0.25	0.65	151	5.6	91.8	86.2	18.0	0.23
4. Straight N (Floranid N31), P, K, Mg	3.80	0.35	1.65	0.26	0.66	180	6.0	90.9	106.1	20.0	0.23

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	3.06	0.25	1.30	0.21	0.60	189	4.5	99.0	91.2	24.9	0.19
2. Grower standard	3.32	0.27	1.30	0.24	0.66	179	4.6	99.7	87.3	25.5	0.22
3. Straight N, P, K, Mg	3.44	0.25	1.30	0.23	0.61	161	4.2	98.1	72.6	25.2	0.21
4. Straight N (Floranid N31), P, K, Mg	3.31	0.26	1.27	0.21	0.57	189	4.7	94.2	90.5	26.5	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	4.04	0.30	1.34	0.29	0.86	371	4.8	203.2	83.6	32.3	0.28
2. Grower standard	3.65	0.40	1.32	0.25	0.74	415	5.4	171.6	118.1	35.9	0.23
3. Straight N, P, K, Mg	4.99	0.27	1.38	0.31	0.91	403	3.8	155.4	96.8	27.2	0.27
4. Straight N (Floranid N31), P, K, Mg	5.84	0.30	1.21	0.26	0.77	371	5.0	206.1	92.3	35.7	0.27

Appendix 2 – Tissue Analysis ***Carpinus betulus***

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	2.68	0.20	1.12	0.26	1.18	347	4.4	87.7	30.0	14.3	0.17
2. Grower standard	2.75	0.18	1.06	0.24	1.11	292	3.8	93.4	27.8	13.3	0.17
3. Straight N, P, K, Mg	2.86	0.19	1.07	0.24	1.17	208	4.1	92.9	28.3	13.0	0.18
4. Straight N (Floranid N31), P, K, Mg	2.79	0.18	0.99	0.24	1.10	272	4.0	91.6	29.6	11.8	0.17

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	2.63	0.15	1.10	0.19	1.03	302	3.7	88.4	28.0	16.6	0.15
2. Grower standard	2.72	0.15	1.16	0.18	1.07	278	3.6	70.49.0	44.6	20.1	0.15
3. Straight N, P, K, Mg	2.83	0.16	1.15	0.19	1.10	271	3.3	136.1	30.2	17.2	0.16
4. Straight N (Floranid N31), P, K, Mg	2.74	0.16	1.10	0.20	1.15	282	3.8	110.1	29.0	15.8	0.16

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	2.77	0.18	1.23	0.19	1.26	493	3.5	98.8	28.3	20.8	0.17
2. Grower standard	3.84	0.18	1.34	0.17	1.22	416	3.2	86.0	29.3	22.3	0.17
3. Straight N, P, K, Mg	3.41	0.17	1.43	0.18	1.26	415	3.5	100.3	28.9	20.7	0.18
4. Straight N (Floranid N31), P, K, Mg	5.01	0.22	1.46	0.21	1.35	383	3.6	94.4	29.2	22.3	0.17

Appendix 3 – Tissue Analysis ***Crataegus monogyna***

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	2.24	0.14	1.70	0.29	1.27	93	1.9	65.4	18.3	9.3	0.16
2. Grower standard	2.24	0.14	1.69	0.29	1.30	99	1.9	59.2	20.8	8.4	0.16
3. Straight N, P, K, Mg	2.23	0.14	1.67	0.30	1.27	86	1.9	57.4	17.4	8.2	0.15
4. Straight N (Floranid N31), P, K, Mg	2.28	0.14	1.73	0.31	1.30	83	1.6	61.0	15.6	9.1	0.15

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	2.14	0.14	1.66	0.29	1.24	99	1.7	82.3	16.6	13.5	0.14
2. Grower standard	2.14	0.13	1.58	0.27	1.26	108	1.8	68.0	18.1	10.9	0.14
3. Straight N, P, K, Mg	2.13	0.13	1.55	0.28	1.24	101	1.7	74.9	16.4	10.8	0.14
4. Straight N (Floranid N31), P, K, Mg	2.12	0.13	1.54	0.28	1.26	99	1.4	72.0	15.3	11.2	0.14

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	2.44	0.16	1.56	0.27	1.26	106	1.4	77.1	21.4	12.7	0.16
2. Grower standard	2.53	0.14	1.49	0.25	1.24	120	2.0	64.7	20.9	10.6	0.15
3. Straight N, P, K, Mg	2.46	0.14	1.68	0.27	1.33	112	1.5	61.2	17.1	11.5	0.16
4. Straight N (Floranid N31), P, K, Mg	2.49	0.15	1.65	0.27	1.28	107	1.2	58.9	16.3	12.0	0.17

Appendix 4 – Chlorophyll content – 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 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	53.43	54.60	54.5
2	Grower standard	52.45	54.83	59.4
3	Straight N, P, K, Mg.	51.43	55.88	55.0
4	Straight N (Floranid N31), P, K, Mg.	54.68	54.15	58.6
p value		(NS)	(NS)	(NS)
L.S.D.		-	-	-

Table 2. Average chlorophyll content (measured with handheld atLEAF) for ***Carpinus betulus*** leaves during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	37.8	47.2	51.6
2	Grower standard	39.7	47.7	51.3
3	Straight N, P, K, Mg.	37.1	48.5	50.2
4	Straight N (Floranid N31), P, K, Mg.	35.8	47.1	52.1
p value		(NS)	(NS)	(NS)
L.S.D.		-	-	-

Table 3. Average chlorophyll content (measured with handheld atLEAF) for *Crataegus monogyna* leaves during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	46.65	49.65	53.0
2	Grower standard	50.20	53.37	51.2
3	Straight N, P, K, Mg.	48.50	50.50	55.1
4	Straight N (Floranid N31), P, K, Mg.	46.08	48.87	52.9
p value		(NS)	(NS)	(NS)
L.S.D.		-	-	-

Appendix 5 – Soil volumetric water content (VMC)

Table 1. Average soil volumetric water content (VMC) % for *Betula pendula* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	9.35	12.23	11.65
2	Grower standard	10.17	12.30	12.38
3	Straight N, P, K, Mg.	11.70	12.00	11.95
4	Straight N (Floranid N31), P, K, Mg.	11.32	14.35	12.50
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 2. Average soil volumetric water content (VMC) for *Carpinus betulus* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	14.6	14.4	13.3
2	Grower standard	13.1	14.6	14.5
3	Straight N, P, K, Mg.	13.3	14.2	12.8
4	Straight N (Floranid N31), P, K, Mg.	14.1	15.3	14.5
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 3. Average soil volumetric water content (VMC) for *Crataegus monogyna* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	11.45	15.12	13.53
2	Grower standard	11.63	12.30	13.75
3	Straight N, P, K, Mg.	12.55	12.70	13.73
4	Straight N (Floranid N31), P, K, Mg.	12.13	14.70	14.43
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

* Statistically significant at 95% confidence

Appendix 6 – Soil electronic conductivity (EC) in Microsiemens (µS/cm)

Table 1. Average Soil electronic conductivity (EC) in Microsiemens (µS/cm) for *Betula pendula* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	840	1778	1350
2	Grower standard	1535	3158*	1738
3	Straight N, P, K, Mg.	2175	3460*	2532*
4	Straight N (Floranid N31), P, K, Mg.	1838	3170*	1922
L.S.D.		(N/S)	655.3	(N/S)
p value		-	0.001	-

*Statistically significant at 95% confidence

Table 2. Average soil electronic conductivity (EC) in Microsiemens (µS/cm) for *Carpinus betulus* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	1972	2048	1762
2	Grower standard	2375	3292*	3062
3	Straight N, P, K, Mg.	2652	3080*	2995
4	Straight N (Floranid N31), P, K, Mg.	2802	3412*	2992
L.S.D.		(N/S)	508.8	(N/S)
p value		-	<0.001	-

*Statistically significant at 95% confidence

Table 3. Average soil electronic conductivity (EC) in Microsiemens (µS/cm) for *Crataegus monogyna* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	1535	2372	1932
2	Grower standard	1922	3045	2510
3	Straight N, P, K, Mg.	2130	3265	3012
4	Straight N (Floranid N31), P, K, Mg.	1882	3035	2788
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Appendix 7 – Temperature in °C

Table 1. Average soil temperature (°C) for *Betula pendula* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
1	Untreated	24.1	21.3	19.1
2	Grower standard	24.0	21.4	19.5
3	Straight N, P, K, Mg.	24.1	21.4	19.3
4	Straight N (Floranid N31), P, K, Mg.	24.1	21.5	19.1
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 2. Average soil temperature (°C) for *Carpinus betulus* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
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
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Table 3. Average soil temperature (°C) for *Crataegus monogyna* plots during 2022 by week number.

Treatment. Number.	Treatment.	Week 30	Week 34	Week 37
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
L.S.D.		(N/S)	(N/S)	(N/S)
p value		-	-	-

Appendix 8 – Photographs of treatments by Genus, week 30

Figure 1: *Betula pendula* T1

Figure 2: *Betula pendula* T2

Figure 3: *Betula pendula* T3

Figure 4: *Betula pendula* T4

	
Figure 5: *Carpinus betulus* T1	**Figure 6:** *Carpinus betulus* T2
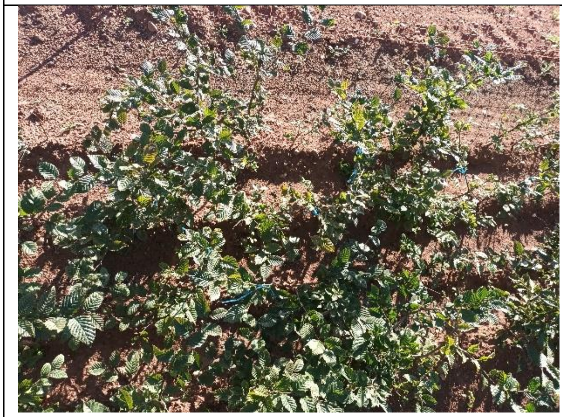	
Figure 7: *Carpinus betulus* T3	**Figure 8:** *Carpinus betulus* T4

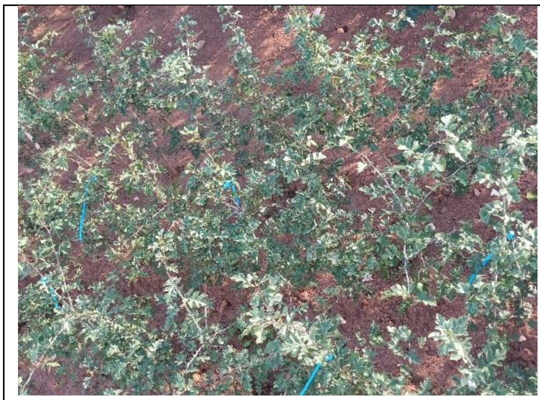

Figure 9: *Crataegus monogyna* T1

Figure 10: *Crataegus monogyna* T2

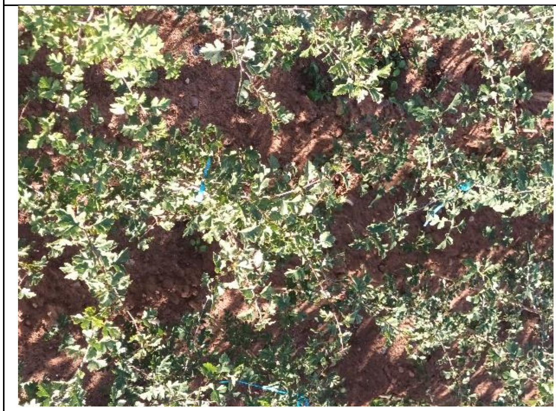

Figure 11: *Crataegus monogyna* T3

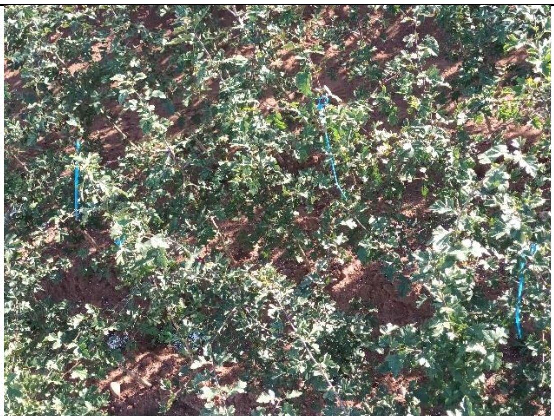

Figure 12: *Crataegus monogyna* T4

