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

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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.

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Grower Summary

Headlines

- Under high soil P, K and Mg indices, growth was not affected by additional fertiliser.
- Crop nutrient offtake (nutrients removed by plants when the crop is lifted) is relatively low in *Betula utilis* var*. jacquemontii*

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), 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 residual N is less common than sampling for P, K & Mg. Other nurseries do not currently carry out regular soil analysis; some of those that do carry out soil analysis sometimes struggle to interpret the results and simply apply the same rates of fertiliser every year, regardless of soil nutrient indices / crop need. 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.

Because of the high value of field grown HNS in relation to the price of fertiliser, the cost of 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) that can be applied in Nitrate Vulnerable Zones (NVZs) to prevent the pollution of water. Fertiliser production and usage directly contributes to greenhouse gas emissions and hence climate change so efficient use of N fertilisers is vitally important. 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 pollution 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. Urea-based N fertilisers are generally cheaper than ammonium nitrate however ornamental species do not all respond as well to urea.

Aim of the trial: To establish baseline information on nutrition for field-grown HNS trees, 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 1

Objective 1: To take soil and tissue analyses from one species with existing data for comparable nutrient levels (samples taken up to 4 times per growing season), measure soil EC and use chlorophyll meters to determine crop nutrient status.

Objective 2: To determine which method provides the most robust data on the test crop nutritional status, correlates most closely with crop nutritional needs and is easy to interpret.

Objective 3: To compare crop nutrient status due to novel targeted fertiliser application methods (broadcast vs band application).

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 2019 a field tree nutrition trial was carried out on field grown *Betula utilis* var. *jacquemontii* using the host nursery's standard rate of fertiliser.

Table 1. 2019 Field tree trial year one treatments.

Treatment number	Application method	Product (name)	Nutrient content	Rate (L/ha or kg/ha)
1.	-	-	-	Untreated
2.	Broadcast (nursery standard treatment)	Glasson Fertilisers 20 -10 - 10	Ammonical nitrogen (Ammonia) 11.1% Nitric nitrogen 8.1% Phosphorus pentoxide (P205) Potassium oxide (K20) as muriate of Potash	370
3.	Band application to crop rows	Glasson Fertilisers 20 -10 - 10	Ammonical nitrogen (ammonia) 11.1% Nitric nitrogen 8.1% Phosphorus pentoxide (P205) Potassium Oxide (K20) as muriate of Potash	370

2019 Field Tree Trial

This field tree nutrition trial was set up in 2019 at James Coles & Sons (Nurseries) Ltd, Gaddesby, Leicestershire on field grown *Betula utilis* var. *jacquemontii.* Trees were planted in the field as 5 L container grown trees in late winter / early spring of 2019 to be grown on in field production as trees in medium loam soil. The aim of the work carried out was to determine if band applications of fertiliser to crop rows were more effective than traditional broadcast applications.

The fertiliser used was the nursery's standard 20-10-10 product supplied by Glasson Fertilisers Ltd. It was applied at a rate of 370 Kg/ha, as a single application in spring, as routinely used by the nursery; the K source was muriate of potash. 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 girth of selected young trees was also measured through the growing season to determine differences in growth between treatments.

Soil analysis was taken prior to fertiliser application (see **Table 3, Science section)** and at the end of the growing season (see **Table 9, Science section).**

There were no differences in mean girth measurements between treatments (including the untreated controls) when measured in weeks 26, 34 and 43.

There were no differences in mean chlorophyll content measured by the atLEAF until week 30, when chlorophyll content within broadcast plots was higher than in untreated plots. This trend continued when the final assessment was carried out in week 34.

Although tissue analysis showed some significant differences between means on the assessment dates, none of these significant differences persisted through the season. Tissue analysis, compared with published figures, indicated that levels of micronutrients were low in all treatments throughout the growing season.

Discussion

None of the treatments resulted in any difference in the growth (determined by girth measurements) of *Betula* within this trial during the 2019 growing season.

Levels of P, K and Mg were found to be high before fertiliser was applied. The fact that plants performed equally well where fertiliser (regardless of application method) and no fertiliser was applied, highlights the importance of regular soil analysis (before planting or every three years), to check soil nutrient levels to determine which nutrients are required. Growers should also note that excessive amounts of most nutrients can create nutrient incompatibility, where an excess of one nutrient inhibits the uptake of another, potentially creating unnecessary deficiency symptoms and associated reductions in growth. P, K and Mg soil indices decline slowly hence soil analysis is typically only required every three years. Soil pH was 7.3, and lime only needs to be applied to maintain a soil pH between 6 – 6.5, so there was no lime requirement either. Levels of micronutrients were found to be low when compared to published figures; low levels of micronutrients may be limiting potential crop growth.

There was no correlation between chlorophyll content and growth in *Betula utilis* var. *jacquemontii* (a crop with available tissue analysis data) at high soil P, K and Mg indices.

Conclusions

- No difference in growth (determined by girth measurements) occurred between *Betula utilis* var. *jacquemontii* trees in plots where no fertiliser was applied, where fertiliser was broadcast or applied as a band treatment.
- P 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.
- P index should not be maintained above Index 2-3.
- K index should not be maintained above Index 3.
- Mg index should not be maintained above Index 2.
- Unnecessary applications of nutrients are potentially environmentally damaging whilst also increasing production costs.
- There is potential for savings on fertiliser use and associated costs through the use of regular soil analysis.
- Tissue analysis can be used to check micro nutrient levels within crops to determine when micronutrients should be applied.
- More work is required to determine if chlorophyll meters can be used to determine crop nutrient status of *Betula utilis* var. *jacquemontii.*

Financial Benefits

The host nursery single application of 370 kg/ha 20–10-10, (19.2% N), P, K fertiliser cost £188.70/ha. Soil analysis showed that P and K Index was high, therefore it was not necessary to apply any more P or K to this crop as both were at a high index (above Index 3). Applying P and K where the soil is already at a high index is potentially environmentally damaging, can be detrimental to optimum crop growth due to nutrient incompatibility, and also results in unnecessary expenditure on fertilisers. This resulted in 71.04 kg/ha of N being applied to the crop in a single application; applying this much N in one go carries a high risk of N leaching before it is taken up by the crop, especially on light textured soils.

In growing seasons where this occurs, it is likely that the crop would be short of N during at least part of the growing season which may result in sub-optimal growth.

If ammonium nitrate (34.5% N) was applied as the sole fertiliser (as P and K were not needed) applying 206 kg/ha of product would supply a similar amount of N (71.07 kg/ha) as the nursery standard treatment, which would cost £54.18, resulting in a saving of £134.52/ha. Given that N readily leaches it is standard practice to apply all forms of N that are readily available (such as ammonium nitrate) splitting the dose between three applications during the growing season to enable crops to best use the N supplied, whilst optimising crop growth.

There was no difference in growth within any of the treatments / application methods including the untreated plots that received no fertiliser (where N was the only likely limiting factor). Therefore *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. There may be potential to further reduce N applications to this species whilst maintaining crop growth.

Annual *Betula* offtakes of P, K and Mg are relatively low (see **Table 10, Science section**) so fertiliser savings can be achieved over a number of years where high indices occur as it typically takes a number of years for the soil Index to decline to levels where P, K and Mg fertiliser applications are required.

Action Points

- Always carry out soil analysis to base fertiliser application decisions on.
- Where P and K Index is above Index 3 there is no need to apply either of these nutrients.
- Only apply Mg where the soil Index is below 3.

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 to help determine rates of fertiliser to apply. Soil sampling for residual nitrogen (N) 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. 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.

Growers must comply with legislation such as limits on the amount of N (a total N limit of 250 kg/ha) that can be applied in nitrogen Vulnerable Zones (NVZs) to prevent the pollution of water. High levels of P should be avoided (above Index 3) as surface run off (particularly where erosion is a problem) can transport P into water courses where it can contribute to eutrophication.

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 placement which could deliver a number of 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 slow establishment of some ornamental chloride-sensitive genera. Ornamental species do not generally respond well to urea based N sources but the lower cost of urea can make its use more attractive than alternatives such as ammonium nitrate.

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

Year 1

Objective 1: To take soil and tissue analyses from one species with existing data for comparable nutrient levels (samples taken up to 4 times per growing season), measure soil EC and utilise chlorophyll meters to determine crop nutrient status.

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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 2019 at James Coles & Sons (Nurseries) Ltd, Gaddesby, Leicestershire on field grown *Betula utilis* var*. jacquemontii.* Trees were planted in the field as 5 L container grown trees in late winter / early spring of 2019 to be grown on as trees in a field of medium loam. Soil analysis was taken in spring 2019, prior to fertiliser application and sent to NRM laboratories for analysis, results are shown below in **Table 3**

A restricted randomisation block design with three treatments was used, including an untreated control, a commercial standard (broadcast application) and a band application to crop rows. The fertiliser used was the nursery's standard 20-10-10 product supplied by

Glasson Fertilisers Ltd. It was applied at a rate of 370 Kg/ha, applied as a single application in spring as routinely used by the nursery; the K source was muriate of potash. Fertiliser was applied either as a broadcast treatment, or as a band application applied on one side of the planting ridge (to simulate mechanical application) (**Figure 1**). An untreated control had no fertiliser applied. All treatments were replicated four times. Plots measured 6 m x 4 m.

Figure 1: Band application of fertiliser.

Half of the block of trees within the trial had fertiliser broadcast over plots by the nursery whilst band applications were applied on 16/05/19; untreated controls had no fertiliser applied. The girth of five selected trees per plot were measured on 16/05/19 (week 20). These trees were tagged so that girth measurement (further measurements recorded in weeks 26, 34 and 43) could be tracked throughout the growing season. Chlorophyll measurements using the atLEAF hand held device, avoiding the main leaf rib, and samples for leaf tissue analysis were taken from the same plants at each assessment date (taken in weeks 22, 26, 30 & 34). 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 were taken with a Decagon Procheck with a gs3 Sensor (now available as Terros 12) in weeks 22, 26, 30 & 34. These measurements were taken from the central row of each plot, soil EC measurements were taken the same side of the ridge that fertiliser was applied in band treated plots. The treatment list is shown below in **Table 2.**

Table 2. 2019 Field tree trial year one treatments.

Treatment number	Application method	Product (name)	Nutrient content	Rate (L/ha or kg/ha)
1.	-	-	-	Untreated
2.	Broadcast (nursery standard treatment)	Glasson Fertilisers 20 -10 - 10	Ammonical nitrogen (Ammonia) 11.1% Nitric nitrogen 8.1% Phosphorus pentoxide (P205) Potassium oxide (K20) as muriate of Potash	370
3.	Band application to crop rows	Glasson Fertilisers 20 -10 - 10	Ammonical nitrogen (Ammonia) 11.1% Nitric nitrogen 8.1% Phosphorus pentoxide (P205) Potassium oxide (K20) as muriate of Potash	370

A soil analysis was taken in week 43 from untreated controls to determine nutrient status at the end of the growing season where no fertiliser had been applied.

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

Results

Soil analysis was done in spring prior to fertiliser application (**Table 3)** and at the end of the growing season (**Table 9).**

Table 3. 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**

7.3	5	83.4	6	1247	5	282	6.7

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

There were no significant differences in mean girth measurements between treatments when measured in weeks 20, 26, 34 and 43 (**Table 4**).

Table 4. Average girth measurements in centimetres (cm) for *Betula utilis* var. *jacquemontii* main stem during 2019 by week number.

Treatment. Number.	Treatment.	Week 20	Week 26	Week 34	Week 43
1	Untreated	2.79	3.31	4.81	4.47
2	Broadcast	2.63	3.07	4.42	4.56
3	Band application	2.40	2.96	4.50	4.58
d.f.		9	9	9	9
S.E.D.		0.1703	0.2335	0.416	0.390
L.S.D.		0.3853	0.5283	0.941	0.882
p value		0.130	0.354	0.618	0.848

There were no significant differences in mean chlorophyll content until week 30 when chlorophyll content within broadcast plots was significantly higher than untreated plots. This trend continued when the final assessment was carried out in week 34 (See **Table 5**).

Table 5. Average chlorophyll content (measured with hand held AtLEAF) for *Betula utilis* var. *jacquemontii* leaves during 2019 by week number.

Treatment. Number.	Treatment.	Week 22	Week 26	Week 30	Week 34
1	Untreated	56.94	52.3	54.77	61.31
2	Broadcast	57.94	53.5	60.27*	63.87*
3	Band application	56.98	53.0	57.87	63.10
d.f.		9	9	9	9
S.E.D.		1.102	2.98	1.617	0.956
L.S.D.		1.102	2.98	3.658	2.184
p value		0.607	0.927	0.024	0.068

* Significantly different to untreated at 95% confidence.

There were no significant differences in mean soil EC until week 30 when soil EC was significantly higher in broadcast plots than those treated with a band application of fertiliser. There was no significant difference in soil EC between treatments (including the untreated) at the next and final assessment in week 34 (**Table 6**).

Table 6. Average soil electronic conductivity measurements in Microsiemens (µS/cm) for *Betula utilis* var. *jacquemontii* plots during 2019 by week number.

Treatment. Number.	Treatment.	Week 22	Week 26	Week 30	Week 34
1	Untreated	0.0267	0.0756	0.0485	0.0373
2	Broadcast	0.0179	0.0675	0.0755*	0.0384
3	Band application	0.0246	0.1090	0.0431	0.0457
d.f.		9	9	9	9
S.E.D.		0.00729	0.01804	0.01239	0.00877
L.S.D.		0.01650	0.04080	0.02803	0.01983
p value		0.485	0.102	0.059	0.598

* Significantly different at 95% confidence.

The only significant difference in mean soil VMC was in week 26 when band application plots were significantly higher than broadcast plots (See **Table 7**).

Table 7. Average soil volumetric water content (VMC) for *Betula utilis* var. *jacquemontii* plots during 2019 by week number.

Treatment. Number.	Treatment.	Week 22	Week 26	Week 30	Week 34
1	Untreated	12.1	20.79	16.32	16.87
2	Broadcast	11.7	19.74	15.09	14.09
3	Band application	21.9	22.16*	14.83	15.06
d.f.		9	9	9	9
S.E.D.		7.45	0.918	0.896	1.470
L.S.D.		16.85	2.077	2.027	3.324
p value		0.339	0.076	0.261	0.212

* Significantly different at 95% confidence.

The only significant difference in mean soil temperature was in week 22 when the soil temperature within broadcast plots was significantly higher than in both band application and untreated plots (See **Table 8**).

Table 8. Average soil temperature in degrees Celsius (°C) for *Betula utilis* var. *jacquemontii* plots during 2019 by week number.

Treatment. Number.	Treatment.	Week 22	Week 26	Week 30	Week 34
1	Untreated	19.11	17.96	42.08	32.36
2	Broadcast	20.31*	18.44	42.38	32.45
3	Band application	19.55	18.25	42.51	32.5
d.f.		9	9	9	9
S.E.D.		0.312	0.2995	0.356	0.1276
L.S.D.		0.706	0.5417	0.806	0.2886
p value		0.012	0.187	0.502	0.553

* Significantly different at 95% confidence.

Although tissue analysis showed some significant differences between means at the assessment dates, none of these significant differences spanned more than one assessment date (See **Tables 1 – 4, appendix 1**).

When comparing tissue analysis results **(Appendix 1 – 4)** with published figures **(Table 11)** the published figures suggest that levels of N, P and K in the plant tissue from all treatments were high. Levels of S were very similar to published figures in all treatments, however levels of Mg, Ca, Fe, Cu, Zn, Mn and B were all on the low side.

Soil analysis was taken at the end of the growing season **(Table 9)** which enabled the *Betula utilis* var. *jacquemontii* tree crop nutrient offtake during 2019 growing season to be calculated **(Table 10)** which was relatively low.

Table 9. Soil analysis taken in week 43 from untreated controls.

Soil pH	P Index	P mg/l available	K Index	K mg/l available	Mg Index	Mg mg/l available	Percentage organic matter
7.4	5	73.6	5	824	5	251	6.6

Table 10. *Betula utilis* var*. jacquemontii* crop nutrient offtake during 2019 growing season, determined by Soil analysis.

P (mg/L)	K (mg/L)	Mg (mg/)L
9.8	423	31

* Soil organic matter declined by 0.1% during the 2019 growing season.

Discussion

None of the treatments resulted in any significant difference in the growth (determined by girth measurements) of *Betula* within this trial during the 2019 growing season.

Levels of P, K and Mg were found to be high before fertiliser was applied. The fact that plants performed equally well where fertiliser and no fertiliser was applied highlights the importance of 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. Where P and K Index is over 3 there is no need to apply P and K, similarly where Mg Index is 3 or above there is no need to apply Mg as sufficient levels of these nutrients are available to the crop in the soil. It is not necessary to maintain high P, K and Mg indices.

P 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. Therefore the P Index should not be maintained above Index 2-3.

Published tissue analysis figures for *Betula utilis* var. *jacquemontii* **(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 data of tissue analysis however do not necessarily represent maximum or minimum levels. These published figures are shown below in **Table 11.**

Table 11. Published tissue analysis figures for *Betula utilis* var. *jacquemontii* **(Mills and Jones, 1996).**

Nutrient	Nutrient abbreviation	Amount	Unit of measurement*
Nitrogen	N	3.71	% Dry matter
Phosphorus	P	0.18	% Dry matter
Potassium	K	1.14	% Dry matter
Magnesium	Mg	0.38	% Dry matter
Calcium	Ca	1.51	% 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.

Significantly higher chlorophyll content in weeks 30 and 34 within plants in plots where fertiliser was broadcast did not correlate to any significant increase in plant growth. Although there were some significant differences in nutrient levels in tissue analysis between treatments, none showed any lasting trends that spanned more than one assessment date. None of these significant differences in nutrient levels in tissue analysis are linked to any significant increase in growth.

One significant difference in soil EC, VMC and temperature were recorded, however these significant differences are more likely to be attributed to slight differences in soil texture between plots than fertiliser application method. Solar radiation is likely to have varied whilst measurements were taken.

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.

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 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 girth measurements) occurred between *Betula utilis* var. *jacquemontii* trees in any of the treatments. This included the untreated plots that received no fertiliser (where N was the only likely limiting factor). Therefore *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.

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

Annual *Betula* offtakes of P, K and Mg are relatively low so fertiliser savings can be achieved over a number of years where high Indices occur as it typically takes a number of years for soil Index to decline to levels where P, K an Mg fertiliser applications are required.

Unnecessary applications of nutrients are therefore 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.

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.

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- Neil Bragg (Substrate Associates Ltd)

References

Ref>30mg/l (nitrates) and 0.1 mg/l (phosphates) DA3 Percentage (on- line accessed 01/02/2020) via: https://assets.publishing.service.gov.uk/government/uploads/system/updates/attachment_data/file162164/defra-stats-observatory-indicators-da3-120224.pdf

GB Fertiliser Price Series bi-monthly report – May 2020.pdf AHDB May 2020

Fertiliser recommendations, Ministry of Agriculture, Fisheries and Food, Reference Book 209 MAFF/ADAS, 5th edition 1988.

Mills H. A, Jones J. B Jr. (1996). Plant analysis handbook. II: a practical sample, preparation, analysis and interpretation guide. Athens (GA): Micromacro Publishing. 422 p.

Taylor, B. K and Goubran, F. H. (1976). The phosphorus nutrition of the apple tree. II. Effects of localized phosphate placement on the growth and phosphorus content of split-root trees. Australian Journal of Agricultural Research 27(4) 533 - 9 http://www.publish.csiro.au/CP/AR9760533

Appendices

Appendix 1 – Tissue Analysis

Table 1. Tissue analysis Week 22. *(NS = no significant differences)*

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	4.540	0.358	1.425	0.183	0.680	49.0	3.02	93.2	53.5	32.62	0.240
2. Broadcast	4.545	0.363	1.587*	0.188	0.617	62.0*	2.88	87.6	63.5	29.20	0.243
3. Band	4.520	0.350	1.327	0.190	0.698	52.0	3.10	86.3	56.0	30.40	0.240
d.f.	9	9	9	9	9	9	9	9	9	9	9
S.E.D.	0.1169	0.01280	0.0689	0.01041	0.0412	2.81	0.292	4.64	4.61	1.689	0.00905
L.S.D.	0.2645	0.02896	0.1559	0.02355	0.0932	6.35	0.661	10.49	10.42	3.821	0.02048
p value	0.975	0.632	0.013	0.770	0.180	0.003	0.742	0.327	0.130	0.176	0.951

* Significantly different to untreated at 95% confidence.

Table 2. Tissue analysis during 2019 week 26. *(NS = no significant differences)*

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	3.833	0.433	1.375	0.150	0.492	34.2	4.03	92.4	67.7	38.65	0.240
2. Broadcast	4.248	0.453	1.422	0.150	0.432	32.2	3.88	86.0	66.5	31.03*	0.253
3. Band	3.860	0.433	1.262*	0.180	0.588	41.8	4.20	84.6	71.4	39.25	0.233
d.f.	9	9	9	9	9	9	9	9	9	9	9
S.E.D.	0.1877	0.01208	0.0436	0.01764	0.0912	7.87	0.351	8.22	5.58	1.997	0.00928
L.S.D.	0.4247	0.02732	0.0987	0.03990	0.2064	17.81	0.794	18.60	12.63	4.518	0.02099
p value	0.097	0.216	0.014	0.201	0.281	0.475	0.663	0.619	0.666	0.004	0.149

* Significantly different to untreated at 95% confidence.

Table 3. Tissue analysis during 2019 week 30. *(NS = no significant differences)*

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	4.040	0.365	1.600	0.175	0.475	18.75	4.20	91.30	43.6	49.1	0.250
2. Broadcast	4.080	0.370	1.725*	0.183	0.550*	24.75*	3.52	96.95*	42.0	48.3	0.265
3. Band	4.123	0.355	1.613	0.175	0.485	20.75	4.17	88.70	43.9	44.2	0.253
d.f.	9	9	9	9	9	9	9	9	9	9	9
S.E.D.	0.0781	0.01333	0.0443	0.00697	0.02357	2.288	0.328	2.122	2.55	4.29	0.00808
L.S.D.	0.1767	0.03016	0.1003	0.01577	0.05332	5.176	0.742	4.800	5.77	9.71	0.01828
p value	0.591	0.542	0.038	0.491	0.022	0.072	0.119	0.010	0.732	0.504	0.194

* Significantly different to untreated at 95% confidence.

Table 4. Tissue analysis during 2019 week 34. *(NS = no significant differences)*

Treatment	N %	P %	K %	Mg %	Ca %	Mn %	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg	S %
1. Untreated	4.152	0.370	1.660	0.188	0.657	20.75	3.98	97.3	36.1	63.7	0.250
2. Broadcast	4.275	0.375	1.643	0.168*	0.620	21.75	3.35	94.1	38.8	51.7*	0.263
3. Band	4.135	0.345	1.570	0.193	0.665	22.25	3.98	100.8	35.8	61.4	0.250
d.f.	9	9	9	9	9	9	9	9	9	9	9
S.E.D.	0.0638	0.01915	0.0489	0.00825	0.0398	1.860	0.356	5.66	2.88	3.16	0.00697
L.S.D.	0.1443	0.04332	0.1107	0.01866	0.0901	4.207	0.806	12.81	6.52	7.14	0.01577
p value	0.109	0.294	0.205	0.032	0.507	0.722	0.184	0.519	0.557	0.010	0.173

* Significantly different to untreated at 95% confidence.