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Project leader:	**Dr Jim Monaghan** **HRI-Wellesbourne** **Warwick** **CV35 9EF**
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Location:	**HRI-Efford**
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HEATHERS – A STUDY OF POTENTIAL IMPROVEMENTS IN NUTRITION

HNS 96a

Heathers – A study of potential improvements in nutrition

Headline

A relatively low rate of 1.5 kg m^{-3} of a medium – long term CRF such as Vitacote, Multicote 8, Osmocote Plus (12-14) Autumn, or Osmocote Exact Standard, is suitable for quality production of a range of heathers either outdoors or under protection, and will minimise risk of salt damage with sensitive cultivars. Studies on iron nutrition were inconclusive, but using acidified irrigation (with hard water supplies) should ensure trace elements supplied by CRF's remain available to heathers.

Background and expected deliverables

An HDC funded study (HNS 96) of different CRF rates and products with Heather cultivars was undertaken in the 1998/99 growing season. Rates of application were studied using the industry standard, Osmocote Plus 12-14 (Autumn) with each cultivar at 1.0, 1.5 and 2.0 kg m^{-3}. Surprisingly, in light of the rates used on nurseries, no benefit was observed at rates above 1.5 kg m^{-3} with moderate and vigorous cultivars. With *Calluna vulgaris* 'Peter Sparkes' (a vigorous cultivar) plants of adequate quality were grown with only 1.0 kg m^{-3}.

Of the other products studied at 1.5 kg m^{-3} only, Vitacote produced the best plants with all the cultivars studied. Whereas some of the salt sensitive plants died with Osmocote Plus, no plant deaths occurred at the same rate of Vitacote. This finding was of particular interest – if one rate of CRF could produce quality plants of both vigorous and salt sensitive cultivars one mix could be prepared for most cultivars on a nursery saving preparation time and complication.

In this two year project, three cultivars were common to both years: *Erica carnea* 'King George', C*alluna vulgaris* 'Peter Sparkes' and *E. vagans* 'Mrs D F Maxwell'. In year 1 *E. carnea* 'Myretoun Ruby' was included, and was replaced by *E. carnea* 'Rosalie' in year 2.

CRFs (see Table 1) were incorporated at 1.0, 1.5 and 2.0 kg m^{-3} in year 1 and 1.5 and 2.0 kg m^{-3} in year 2. Multicote 8 was used in three treatments: alone; with 30 g m^{-3} Fe-Hi; and with 60 g m^{-3} Fe-Hi. Plants were irrigated with either mains or acidified water in year 1 and acidified water only in year 2.

Table 1. Analysis of products involved.

Product	Analysis
Multicote 8	18:6:12 (traces)
Osmocote Plus 12-14 (Autumn)	15+9+11+traces
Osmocote Exact Standard	15+9+9+traces
Vitacote	18-6-12+T.E.
Librel Fe-Hi	6.7% Fe

In essence this project asked the following questions:

- What is the factor that allowed one rate of CRF to be used with a wide range of salt sensitivities in HNS 96?
- What is the most cost-effective CRF rate for a range of Heathers?

Summary of the project and main conclusions

These experiments were undertaken for two years only. Any findings are for the conditions *under which the experiments were carried out*. Extrapolation to other years is possible, but must be made with a full understanding of the conditions studied in this work. Additionally, account must be made of irrigation system, incorporation of base fertiliser and geographical location if they differ from those in this study.

Year 1 (for full details see preceding annual report)

Overall, the growing year 2000-01 was unusually wet and warm in December and February and higher than normal amounts of nutrients leached from the granules, especially during February. This has had a major effect on the trial, limiting differences between treatments and lessening the effect of acid dosing, as this was only applied during the dry periods. This explains why there was little consistent difference in plants irrigated either with mains or acidified water.

***Erica vagans* 'Mrs D F Maxwell' by late spring 2001. Multicote 8 + additional iron chelate as Fe EDDHA (Librel Fe-Hi).**
L to R CRF @ 1.0, 1.5 and 2.0 kg/m^3

The main effect of CRF treatments showed that 1.0 kg/m^3 was insufficient to maintain adequate growth, but in most cases there was little extra growth from rates above 1.5 kg/m^3.

In contrast to HNS 96, *by the end of the trial* Vitacote was not consistently better than any of the CRFs studied. However, plants responded to CRF treatment prior to the heavy winter rainfall, with Vitacote producing plants by autumn that were larger than one or more treatments, with all cultivars. Interestingly, at the first record, acidification of the growing medium had removed the benefit of Vitacote at lower rates of CRF, i.e. other CRFs performed as well as Vitacote when the Fe available to the plants increased with acidification of the growing medium. There was little effect of adding iron chelate to Multicote 8, except for with Peter Sparkes, where it produced some benefit.

Year 2

The experimental conditions in year 2 were altered in light of the first years results; the lowest CRF rate of 1.0 kg/m^3 was dropped, plants were moved under protection during winter and spring, and were irrigated with acidified water only. Vitacote again produced significantly larger plants than some other treatments by autumn with both 'King George' and 'Peter Sparkes'. However, some other treatments, especially Multicote + Fe-Hi 30, were producing similar sized plants. And by the end of the experiment all treatments, including Vitacote, were producing saleable plants of similar size. In general, all nutrition treatments (1.5 – 2.0 kg/m^3 CRF) were producing broadly similar quality marketable plants by the end of experiment.

1) Differences among CRFs were more marked prior to the winter in both years.

There are a number of explanations for the disappearance of initial treatment differences by the end of each crop year. Nutrient supply may have been limiting growth up to autumn in some treatments, followed by excess nutrients in the spring. HNS 43d concluded that the greatest release of nutrients from CRFs occurs before autumn, with approximately half of nutrients in the granule being released. Differences between some of the CRF formulation release rates would have had a larger effect in the first part of the trial from potting until the end of summer, while the plants were growing rapidly. Vitacote and Multicote 8 have a slightly faster release rate and a higher % N content than the Osmocote Plus and Osmocote Exact formulations used in this project. This extra N availability early in the trial may well have been a more significant factor affecting growth rates up to the autumn assessment, than the availability of iron. However, further research would be needed to study the pattern of nutrient release more closely to confirm this.

2) The Role of Iron in Heather nutrition

The affect of Vitacote was pH related – suggesting that the Fe coating on this CRF may have contributed to this effect. However, comparisons using Multicote 8, a CRF product similar longevity and major nutrient analysis, with and without additions of chelated iron, gave variable results. In year 1 where chelated iron was added to the substrate, only 'Peter Sparkes' appeared to benefit. In year 2, (all treatments with acidified water), again, additional iron chelate was not consistently beneficial, and with ‘King George’, the 60 g m^{-3} addition of Fe-Hi gave poorer growth than Multicote 8 alone, Multicote plus 30 g m^{-3} Fe-Hi, or with Vitacote. Iron deficiency as an explanation for some growth differences between treatments therefore could not be proved in this project.

3) Where plants were grown with acid-dosed irrigation water all CRFs studied produced similar quality plants at the end of both cropping seasons.

Where plants were grown with irrigation water below about pH 6.0, all CRFs studied produced similar quality plants at the end of each cropping season. Acidification of hard water supplies to prevent excessive pH rise in growing media should ensure micronutrients in CRF formulations, especially iron, remain available to heathers. However, where mains water is used, and is alkaline (HRI-Efford has a pH of 7.5 – 8.2), there may be some benefit in using a CRF such as Vitacote, or supplying extra iron as a suitable chelate, as a precaution against iron deficiency problems.

4) A rate of 1.5 kg m^{-3} is suitable for quality production of a range of heathers either outdoors or under protection.

In year 1 a rate of 1.0 kg m^{-3} produced plants of insufficient size, and this rate was dropped from year 2. Over the two years 1.5 kg m^{-3} and 2.0 kg m^{-3} produced similar quality saleable plants with the CRFs studied, both when plants received heavy winter rain (year 1) or when grown under protection during winter (year 2). This work supports the use of 1.5 kg m^{-3} of CRF for producing a range of Heathers. The higher rate may have some benefit for shelf-life and/or garden establishment, but these factors were outside of the remit for this study.

Year 1 trial (above) February 2001 irrigated with mains and acidified water. Year 2 trial (right) October 2001.

Action Points

- **A rate of 1.5 kg m^{-3} of a medium – long term CRF such as Vitacote, Multicote 8, Osmocote Plus (12-14) Autumn, or Osmocote Exact Standard, is suitable for quality production of a range of heathers either outdoors or under protection, and will minimise risk of salt damage with sensitive cultivars.**

- **The best quality plants are grown with acidified irrigation water. This will help ensure micronutrients from CRF's, including iron, remain available to plants.**

- **Where acid dosing is impractical in a high pH / hard water area, the addition of available iron (as a suitable iron chelate*) may benefit the crop.**

*** Advisory note:** *Iron chelates are available as Fe EDTA (e.g. Librel Fe-Lo or Vytel Iron 14, approx.13% Fe), Fe EDDHA and Fe DTPA (e.g. Librel Fe-Hi or Vytel Iron 6 and Librel Fe-DP, both approx. 7 %Fe). Fe EDTA is only recommended for use where pH will not rise above 6.5. pH can rise above this in hard water areas, even using low lime (calcifuge mix) growing media, unless water is acidified. Fe DTPA and Fe EDDHA, although more expensive, can be used with higher pH's. Chelates can be incorporated into growing media (as in this project), or applied as foliar sprays or media drenches during the growing season. Where iron chelates are used, particularly as sprays, it is important to follow product labels guidelines for rates and methods of use to minimise the risk of crop damage.*

Science Section

Introduction

An HDC funded study (HNS 96) of different CRF rates and products with Heather cultivars was undertaken in the 1998/99 growing season. Rates of application were studied using the industry standard, Osmocote Plus 12-14 (Autumn) with each cultivar at 1.0, 1.5 and 2.0 kg m^{-3}. Surprisingly, in light of the rates used on nurseries, no benefit was observed at rates above 1.5 kg m^{-3} with moderate and vigorous cultivars; and with *Calluna vulgaris* 'Peter Sparkes' plants of adequate quality were grown with 1.0 kg m^{-3}.

Of the other products studied at 1.5 kg m^{-3} only, Vitacote produced the best plants with all the cultivars studied. Whereas some of the salt sensitive plants died with Osmocote Plus, no plant deaths occurred at the same rate of Vitacote. This finding was of particular interest – if one rate of CRF could produce quality plants of both vigorous and salt sensitive cultivars one mix could be prepared for most cultivars on a nursery saving preparation time and complication.

There are a number of explanations for the improved plant quality with Vitacote:

- a coating of iron pigment
- shorter longevity
- higher N analysis

The results of HNS 96 suggest that it is unlikely, though not impossible, that the improved plant growth observed with Vitacote was due to longevity or analysis, as plants did not respond to increased rates of Osmocote.

The possible role of the iron (Fe) pigment is an intriguing one. Physiological iron deficiency has been observed with ericaceous plants in a number of situations: when there is too much lime in the substrate; when the concentration of HCO^- in the irrigation water is too high i.e. hard water areas; when the levels of certain elements (e.g. copper, manganese, zinc, calcium etc.) are too high; and in a low K : high P environment.

It has been claimed that iron chelates "deepen the colour of many of the blue green conifers... [and]… are also used to produce a richer green in various kinds of nursery stock." (Anon, 1980). Lime-induced chlorosis / iron deficiency is a major problem in world agriculture and as such a wealth of data is available on the role of iron in plant growth and development. Most of this work concentrates on the mechanisms of calcifugy and nutrient accumulation rather than the means to ameliorate symptoms. However, it has been known for some time that the addition of iron salts to the leaves of plants (Gris, 1844), and the soil application of chelated iron (Bould, 1955) can overcome lime-induced chlorosis.

A MAFF funded project carried out from 1996-98 at HRI-East Malling and Efford, and the University of Sussex, looked at countering the aversion of hardy ornamentals to chalk soils (OCS 945C). The mechanisms underlying lime chlorosis were studied in *Erica*, at the University of Sussex, and it was demonstrated that the application to the leaves of excess artificial chelates (eg EDTA, EDDHA) led to partial relief of lime chlorosis and could be accounted for by a small proportion entering the leaf cells intact. However, root addition was not studied.

Acidification of hard water supplies (through the addition of concentrated nitric acid) has been shown to improve the growth of both *Erica* and *Calluna* species (Scott and King, 1987), through a combination of limiting the increase in the pH of the growing media over time, and supplying a small additional supply of nitrogen (~ 20 mg l^{-1}). However, if the addition of Fe were shown to be of advantage, especially with higher pH water sources, then it could provide a low cost, safe alternative to acid dosing irrigation systems.

This study aims to establish whether improvement in the quality of heather growth can be achieved through adjustment in

- iron supply,
- nitrogen supply
- or CRF longevity,
- and whether this improvement can be maintained across a range of irrigation water pH.

Materials and Methods (Year 2)

The results from 2000-01 (Year 1) are described in the preceding annual report.

Four species were studied in year 2:

- *Erica carnea* 'King George' - Winter flowering, salt sensitive
- *Erica carnea* 'Rosalie'* – Winter flowering, moderately salt sensitive
- C*alluna vulgaris* 'Peter Sparkes' – Late Autumn flowering, vigorous
- *Erica vagans* 'Mrs D F Maxwell' – Summer flowering, vigorous

Following discussion with the grower co-ordinator, the experiment was carried out using acidified water (pH 5.6-6.0) only. Plugs were potted-on into 9cm containers in week 21, into a mix of 100% Irish Premium peat, 1.0 kg m^{-3} Mg Lime and 750 g m^{-3} SuSCon green. The fertiliser treatments incorporated (Table 2) and products (Table 3) are shown below.

Plants were initially grown outdoors on sand beds covered with a double layer of Mypex, to limit capillary action, with overhead irrigation. Plants were moved into a polythene tunnel week 44 to

* *Erica carnea* 'Rosalie' replaced *E. carnea* 'Myretoun Ruby' due to lack of plant material.

protect plants from heavy winter rains. Routine applications of prochloraz (Octave), dichlofluanid (Elvaron), tolclofos-methyl (Basilex) and Imidacloprid (Intercept), were utilised in a commercial pest and disease programme.

Throughout the trial plants were set out in randomised blocks with three replicates. This gave 20 plants per plot with 9 recorded and 11 guards (see Layout, Appendix 1 and Photo 2, Appendix 2).

Table 2. Experimental treatments (Year 2)

Treatment	Product	kg m^{-3}	Fe EDDHA g m^{-3}
1	Vitacote	1.5	
2	"	2.0	
3	Multicote 8	1.5	
4	"	2.0	
5	Multicote 8 & Fe-EDDHA	1.5	30
6	"	2.0	30
7	Multicote 8 & Fe-EDDHA	1.5	60
8	"	2.0	60
9	Osmocote Plus 12-14 (Autumn)	1.5	
10	"	2.0	
11	Osmocote Exact Standard	1.5	
12	"	2.0	

Table 3. Analysis of products involved in experiment.

Product	Analysis	UK Supplier
Multicote 8	18:6:12 (traces)	Hi-Chem (UK) Ltd
Osmocote Plus 12-14 (Autumn)	15+9+11+traces	Scotts UK Ltd
Osmocote Exact Standard	15+9+9+traces	Scotts UK Ltd
Vitacote	18-6-12+T.E.	Vitax Ltd.
Librel Fe-Hi	6.7% chelated Fe	Ciba

The longevity of CRF's is primarily affected by temperature. Release patterns can thus vary from season to season. However, Osmocote Plus 12-14 and Osmocote Exact Standard should still be supplying nutrients 12 – 14 months after a spring potting under typical outdoor conditions. The '8' in Multicote 8 refers to an 8-month longevity at a 21 °C temperature. Multicote and Vitacote have a shorter longevity than these Osmocote products, although in practice, under outdoor temperatures may still be providing some nutrients 12 months after potting.

Assessments

Plants were assessed in October 2001 and after the first flush of growth, in May 2002. The variables recorded differed with species, as appropriate, and are outlined in the results section.

Scoring of size and flowering was subjective; made by visual comparison against selected standards each time. Photographs and measurements of these standards were taken (see Photos 3 and 4, Appendix 2).

Standard plants were selected for each assessed variable as follows: 6 plants displaying the full range of the variable were chosen from within the experimental plots and replaced into the body of plants after all plants had been scored against them. These plants were termed standard 1 to standard 5, with the variable the least for 1 and the greatest for 5; e.g. for size, 1 was the smallest plant and standard 5 was the largest plant. The standards were grown under the same condition as all the recorded plants and were measured and photographed before being replaced. Standards were selected anew each time plants were scored.

Above ground dry weight was recorded for half of all recorded plants (n=6) by destructive sampling after the spring flush of growth.

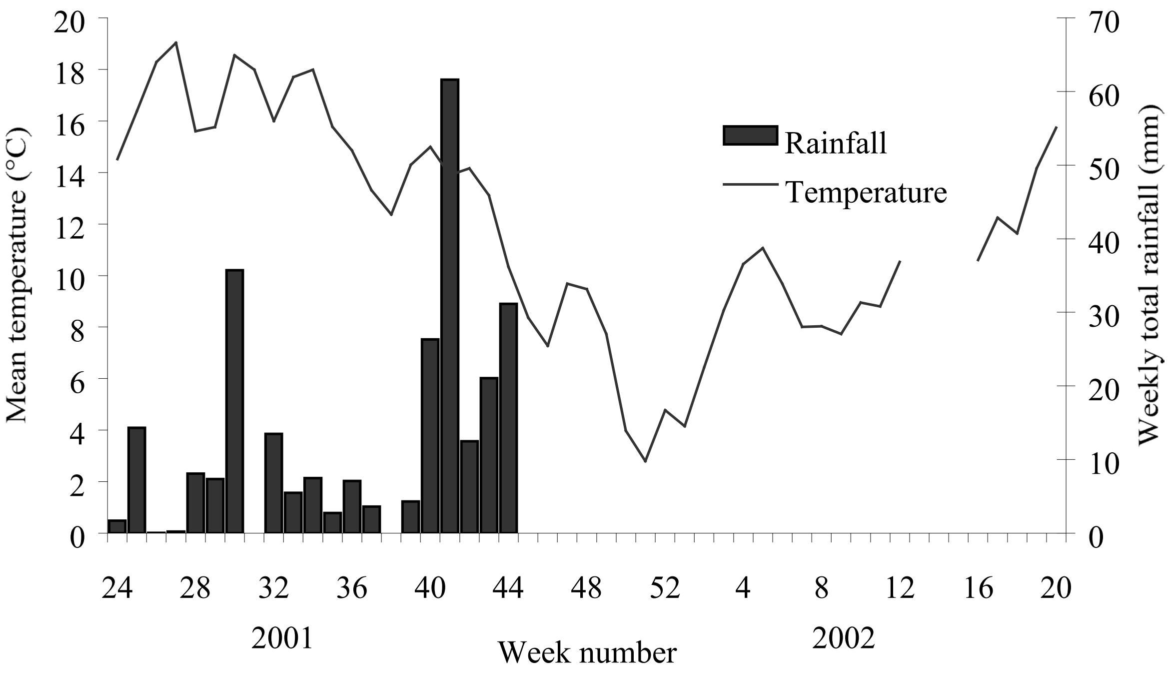
Statistical analysis of all variables was carried out by the Biometrics department at HRI-Wellesbourne. ANOVA was used to derive significance of treatment responses. Least significant differences ($LSD_{(0.05)}$) were calculated to aid interpretation of the data.

Results (Year 2)

Weather data

Following potting the plants were exposed to high average weekly temperatures until week 34 after which temperatures decreased (Figure 1). Plants were moved under protection in week 44 and consequently did not experience temperatures below freezing. Weekly total rainfall was high (> 30 mm) in week 30, 41 and 44 (Figure 1). By moving plants under protection the heavy rainfalls, experienced in year 1, were avoided.

Figure 1. Temperature and rainfall throughout the trial.



Growth Responses

Erica carnea 'King George'

Clear differences were apparent between treatments in the size of plants and flowering, at the autumn record. However, significant differences were associated with the fertiliser used rather than the rate applied, as there was no significant difference between the 1.5 and 2.0 kg m^{-3} rates for any of the treatments. Vitacote, Multicote and Multicote (Fe 30) all produced plants significantly larger, and with more flowers, than the remaining treatments (Figure 2a & b). By the end of the trial, having been over-wintered under protection, the smaller plants had 'caught up' with the larger ones and no significant differences were observed in either plant size or dry weight. A main effect of CRF rate, regardless of CRF product, was observed on flowering with the higher rate of CRF associated with a significant reduction in flowering.

Erica carnea 'Rosalie'

At the autumn record only one significant difference was observed in plant growth, plants grown at the higher rate of Multicote were larger than those grown at the lower rate, having an average size score of 4.2 compared to 2.9 ($LSD_{(0.05)}$ = 0.88). By the end of the trial this difference was still present in Multicote but, in addition, the rate of Osmocote Exact and Osmocote Plus significantly affected plant growth, with the higher rate actually reducing plant size (Figure 3). These size differences were also observed in plant dry weight, but only the Multicote response was statistically significant with an average of 5.47 and 4.06 g plant^{-1} at 2.0 and 1.5 kg m^{-3} CRF respectively ($LSD_{(0.05)}$ = 1.23).

When averaged across the two rates of CRF, there was a main effect of CRF product with Osmocote Exact and Multicote (Fe 60) producing larger plants than four and one other treatments respectively (Figure 3). However, these effects were not observed in the final plant dry weights.

Calluna vulgaris 'Peter Sparkes'

When averaged across both rates of CRF, Osmocote Plus produced plants significantly smaller than Vitacote, Multicote (Fe 30) and Osmocote Exact at the autumn record (Figure 4a). A similar response was observed for flowering, with Osmocote Plus producing significantly fewer flowers than Multicote (Fe 30), Multicote (Fe 60) and Osmocote Exact, having an average flower score of 3.7 compared to 4.2, 4.3 and 4.2, respectively ($LSD_{(0.05)}$ = 0.47). By the end of the trial Osmocote Plus was still producing the smallest plants but the difference to the other treatments was less marked with only Osmocote Exact producing plants larger than Multicote, Multicote (Fe 60) and Osmocote Plus (Figure 4b).

Erica vagans 'Mrs D F Maxwell'

When averaged across CRF rates, both Multicote (Fe 30) and Osmocote Exact had produced significantly larger plants by the first record, larger than Multicote and Osmocote Plus (Figure 5, and Photo 6, Appendix 2). By the end of the trial this effect had disappeared and no significant differences were observed in either size or dry weight. Nevertheless, flowering showed a response in autumn, with the higher rate of CRF, regardless of CRF product, producing significantly more flowers.

Figure 2. ***Erica carnea*** **'King George'**
Autumn 2001

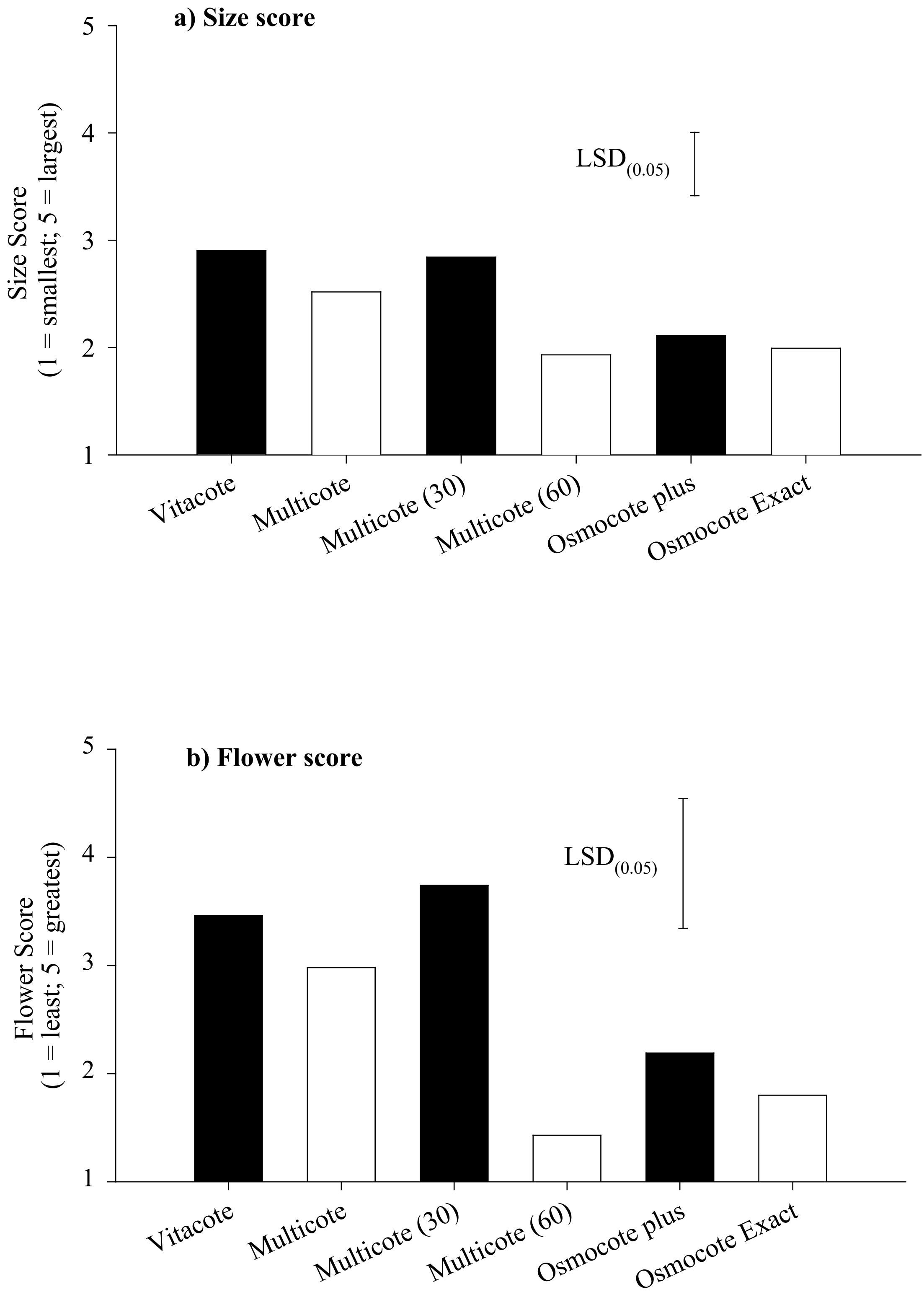


Figure 3. ***Erica carnea*** **'Rosalie'**
Size score; Spring 2002

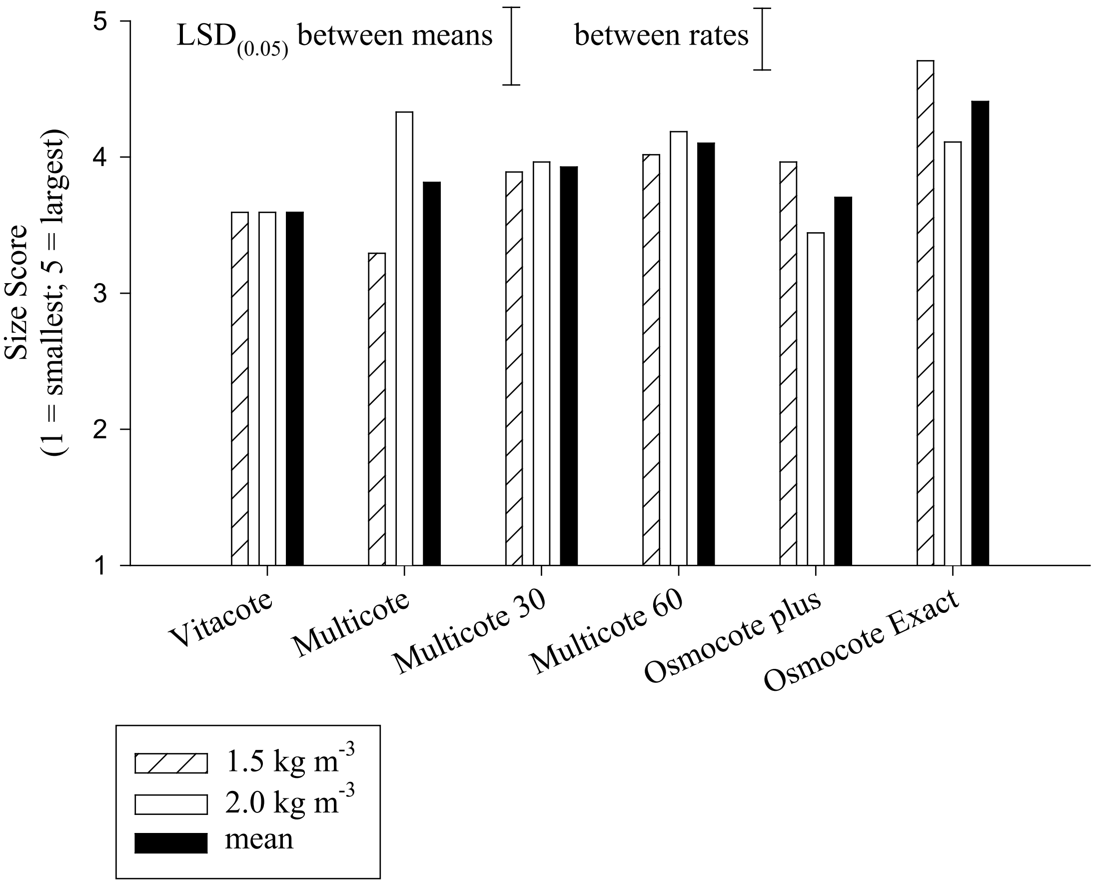
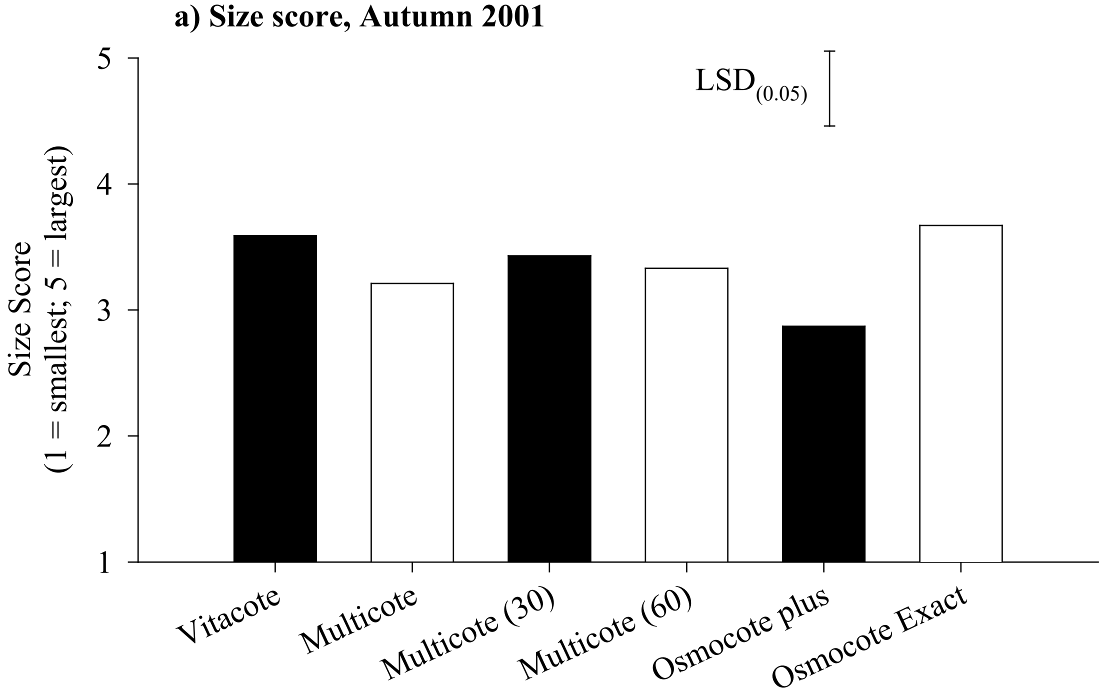


Figure 4. ***Calluna vulgaris*** **'Peter Sparkes'**



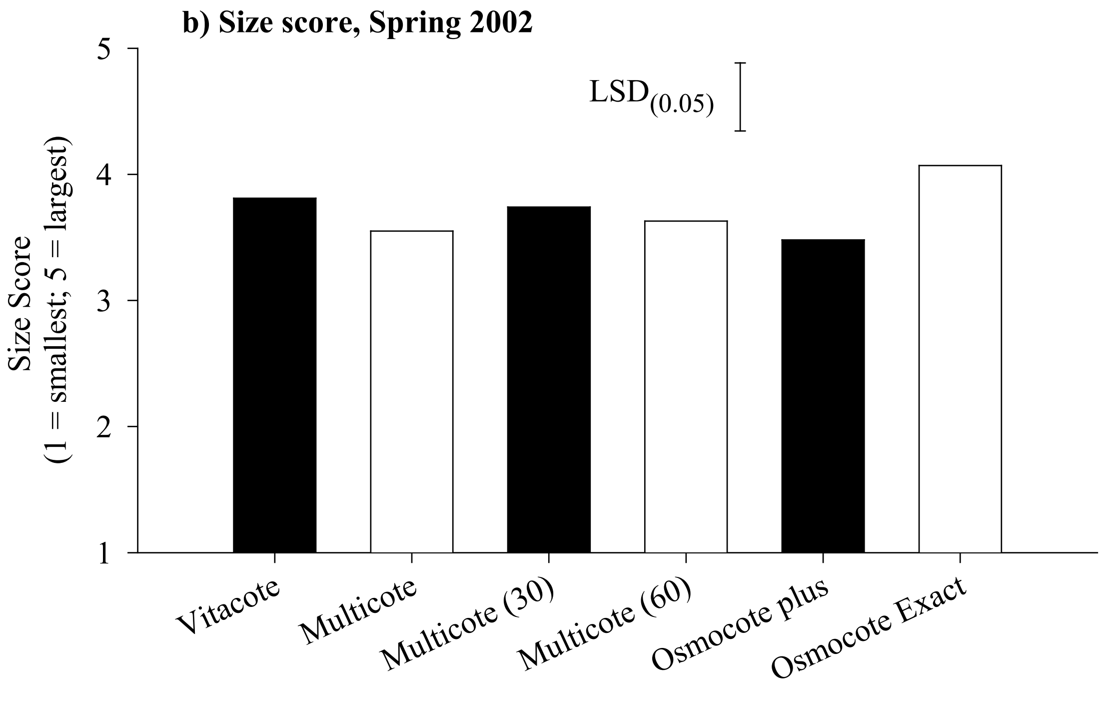
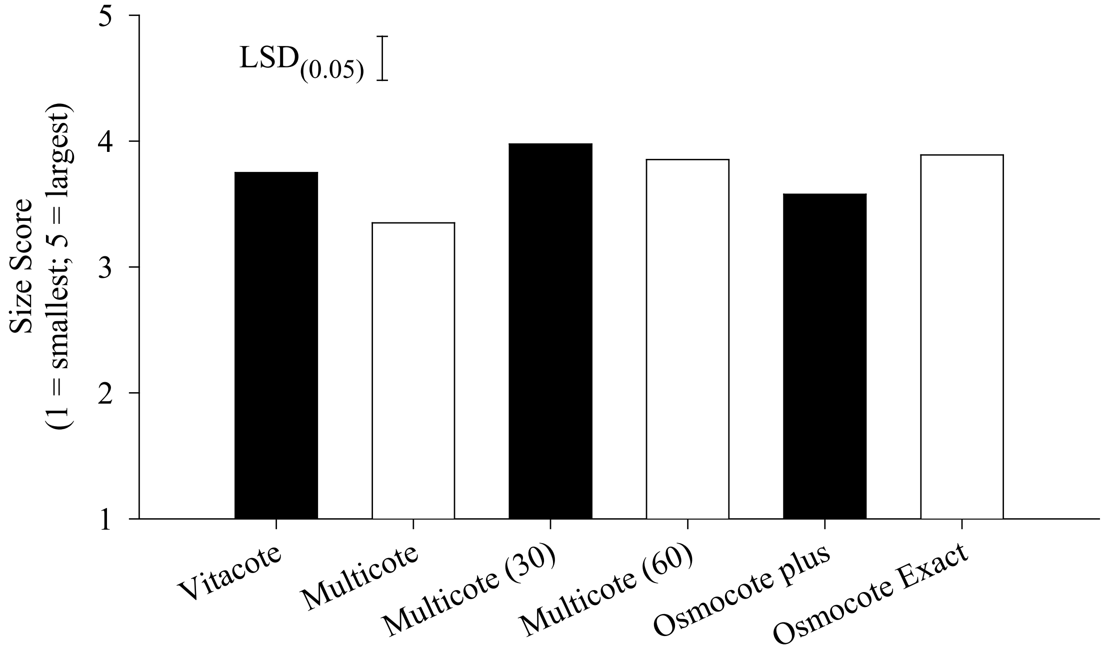


Figure 5. ***Erica vagans*** **'Mrs Maxwell'**
Size score, Autumn 2001



Discussion (Years 1 & 2)

Findings are discussed for the conditions *under which the experiments were carried out*. Extrapolation to other years must be made with a full understanding of the conditions studied in this work. Account should also be taken of how the irrigation system, incorporation of base fertilisers and geographical location differ from those in this study.

The products studied were all controlled release fertilisers. The 'control' of nutrient release is moderated by temperature. At a higher temperature, nutrients diffuse faster from the granule, resulting in a shorter 'life time' for the granule. The opposite is true at lower temperatures. Following prolonged rain, or heavy irrigation (especially overhead), a proportion of the nutrients, already released from the granules, can be leached from the pots. Consequently, nutrient availability to the plant is affected by the interaction of two factors: temperature and moisture (irrigation / rain). When the conditions are warm with heavy rainfall / irrigation the life span of CRFs will be reduced compared to cold and dry conditions.

1. What is the factor that allowed one rate of CRF to be used on heathers with a wide range of salt sensitivities?

The findings of HNS 96 showed that heather crop quality was improved through the use of Vitacote, when compared to a number of 12-14 month CRFs. And the first aim of this work was to identify whether plant quality was best improved through increased iron availability, reduced CRF longevity, or higher N supply compared to a standard 12-14 month CRF.

Growth by Autumn and by Spring

In year 1 of HNS 96a, Vitacote produced plants significantly larger than one or more treatments with all cultivars by Autumn 2000. Interestingly, the rate at which this benefit was observed differed for the mains watered and acid watered plants. Plants irrigated with mains water (~ pH 8.0) exhibited the greatest responses at 1.5 kg m^{-3} for all cultivars, whereas plants receiving acidified water showed more treatment responses at the highest rate (2.0 kg m^{-3}). However, by the end of year 1 these differences were no longer apparent, all treatments at either 1.5 or 2.0 kg m^{-3} were producing saleable plants.

It was concluded that the high rainfall over winter in year 1, on an outdoor crop had affected treatment responses by a) leaching nutrients from the growing medium, and b) reducing the need for irrigation and hence the differences in rhizosphere pH achieved through acid dosed irrigation when compared to mains water irrigation.

The experimental conditions in year 2 were altered in light of the first years results; the lowest CRF rate of 1.0 kg/m^3 was dropped, plants were moved under protection during winter and spring, and were irrigated with acidified water only. Vitacote again produced significantly larger plants than some other treatments by autumn with both 'King George' and 'Peter Sparkes'. However, some other treatments, especially Multicote + Fe-Hi 30, were producing similar sized plants, and by the end of the experiment all treatments, including Vitacote, were producing saleable plants of similar size. The use of protection in year 2 would have prevented leaching of nutrients by rain overwinter. Indeed, if salt accumulation in winter and spring was to be a potential problem, the year 2 trial would have been more likely to show evidence of this compared to year 1, but neither symptoms of salt damage nor starvation were apparent. In general, all nutrition treatments (1.5 – 2.0 kg/m^3 CRF) were producing broadly similar quality marketable plants by the end of experiment.

The relative performance of Vitacote can be summarised as follows:

1) Differences among CRFs were more marked prior to the winter in both years.

2) Acidification of the growing medium removed the benefit of Vitacote observed in HNS 96

There are a number of explanations for the disappearance of initial treatment differences by the end of each crop year. Nutrient supply may have been limiting growth up to autumn in some treatments, followed by excess nutrients in the spring. HNS 43d concluded that the greatest release of nutrients from CRFs occurs before autumn, with approximately half of nutrients in the granule being released. Differences between some of the CRF formulation release rates would have had a larger effect in the first part of the trial from potting until the end of summer, while the plants were growing rapidly. Vitacote and Multicote 8 have a slightly faster release rate and a higher % N content than the Osmocote Plus and Osmocote Exact formulations used in this project. This extra N availability early in the trial may well have been a more significant factor affecting growth rates up to the autumn assessment, than the availability of iron. However, further research would be needed to study the pattern of nutrient release more closely to confirm this. Finally, it could be that pot size (9 cm ~ 0.3 l) limited overall plant growth leading to a similar size for all treatments, i.e. some treatments arrived at this point sooner. However, observation of plant roots did not indicate that root restriction was limiting (see Photo 7, Appendix 2).

Role of iron nutrition

Physiological iron deficiency is observed with ericaceous plants when there is too much lime in the substrate and/or the concentration of HCO^- in the irrigation water is too high i.e. hard water areas. It is well known that this can be ameliorated through the addition of chelated iron (Tobbutt & Flowers, 1997). The fact that acid-dosing removed the growth improvement associated with Vitacote supports the theory that the iron coating on Vitacote may have contributed to this effect. However, in year 1, where chelated iron was added to Multicote 8 in the substrate, only 'Peter Sparkes' appeared to benefit compared to straight Multicote. In year 2, (all treatments with acidified water), again, additional iron chelate was not consistently beneficial, and with 'King

George', the high rate (60 g m^{-3}) addition of Fe-Hi gave poorer growth than Multicote 8 alone, Multicote plus 30 g m^{-3} Fe-Hi, or Vitacote.

Repeated doses of iron throughout the growing season was not examined, and may have given different results. The easiest way of doing this would have been to use a series of foliar sprays of iron chelate.

Iron chelates are available as Fe EDTA (e.g. Librel Fe-Lo or Vytel Iron 14, approx.13% Fe), Fe EDDHA and Fe DTPA (e.g. Librel Fe-Hi or Vytel Iron 6 and Librel Fe-DP, both approx. 7 %Fe). Fe EDTA is only recommended for use where pH will not rise above 6.5. pH can rise above this in hard water areas, even using low lime (calcifuge) growing media, unless water is acidified. Fe DTPA and Fe EDDHA, although more expensive, can be incorporated where pH's might rise. Chelates can be incorporated into growing media (as in this project), or applied as foliar sprays or media drenches during the growing season. Where iron chelates are used, particularly as sprays, it is important to follow product labels guidelines for rates and methods of use to minimise risk of crop damage.

Foliage analyses were carried out on a cross section of cultivars and nutrition treatments at the end of the year 1 trial. Mean levels of iron, and other key trace elements with which it can interact, were as follows:

	mg/kg	(± s.e. of mean)
Fe	66.7	(± 5.65)
Mn	83.2	(± 5.02)
B	17.9	(± 0.65)
Cu	1.65	(± 0.11)

With little published data on satisfactory standards for micronutrient levels for Heathers, it is difficult to interpret these precisely. Iron foliage analyses can also be notoriously misleading, unless there are gross deficiency symptoms present, for example. Aendekerk (1997) found with *Calluna vulgaris* 'H.E. Beale' that adequately fertilised plants had foliage Fe levels of 170 mg/kg whereas those without Fe had 90 mg/kg. He did not include Cu or B, but his Mn guideline levels were similar to ours. Although this suggests our Fe levels were low, treatments with very different Fe applications showed little difference at this time, and no obvious foliage symptoms such as yellowing of growth points were apparent. Also, levels of Mn, B and Cu were broadly in line with what would be expected in other crops, indicating that these were neither excessive nor deficient which might have had a 'see-saw' interaction with Fe.

It appears easiest to acidify water and thus ensure trace elements supplied by the CRF are readily available. Where water cannot easily be acidified, addition of extra Fe as chelated traces <u>may</u> be beneficial, although this was not proven in this project. For example the addition of extra iron as Fe-EDDHA chelate to Multicote 8 at a range of rates either gave inconsistent improvement in growth (i.e. it worked on one or two cultivars for early growth in one year only) or it performed less well than Multicote 8 alone.

In summary, results from this project did not provide evidence of significant or consistent growth benefits from adding extra iron chelate to CRF formulations, nor that iron deficiency was responsible for poorer growth of some treatments, but neither can the influence of iron be entirely ruled out.

In conclusion, acid dosed irrigation should ensure trace elements remain available, and under these conditions, a range of medium to long term CRFs are equally capable of producing quality plants. However, where mains water is used, and is alkaline (HRI-Efford mains water has a pH of 7.5 – 8.2), there may be some benefit in using a CRF such as Vitacote, or supplying extra iron as a suitable chelate as a precaution against iron deficiency problems.

2. What is the most cost-effective CRF rate for a range of Heathers?

CRF treatments were included at a range of rates over the two years. In year 1, a rate of 1.0 kg m^{-3} produced plants of insufficient size (Photo 5, Appendix 2), consequently this rate was dropped from year 2. Over the two years 1.5 kg m^{-3} and 2.0 kg m^{-3} of all CRFs produced similar quality saleable plants, both when plants received heavy winter rain (year 1) or when grown under protection during winter (year 2). This work supports the use of 1.5 kg m^{-3} of CRF for producing a range of Heathers. The higher rate may have some benefit for shelf-life and/or garden establishment, but these factors are outside of the remit for this study.

Rates of CRF used here, and which gave good results, are less than the manufacturer's recommendations. The fact that there was little if any extra growth between 1.5 and 2.0 kg m^{-3} suggests that nutrient supply overall was not limiting. In HNS 96, some losses, believed to be due to salt damage, did occur and these were greatest at the highest rates of 2.0 kg m^{-3} CRF. However, plant losses in HNS 96a have been lower, with virtually none in the year 2 trial. That under some conditions damage can still occur from CRF's at relatively low rates, supports the well-known salt sensitivity of heathers. Also that optimum CRF rates for heathers falls within a relatively narrow band.

Overall conclusions (Years 1 & 2)

- **Vitacote again gave good results under high pH irrigation, – suggesting that the form of Fe coating on this CRF may have contributed to this effect. However, comparisons using Multicote 8, (a CRF product of similar longevity and major nutrient analysis to Vitacote), with and without additions of chelated iron, gave variable results, and iron deficiency as an explanation for some growth differences between treatments could not be proved.**

- **Where plants were grown with irrigation water below about pH 6.0, all CRFs studied produced similar quality plants at the end of each cropping season. Acidification of hard water supplies to prevent excessive pH rise in growing media should ensure micronutrients in CRF formulations, especially iron, remain available to heathers. Where acidification of hard water is not practical, then Vitacote may give better results than some other CRFs, or extra iron can be supplied as a suitable chelate as a precaution against iron deficiency problems.**

- **A rate of 1.5 kg m^{-3} of several medium to long term CRF formulations is suitable for quality production of a range of heathers either outdoors or under protection. Rates of 2.0 kg m^{-3} may be damaging to salt-sensitive cultivars under some conditions.**

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APPENDIX 1 Trial Layout Year 2 (2001 / 02)

File : trial2layout **Heather Trial 2 2001/02** **3094**

N ↑

REP 1

V.1

1 A	2 B	3 C
4 D	5 E	6 F
7 G	8 H	9 I
10 J	11 K	12 L

V.2

75 A	74 C	73 B
78 G	77 I	76 K
81 H	80 E	79 D
84 J	83 L	82 F

V.3

13 H	14 G	15 I
16 F	17 D	18 E
19 B	20 C	21 J
22 K	23 A	24 L

V.4

87 B	86 E	85 C
90 F	89 L	88 H
93 I	92 K	91 G
96 A	95 J	94 D

REP 2

V.2

25 I	26 E	27 H
28 L	29 F	30 D
31 J	32 K	33 G
34 A	35 C	36 B

V.3

99 E	98 A	97 F
102 C	101 K	100 D
105 L	104 G	103 J
108 I	107 B	106 H

V.1

37 G	38 L	39 E
40 A	41 B	42 F
43 D	44 C	45 J
46 K	47 H	48 I

V.4

111 D	110 E	109 F
114 L	113 H	112 C
117 J	116 B	115 G
120 K	119 I	118 A

REP 3

V.4

49 I	50 A	51 E
52 J	53 B	54 F
55 K	56 C	57 G
58 L	59 D	60 H

V.1

123 K	122 F	121 D
126 A	125 B	124 E
129 L	128 C	127 I
132 J	131 G	130 H

V.3

61 E	62 G	63 C
64 F	65 B	66 L
67 I	68 H	69 A
70 J	71 D	72 K

V.2

135 F	134 A	133 D
138 L	137 G	136 H
141 J	140 I	139 C
144 E	143 B	142 K

Cultivars

V.1 = King George
V.2 = Rosalie
V.3 = Mrs Maxwell
V.4 = Peter Sparkes

Nutrition Treatments

		CRF kg/m3	Fe-Hi g/m3
A	Vitacote	1.5	-
B	"	2.0	-
C	Multicote 8	1.5	-
D	"	2.0	-
E	Multicote 8 + FeHi	1.5	30
F	" "	2.0	30
G	" "	1.5	60
H	" "	2.0	60
I	Osmo Plus 12-14 Autumn	1.5	-
J	" "	2.0	-
K	Osmo Exact Standard	1.5	-
L	" "	2.0	-

APPENDIX 2 Photographs

Photo 1 Year 1 Trial - February 2001. Beds with mains and acidified treated irrigation.

Photo 2 Year 2 Trial - October 2001.

Photo 3 Year 2 Trial - Size grades 5 - 1 in October 2001.
Clockwise from top left: 'King George', 'Rosalie', 'Peter Sparkes', 'Mrs Maxwell'.

Photo 4 Year 2 Trial - Size grades 5, 3, 1 in May 2002.
Clockwise from top left: 'King George', 'Rosalie', 'Peter Sparkes', 'Mrs Maxwell'.

Photo 5 Year 1 Trial - Mrs Maxwell assessments in Autumn 2000 (top row) and Summer 2001 (bottom row).
CRF's at 1.0, 1.5 and 2.0 kg m^{-3}. Left picture Vitacote; right picture Multicote 8 + Fe-Hi iron chelate. All with acidified water.

Photo 6 Year 2 Trial - Mrs Maxwell assessments in Autumn 2001.
Within each picture CRF's at 1.5 and 2.0 kg m^{-3}. All with acidified water. Top row: Vitacote; Multicote 8; Multicote 8 + FeHi @ 30 g m^{-3}
Bottom row: Multicote 8 + FeHi @ 60 g m^{-3}; Osmocote Plus (12-14) Autumn; Osmocote Exact Standard.

Photo 7 Year 2 Trial – Root systems and top growth by June 2002.
In each picture: Left, Vitacote @ 2.0 kg m^{-3}; Right – Osmocote (12-14) Autumn @ 2.0 kg m^{-3}
Top picture: *Erica carnea* 'King George'; Bottom picture: C*alluna vulgaris* 'Peter Sparkes'