FINAL REPORT

Nursery stock propagation:
nutrition of rooted cuttings in modular trays

HNS 90

2001-2004

Project title:	**Nursery stock propagation: nutrition of rooted cuttings in modular trays**
Project number:	**HNS 90**
Report:	**Final, 2001 – 2004**
Previous reports:	**Annual 2001 - 2003**
Project leader:	**Margaret Scott MBE** **HRI-Efford** **Lymington,** **Hampshire** **SO41 0LZ** **David Hutchinson** **ADAS**
Key workers:	**Project Management - Carrie Hawes and Sarah Williams** **Nursery Staff - Trevor Hiscock, Sid Stagg, Ken Herridge and David Joblin**
Location:	**HRI-Efford**
Project Co-ordinator:	**John Hedger, New Place Nurseries, London Road, Pulborough, West Sussex, RH20 1AT**
Date project commenced:	**October 1998**
Date project completed:	**January 2004**
Key words:	**HNS, propagation, nutrition, phosphate**

CONTENTS

HNS 90: Nursery stock propagation: nutrition of rooted cuttings in modular trays

1.1 Headline

- CRF mini granules enhanced HNS quality after potting and growing on of cuttings held for three months or less
- Fortnightly application to rooted cuttings held in modules of a 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O liquid feed greatly enhanced HNS quality after potting and growing on.
- The application of a nutrient trigger six weeks before module-raised, rooted cuttings are potted on cannot be recommended as a substitute for balanced feeding (with phosphate) during the maintenance phase.

1.2 Background and expected deliverables

Marked improvements in HNS quality have been observed in past trials by the adoption of appropriate nutritional regimes designed to ensure that rooted cuttings are in active growth at the time they are potted on. However, this can be difficult to ensure when rooting is done in small-volume modules, now an industry standard, and the modules have to be held for an extended period prior to potting on. Not feeding these leads to nutrient-starved plants, but weekly fertigation with a balanced N : P_2O_5 : K_2O feed can also lead to excessive growth and unwanted competition in the module tray.

Phase 1 of this project (2001-03) showed that excessive growth in the module tray could be avoided by dropping the P_2O_5 from the liquid nutrient feed. This preserved foliage colour and allowed rooted cuttings to be held for at least one year before potting on. However, they appeared rather "hard" and "inactive" at the end of this period, and it was concluded that a balanced "trigger" feed regime with phosphate, starting around six weeks before potting, would be beneficial in promoting active growth after potting on.

Liquid feeding can lead to over-watering during the winter, and the incorporation of controlled release fertiliser (CRF) mini-granules could avoid this. However, these have a relatively short nutrient supply life of around 3-4 months. Standard CRF granules have a longer life, but it is difficult to incorporate these uniformly into the rooting medium when small modules are used.

The expected deliverables from this work were:

- An appraisal of the potential benefits of adopting liquid feed regimes, with and without phosphate, on module-rooted cuttings of HNS subjects held for a substantial period before being potting on.
- A comparison of the effects of CRF mini-granules incorporated into the rooting medium and liquid feed regimes on ultimate plant quality after potting on.
- An assessment of the effect of nutritional composition and application regime on the effectiveness of nutrient trigger treatments.

1.3 Summary of the project and main conclusions

Propagation

Winter- and summer-struck cuttings were rooted in a peat/pine bark medium in PG77 module trays (individual cell volume of 55 ml). Species struck in the winter were *Choisya ternata* and *Juniperus communis* 'Repanda'; species struck in the summer were *Cotoneaster dammeri* 'Coral Beauty' and *Azalea* 'Rose Greeley. Rooted cuttings were subsequently held in a maintenance phase for either three months (winter-struck cuttings) or five months (summer-struck cuttings). During this phase, fertilization was either with liquid feed or CRF mini granules. All maintenance treatments subsequently received trigger nutrient treatments prior to potting on into proprietary peat-based compost in 90 mm pots. Final observations were made four months later.

Effects of liquid feed regimes during the maintenance phase

Three maintenance feeds were tested: NLF, no liquid feed (control); LF1, 50 ppm N : 50 ppm K_2O liquid feed applied fortnightly; LF2, as LF1 but with 25 ppm P_2O_5.

Final pot quality, judged on the basis of such characters as numbers of shoots, root score, plant height and dry weight, was not improved in any of the winter and summer struck species by the adoption of the LF1 feed during the maintenance phase. In the case of dry weight (a measure of photosynthetic growth), Table 1 shows that plants of all four species fed with the LF1 feed were ultimately not significantly heavier than unfed NLF plants. It can be expected that adopting the LF1 regime will enable N and K to be supplied to the rooted cuttings without generating unwanted extension growth and crowding in the tray. It should also keep the foliage green (phase 1 of the work). However, this in itself is unlikely to lead to improved final pot quality after potting and growing on.

In contrast, maintaining plants in the LF2 nutrient regime (as LF1 but with an additional 25 ppm P_2O_5) gave very marked improvements to quality at final harvest in all four species. Plants were generally bushier, larger and had greater dry weights (except *Juniperus*). Table 1 indicates that dry weight increases over the control NLF treatment averaged +13.9% over the four species, and ranged from +2.5% in *Juniperus* (not significant) to +21.2% in *Azalea* (significant). Any unwanted competition in the trays (not tested in this work) that was promoted by the use of this maintenance regime was more than compensated for in terms of enhanced quality of the final potted-on product. A possible "down side" of this treatment was additional moss and liverwort cover in the trays, but this appeared not to compromise final quality.

Table 1. Dry weights (g) at final harvest of HNS species fertigated using three different feeds during the maintenance period prior to potting on.

Species	Final plant dry weight (g)		
	NLF	LF1	LF2
Choisya	9.45	10.16 n.s.	10.71 *
Juniperus	3.64	3.53 n.s.	3.73 n.s.
Cotoneaster	23.18	24.55 n.s.	27.51 *
Azalea	13.7	14.47 n.s.	16.61 *

NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, as LF1 but with 25 ppm P_2O_5.
* indicates a significant difference from the NLF treatment at $P<0.05$; n.s., non-significant.

Effects of CRF mini-granules incorporated into the rooting medium

Multicote CRF mini-granules were incorporated into the rooting medium at 0.5 kg/m^3 for the winter-struck cuttings, and 0.75 kg/m^3 for the summer-struck cuttings. No additional liquid feed was applied during the maintenance feed, but nutrient trigger treatments were applied at the 200 ppm N : 150 ppm P_2O_5 rate 6 weeks before potting on.

Overall, comparing against the NLF control treatment, CRF treatment was beneficial in *Choisya* and *Juniperus*, but not in *Cotoneaster* and *Azalea* (see Table 2 for dry weight comparisons). CRF actually out-performed the LF2 treatment in *Juniperus*. It remains a possibility, however, that this apparent species specificity has more to do with time of year that the cuttings were struck. Thus, the two species benefiting from CRF treatment were both struck in winter (with a relatively short maintenance phase), whilst the two species that did not benefit were both struck in summer (with a longer maintenance phase). It may have been that these latter simply “ran out of steam” and were outclassed by the liquid feed treatments.

Table 2. Dry weights (g) at final harvest of HNS species fertigated using either CRF mini-granules incorporated into the rooting medium, or LF2 liquid feed (see Table 1) applied fortnightly during the maintenance phase.

Species	Final plant dry weight (g)		
	NLF	LF2	CRF
Choisya	8.86	10.50 n.s.	11.06 *
Juniperus	3.67	3.76 n.s.	4.78 *
Cotoneaster	23.18	27.05 n.s.	23.11 n.s
Azalea	13.09	17.18 *	14.89 n.s

* indicates a significant difference from the control NLF treatment at $P<0.05$; n.s., non-significant. Note that the NLF and LF2 data differ from those in Table 1 because they relate to just the single nutritional trigger treatment used for the CRF treatment.

CRF mini-granules can be expected to supply nutrients for around three months. When the maintenance phase exceeds three months, it is recommended that a follow-on liquid feeding regime is adopted.

Effects of trigger treatments

Four nutritional trigger treatments were tested, comprising all combinations of two levels of N (100 and 200 ppm) and two levels of P_2O_5 (150 and 300 ppm). Each of the nutrient triggers was applied twice or three times, with two weeks between successive applications. Trigger applications began 6 weeks before potting when three applications were given, and either 4 or 6 weeks before potting when two applications were given.

It was unfortunate that the experiment did not contrast treatments with and without a nutritional trigger, since it is far from certain that nutritional triggering had any major effect at all on final plant quality. Comparisons between nutritional trigger treatments showed no major trends; such significant effects as were found were trivial in the context of commercial growing. There was also no indication that a trigger treatment could make up for the reduced growth and quality that stemmed from the use of LF1 maintenance feed rather than LF2 feed.

Consistent with trigger treatments having no major effect on ultimate quality, there were also no significant and consistent effects of number of trigger applications prior to potting up in *Juniperus*, *Cotoneaster* and *Azalea*. There was, however, a small beneficial effect in *Choisya* when applications were started six weeks before potting rather than four weeks before potting.

On the basis of the trial reported here, trigger treatments cannot be recommended as a substitute for maintenance feeding using a balanced nutrient feed containing P_2O_5.

1.4 Financial benefits

There are probably in excess of 200 million potted HNS plants produced each year in the UK from rooted cuttings. Assuming that the price differential between a first grade pot and a second grade pot is 10p, and the adoption of sound nutritional management of modules raises 1% of these from second grade to first grade, then the annual financial benefit to the UK HNS industry will be around £200,000. This does not take into account any reduction in the losses of rooted cuttings during the maintenance phase. Assuming a rooted cutting has a value of 20p, and sound nutritional management during the maintenance phase reduces the loss of just 1% of the 270 million that are raised annually in the UK, then the annual financial benefit to the UK HNS industry will be around £540,000. The use of CRF mini-granules can be particularly beneficial. Assuming a cost for CRF of £60 (incl. VAT) for 10 kg, then at the rates used in this work, incorporation will increase the cost of 1,000 filled modules by only around 16.5 p in winter (0.5 kg/m^3) and 25p in summer (7.5 kg/m^3). This equates to 1.3 p per 77-module tray in winter and 1.9 p per 77-module tray in summer. There will be no additional feed application costs for at least 3 months, reduced moss and liverwort growth, and environmental benefits stemming from minimal nutrient wastage.

1.5 Action points

- Consider incorporating CRF mini-granules into the HNS rooting medium when modules containing the rooted cuttings are expected to be held for a significant period before being potted on.
- Use a balanced liquid feed (with phosphate) at fortnightly intervals after rooted cuttings with CRF mini-granules have been held for around three months.
- Nutritional trigger treatments applied about six weeks before potting on cannot be recommended as a substitute for balanced feeding during the maintenance phase. Growers using trigger treatments should consider whether this really is justified.

2. Science Section

2.1 Introduction

Trials at Efford between 1979 and 1985 showed marked quality and production benefits by the adoption of appropriate nutritional regimes designed to ensure that rooted cuttings were in active growth at the time of potting-on. However, it can be difficult to ensure that cuttings are in active growth when they are in small-volume modules, now an industry standard, and have to be held for extended periods before potting-on, due to pressure on space, labour, delivery schedules or competing nursery demands. Not feeding these leads to nutrient-starved plants, but weekly fertigation with a balanced N : P_2O_5 : K_2O feed also leads to problems as a consequence of excessive growth and unwanted competition between neighbouring plants. An alternative approach was clearly called for and has been addressed by this project.

Phase one (see Interim Report for HNS 90, 2001-2003) showed that excessive cutting growth could be avoided by dropping the phosphate (P) and adopting a weekly 50 : 50, N : K_2O liquid feed after rooting had been completed. This provided sufficient nutrients to maintain foliage colour and gave good quality plants after about one year's maintenance, albeit that these were rather "hard" and apparently "inactive". P applied around six weeks prior to potting "triggered" the active growth needed at that stage. However, the boost obtained from the applied P resulted in paler foliage and, ultimately, in the case of *Azalea*, chlorosis. The rate of P required may well differ from species to species, and with level of nitrogen (N), but best results were obtained in phase one with P at 100 ppm.

Liquid feeding can lead to over-watering during the winter, so the use of controlled release fertilizers (CRF) was additionally investigated. Mini granules (Osmocote Plus or Multicote) ensured that incorporation into the compost was reasonably uniform (important when small-volume modules are used), but these had a nutrient supply life of only around 3-4 months. The trials showed that CRFs used in this way at 0.5 kg/m^3 produced an early flush of growth, enabling pinching back to be carried out to form the primary branch framework whilst the rooted cuttings were still in their rooting modules. Plants "ran out of steam" after about 3 months, but they could then be held for longer in the modules by adopting a weekly supplementary feeding regime with 50 : 50, N : K_2O liquid feed. If a further flush of growth was required, this could be achieved by incorporating P into the maintenance liquid feed, or applying the same CRF modules as a top dressing at 30 g/m^2.

2.2 Objectives of Phase 2

1. To re-examine the effects of supplementary liquid feed applied after rooting on the maintenance of cutting quality.
2. To compare the incorporation of CRF mini-granules in the rooting medium with supplementary liquid feeding on cutting growth.
3. To examine the growth response to P at different levels of N during triggering.
4. To determine the optimal number of applications of P during triggering.

2.3 Materials and Methods

All cuttings for the experiments were rooted in a 50 : 50 peat (Shamrock medium Irish sphagnum) : pine bark (Cambark fine granulated) medium in PG77 module trays (individual cell volume = 55 ml). Cuttings were struck both in the winter and the summer. A routine fungicide programme was applied at fortnightly intervals comprising a rotation of Rovral (iprodione), Octave (prochloraz) and Benlate (benomyl).

Winter strike:

Two subjects were propagated: *Choisya ternata* and *Juniperus communis* 'Repanda'. The two species were propagated together in the same trays, with 35 (central) cuttings of *Choisya* per tray surrounded by 42 cuttings of *Juniperus* as shown in Appendix Fig. Aa. Cuttings treated with rooting hormone were struck in mid-December 2001 and trays were held initially on heated sand beds (base heat set at a minimum of 15ºC) under low polythene covers, in a double-skin polythene tunnel (Appendix Fig. Ab) until rooting had been completed and weekly maintenance feeding began. This maintenance phase was carried out on benches in an unheated glasshouse (Appendix Fig. Ac). *Choisya* was trimmed three times during this three-month maintenance period – at the start, mid-way through, and immediately prior to triggering - to allow side-shoot growth to be made and to encourage plants to become compact and bushy. Triggering was carried out in June 2002, with subsequent potting-on of 5 plants per species from each propagation tray in August. Potting-on was into 90 mm plastic pots containing a proprietary

100% peat compost, with an appropriate base dressing appropriate to the species, standing on capillary matting (Appendix Fig. Ad). Final observations were made about four months later.

Summer strike:

Species used in summer were *Cotoneaster dammeri* 'Coral Beauty' and evergreen *Azalea* 'Rose Greeley' propagated together in mixed trays. Propagation was in polythene tunnels under mist, with a minimum base temperature of 18ºC. The schedule was: cuttings struck in July 2002, maintenance feeding started in November, "triggering" in April 2003, and potting-on in June into 90 mm plastic pots containing a proprietary 100% peat compost, with an appropriate base dressing appropriate to the species. Final observations were made in October.

Treatments:

Rooted cuttings of the four species were subjected to all combinations of:

3 maintenance feeds,

3 triggering schedules,

2 levels of P in the trigger feed, and

2 levels of N in the trigger feed.

There were thus 36 treatments (3x3x2x2) per species per strike date, with each treatment represented by 3 replicate trays (=108 plots x 2 strike dates x 4 species).

There was also a single mini-granule CRF maintenance treatment which was combined with a single level of P and N in the trigger feed (200 ppm N : 150 ppm P_2O_5), but with each of the 3 triggering schedules. This gave an additional 3 treatments, each with 3 replicate trays per species and strike date (= an additional 9 plots x 2 strike dates x 4 species).

The whole experiment was done as a randomized block design.

<u>Fertiliser treatments</u>

<u>i) Maintenance feeds</u>

NLF, no liquid feed applied

LF1, 50 ppm N : 50 ppm K_2O liquid feed applied fortnightly

LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O liquid feed applied fortnightly.

<u>ii) CRF treatment</u>

Multicote mini-granule CRF incorporated at 0.5 kg/m^3 for the winter propagation, and 0.75 kg/m^3 for the summer propagation. No liquid feed applied.

Triggering schedules

4 x 2 treatment – 2 applications, two-weeks apart, starting 4 weeks before potting

6 x 2 treatment - 2 applications, two-weeks apart, starting 6 weeks before potting

6 x 3 treatment - 3 applications, each two-weeks apart, starting 6 weeks before potting.

Nutritional Triggers

Four nutritional trigger treatments were used in conjunction with the liquid feed maintenance treatments. These comprised all combinations of :

2 levels of N - 100 ppm and 200 ppm

and

2 levels of P_2O_5 - 150 ppm and 300 ppm

The CRF treatment was associated with a single nutritional trigger treatment - 200 ppm N : 150 ppm P_2O_5 (but with all three triggering schedule treatments).

Observations:

Plants of *Choisya* and *Cotoneaster* were scored for final shoot number, root development (a 1, 3, 5 scale being used as shown for *Choisya* in Appendix Fig. B), and dry weight (g) – a measure of photosynthetic growth. *Juniperus* was scored for plant height and dry weight, and *Azalea* for number of side-shoots (breaks), plant height (cm) and dry weight (g). Data were analysed by ANOVA; in the graphs that follow, treatments differing significantly ($P<0.05$) from each other are marked with different letters.

2.4 Results

2.4.1 Effects of liquid maintenance feed treatments

Choisya:

Photographs in Appendix Fig. C show the effects of the three maintenance feeds, NLF, LF1 and LF2 on plants of *Choisya* immediately prior to the destructive sample around four months after potting and growing on of the rooted cuttings. The effects of maintenance feed on final growth appeared similar for each of the four trigger nutrient treatments, so Fig. 1a (below) graphs sample data at final harvest averaged over trigger treatment. The unfertilized control (NLF) plants showed early signs of leaf yellowing and were generally unthrifty up to potting. However, this had generally disappeared at final harvest. The LF1 regime (50 ppm N : 50 ppm K_2O liquid feed applied fortnightly) gave some increase over the unfertilized control (NLF) in number of shoots, root score and plant dry weight, but the differences were not significant ($P>0.05$). In contrast, plants maintained in the LF2 regime (with an additional 25 ppm P_2O_5) had significantly more shoots, were significantly better rooted and had significantly greater dry weights ($P<0.05$).

Juniperus:
Effects of maintenance regime appeared less marked for *Juniperus* 'Repanda' than for *Choisya*. Appendix Fig. 1b (below) and Fig. E indicate a small but progressive effect of increasing nutrition on final plant height whereby plants maintained with LF2 were taller than those maintained with LF1, and these in turn were taller than the unfertilized controls (NLF) ($P<0.05$). There was no significant effect of treatment on dry weight ($P>0.05$).

Cotoneaster:
As in *Choisya,* effects of maintenance feed on final growth in *Cotoneaster* appeared similar for each of the four trigger nutrient treatments (Appendix Fig. F). Averaging over these, there appeared to be no significant benefit to final growth over that of the control NLF treatment by adopting the LF1 maintenance regime. However, plants maintained in the rooting modules with LF2 feed ultimately gave plants with significantly greater ($P<0.05$) dry weight. Appendix Fig. F indicates that increased dry weight was generally accompanied by greater extension growth and plant size.

Azalea:
Results for *Azalea* 'Rose Greeley' were essentially similar to those for *Cotoneaster* (Appendix Fig. G and Fig. 1d below). Thus, the use of LF1 feed gave no final advantage over the unfertilized control treatment in terms of numbers of breaks, plant height or dry weight. However, feeding with LF2 significantly increased breaking, extension growth (height) and dry weight ($P<0.05$).

Moss/liverwort growth:
It became very obvious during the trial that the LF2 maintenance treatment markedly increased the growth of moss and liverwort on the surface of the compost prior to potting on. Adopting a scoring scale shown in Appendix Fig. Ha of 1, 3, 5 against reference trays, LF2 nutrition approximately doubled the moss and liverwort coverage score (see Appendix Fig. Hb). In contrast, feeding with LF1 gave relatively little extra moss and liverwort cover compared to the control treatment.

2.4.2 Effects of CRF treatment

Fig. 2a and Appendix Fig. Cb show that the Multicote mini-granule CRF treatment had very similar, final beneficial effects as the LF2 treatment in *Choisya* for number of shoots, root score and dry weight ($P<0.05$). CRF treatment was also very beneficial *in Juniperus* where this treatment gave at least as great an enhancement of extension growth as LF2, and significantly greater dry weight gain than LF2 ($P<0.05$) (see Fig. 2b and Appendix Fig. E). In contrast however, CRF treatment appeared to give no enhancement of growth over the LF1 control in both *Cotoneaster* and *Azalea* (Figs 2c and d, Appendix Figs Fb and Gb).

2.4.3 Effects of the nutritional makeup of trigger treatments

Fig. 3 shows the effects of nutritional trigger treatments within each of the liquid maintenance feed regimes (averaged over number of trigger applications). Overall, it has to be concluded that where trends are apparent (in *Choisya* and, to a lesser extent, *Cotoneaster* and *Azalea*), these can largely be accounted for solely on the basis of the maintenance treatment applied.

Effects of nutritional trigger are shown for *Choisya* in Fig 3a and representative plants are shown in Appendix Figs Da and b. No significant differences were found for any final character within NLF plants. In LF1 plants, final shoot number was promoted by the 100 N : 150 P_2O_5 trigger treatment, whilst root score was promoted by the 200 N : 150 P_2O_5 treatment. Highest dry weight was given by the highest nutritional trigger (200 N : 300 P_2O_5). In the LF2 plants, root score was lowest in the lowest nutritional trigger, 100 N : 150 P_2O_5, whilst shoot number was enhanced by the highest nutritional trigger (200 N : 300 P_2O_5 treatment).

There was no effect of nutritional trigger on final dry weight in *Juniperus*, and no obvious nutritional trend for plant height (Fig. 3b). There were also relatively few effects in *Cotoneaster*. The highest nutritional trigger, 200 N : 300 P_2O_5, appeared to marginally increase shoot number and dry weight in the LF1 plants, and low P_2O_5 tended to give higher shoot numbers than high P_2O_5 in LF2 plants (Fig. 3c). There were no effects at all of nutritional trigger in *Azalea*.

2.4.4 Effects of trigger application regime

Fig. 4 shows the effects of number (and timing) of trigger applications within each of the trigger nutritional treatments. There was no effect of trigger application regime in *Azalea*, and just a single significant difference in each of *Juniperus* (4x2 treatment gave greater dry weight than 6x2 or 6x3 treatments) and *Cotoneaster* (4x2 and 6x3 treatments gave more shoots than 6x2 treatment). In *Choisya*, the 4x2 treatment seemed to generally reduce final quality, although effects (even when significant at $P<0.05$) were always rather small and generally inconsistent.

2.5 Conclusions

2.5.1 Effects of liquid maintenance feed treatments

There was little or no obvious benefit to final plant quality over the unfed NLF control of adopting the LF1 feed regime (50 ppm N : 50 ppm K_2O liquid feed applied fortnightly). This conclusion was equally applicable to all four species tested (winter and summer strikes). Adopting the LF1 regime will enable N and K_2O to be supplied to the rooted cuttings without generating unwanted extension growth and crowding in the tray. However, this in itself is unlikely to lead to improved final quality when adopted in propagation regimes matching those used in this work at Efford.

In contrast, maintaining plants in the LF2 nutrient regime (as LF1 but with an additional 25 ppm P_2O_5) gave very marked improvements to quality at final harvest. Plants were generally bushier, larger and had greater dry weights (except *Juniperus*). Any competition in the trays that was promoted by the use of this maintenance regime (not tested in this work) was more than compensated for in terms of enhanced quality of the final potted-on product. Increased growth over that of the control treatment as determined by dry weight averaged +13.9% over the four species, and ranged from +2.5% in *Juniperus* (not significant) to +21.2% in *Azalia* (significant at P<0.05). A possible "down side" of this treatment was additional moss and liverwort cover, but this appeared not to compromise final quality.

2.5.2 Effects of CRF treatment

Care needs to be taken in interpreting the effects of the CRF treatment since it was tested in association with only a single trigger treatment, giving a smaller level of replication (compared to liquid feed treatments). This may account for the apparent species specificity of the results. Overall, comparing against the NLF control treatment, CRF treatment was beneficial in *Choisya* and *Juniperus*, but not in *Cotoneaster* and *Azalea*. It actually out-performed the LF2 treatment in *Juniperus*. It remains a possibility, however, that this apparent species specificity has more to do with time of year that cuttings were struck. Thus, the two species benefiting from CRF treatment were both struck in winter (with a relatively short maintenance phase), whilst the two species that did not benefit were both struck in summer (with a longer maintenance phase). It may have been that these latter simply "ran out of steam".

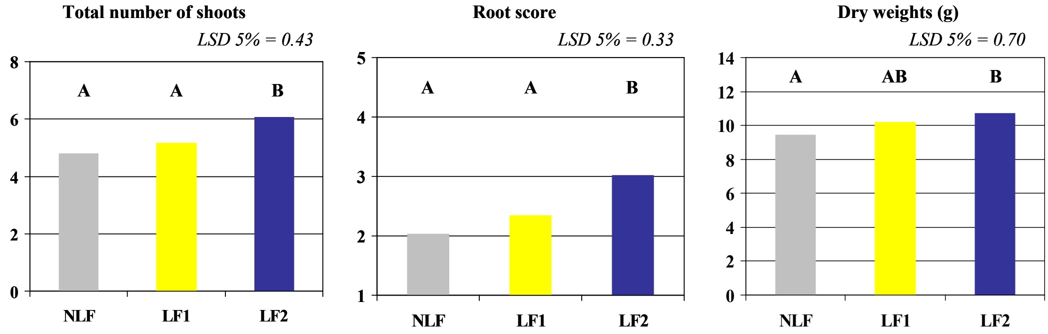
2.5.3 Effects of the nutritional makeup of trigger treatments

It was unfortunate that the experiment did not contrast treatments with and without a nutritional trigger, since it is far from certain that nutritional triggering had any major effect at all on final plant quality. Comparisons between trigger treatments showed no major trends; such significant effects as were found were trivial in the context of commercial growing. There was also no indication that a trigger treatment could make up for the reduced growth and quality that stemmed from the use of LF1 maintenance feed rather than LF2 feed. Highest quality plants were clearly given by LF2 maintenance nutrition, regardless of trigger, in at least *Choisya*, *Cotoneaster* and *Azalea*.

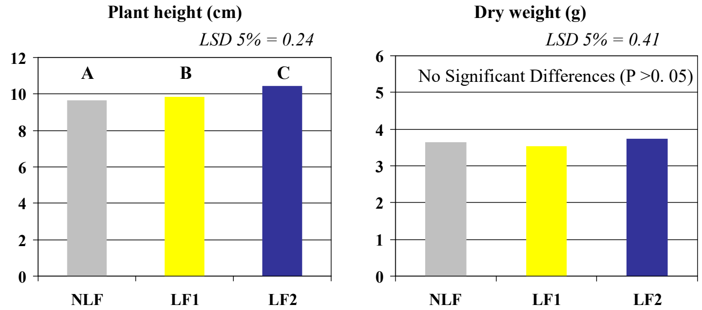
2.5.4 Effects of trigger application regime

Fig. 4 generally supports the conclusion (see 2.5.3) that the nutritional makeup of the trigger feed had no obvious over-riding effect on final plant quality. It was always possible, however, that this conclusion was reached because the beneficial effects of one or two of the application regimes were masked by a poorer response to the remaining application regime(s). There was some indication that this could have been the case in *Choisya*, since the 4x2 treatment frequently gave poorer quality plants than one or other of the 6x2 and 6x3 treatments. The implication of this is that for a trigger treatment to work it must be given starting six weeks before potting; four weeks before is not sufficient for plants to show a positive response. In apparent contrast to *Choisya*, there were no consistent effects of trigger application regime in *Juniperus, Cotoneaster* and *Azalea*.

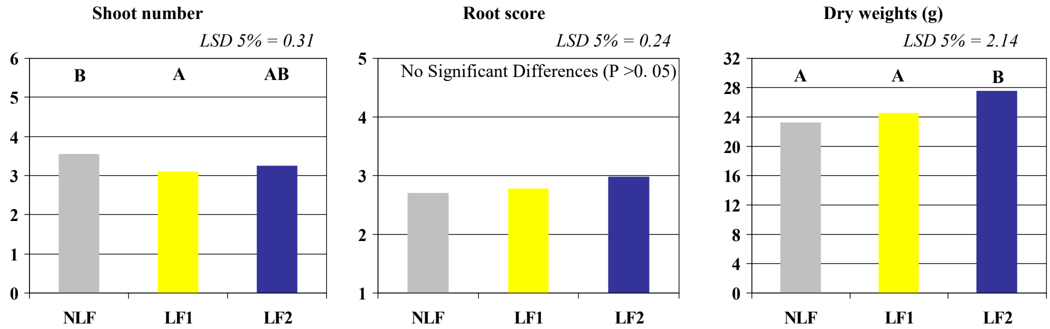
a) *Choisya ternata* (winter strike)



b) *Juniperus* 'Repanda' (winter strike guard)



c) *Cotoneaster* 'Coral Beauty' (summer strike)



d) *Azalea* 'Rose Greeley' (summer strike guard)

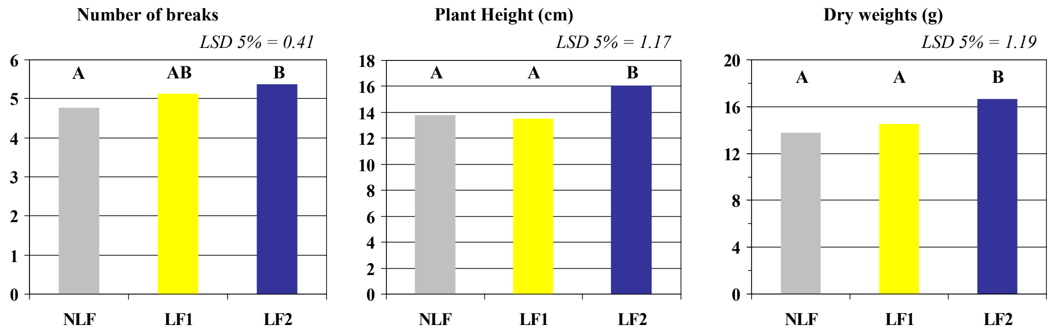
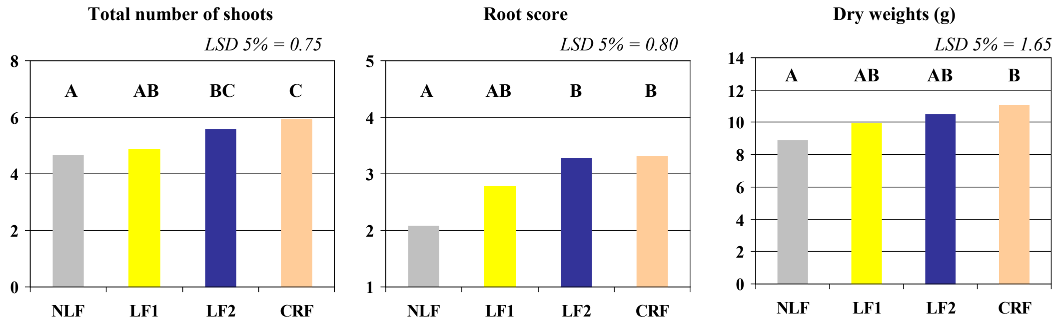
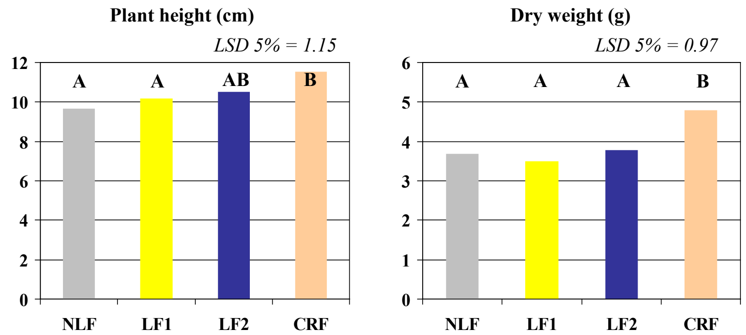


Fig. 1. Effects of maintenance treatments (averaged over trigger treatments): NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O

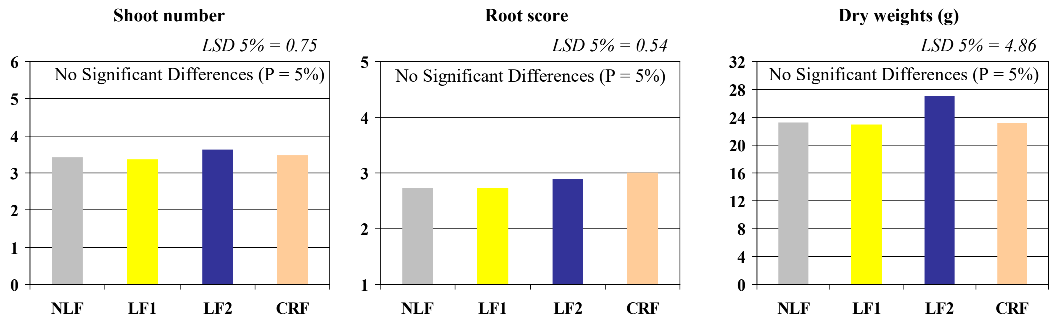
a) *Choisya ternata* (winter strike)



b) *Juniperus* 'Repanda' (winter strike guard)



c) *Cotoneaster* 'Coral Beauty' (summer strike)



d) *Azalea* 'Rose Greeley' (summer strike guard)

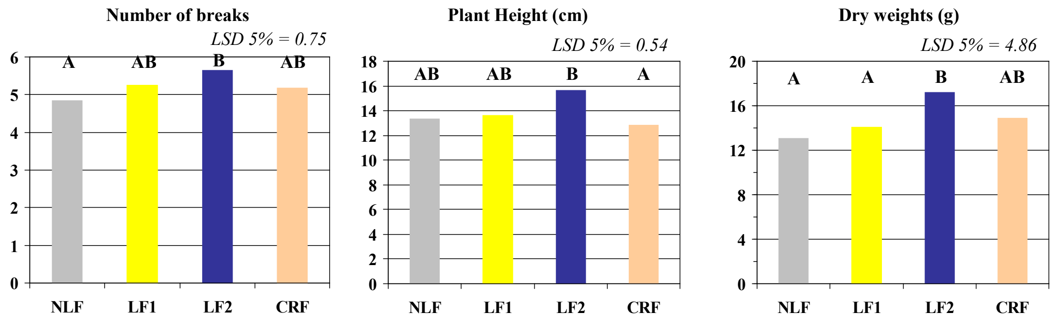
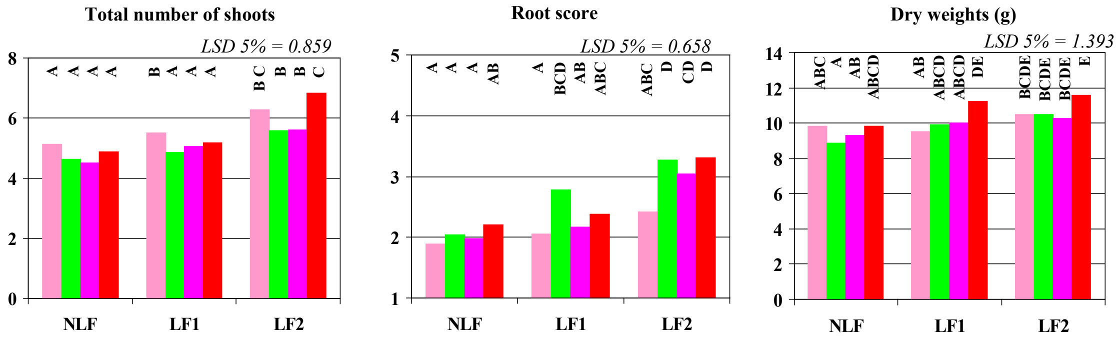
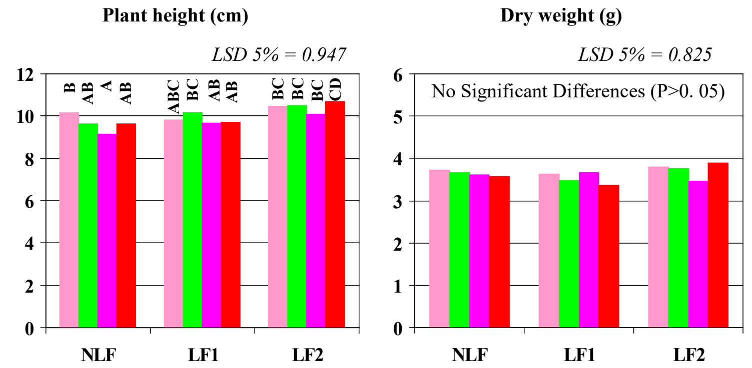


Fig. 2. Effects of CRF maintenance nutrition against liquid feeds (at the 200 ppm N : 150 ppm P_2O_5 trigger treatment rate only): CRF, Controlled release fertiliser treatment; NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O

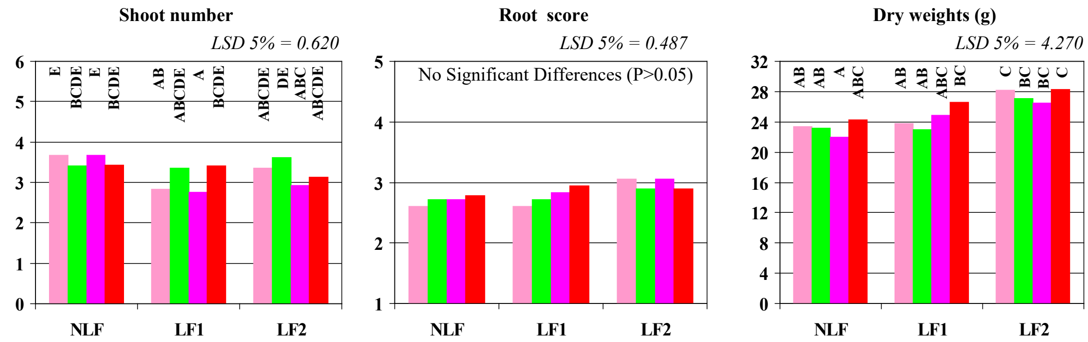
a) *Choisya ternata* (winter strike)



b) *Juniperus* 'Repanda' (winter strike guard)



c) *Cotoneaster* 'Coral Beauty' (summer strike)



d) *Azalea* 'Rose Greeley' (summer strike guard)

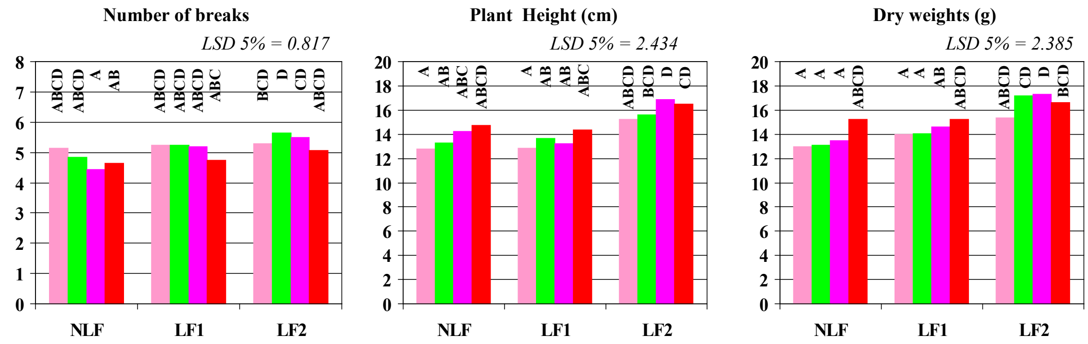
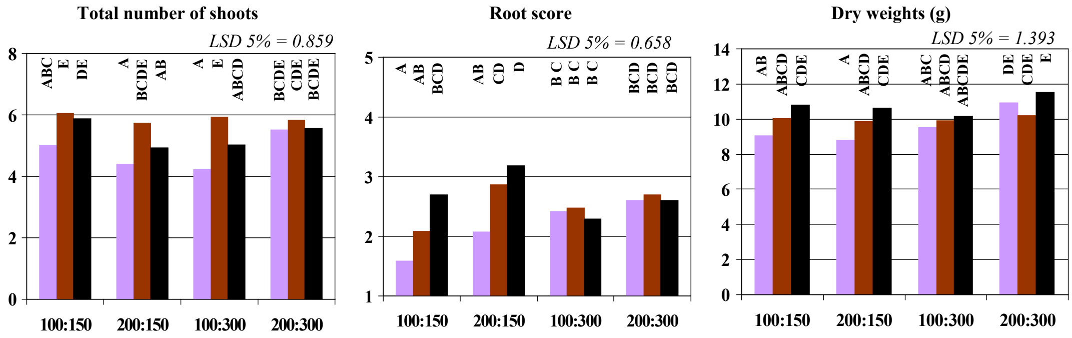
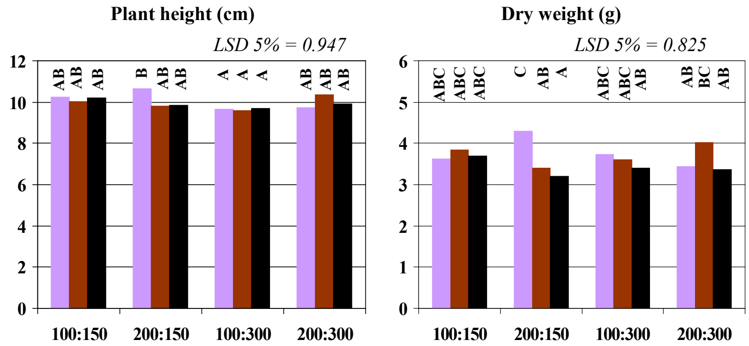


Fig. 3. Effects of trigger treatment (averaged over number of trigger applications) for each of the liquid maintenance feeds: light pink bar, 100 N : 150 P_2O_5; green bar, 200 N : 150 P_2O_5; dark pink bar, 100 N : 300 P_2O_5; red bar, 200 N : 300 P_2O_5.

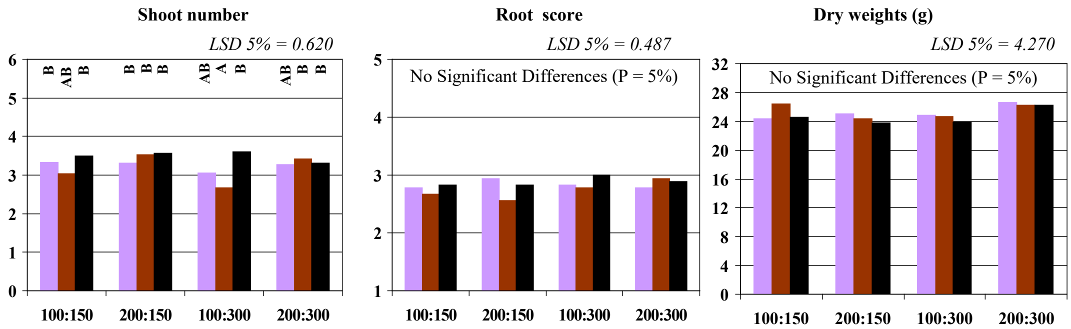
a) *Choisya ternata* (winter strike)



b) *Juniperus* 'Repanda' (winter strike guard)



c) *Cotoneaster* 'Coral Beauty' (summer strike)



d) *Azalea* 'Rose Greeley' (summer strike guard)

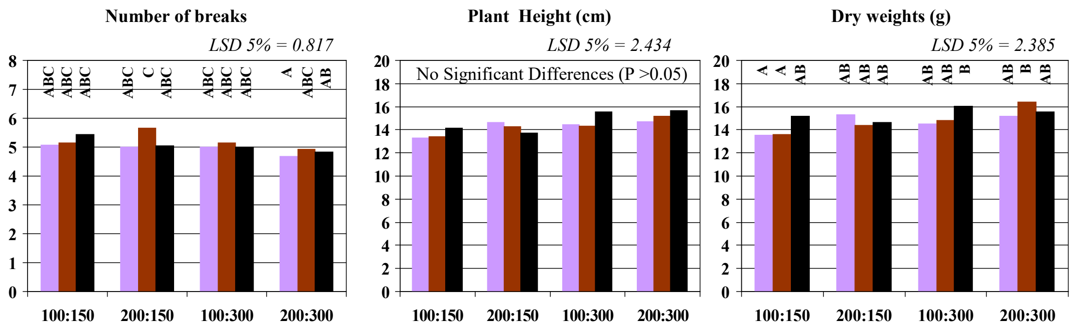


Fig. 4. Effects of number of trigger treatments for each of the trigger N : P_2O_5 nutritional rates (averaged over maintenance treatments): purple bar, 4 x 2 treatment; brown bar, 6 x 2 treatment; black bar, 6 x 3 treatment.

3. Appendix -Plates

Appendix Fig. A. Propagation regime

Aa. *Choisya ternata* propagated in a module tray, surrounded by plants of *Juniperis* “Repanda”

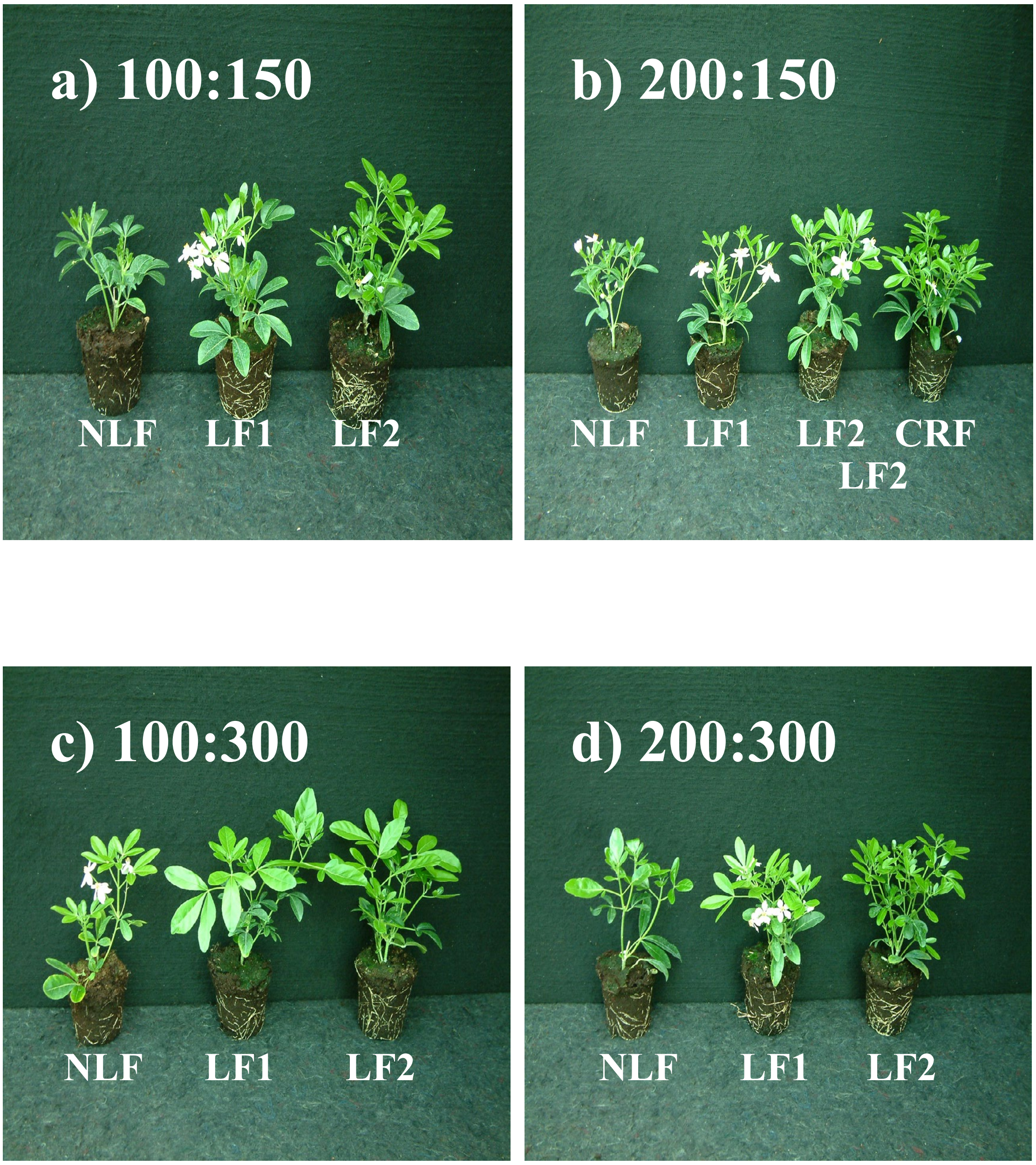
Ab. Cuttings on heated sand beds under low polythene

Ac. Rooted cuttings during the maintenance phase in an unheated glasshouse

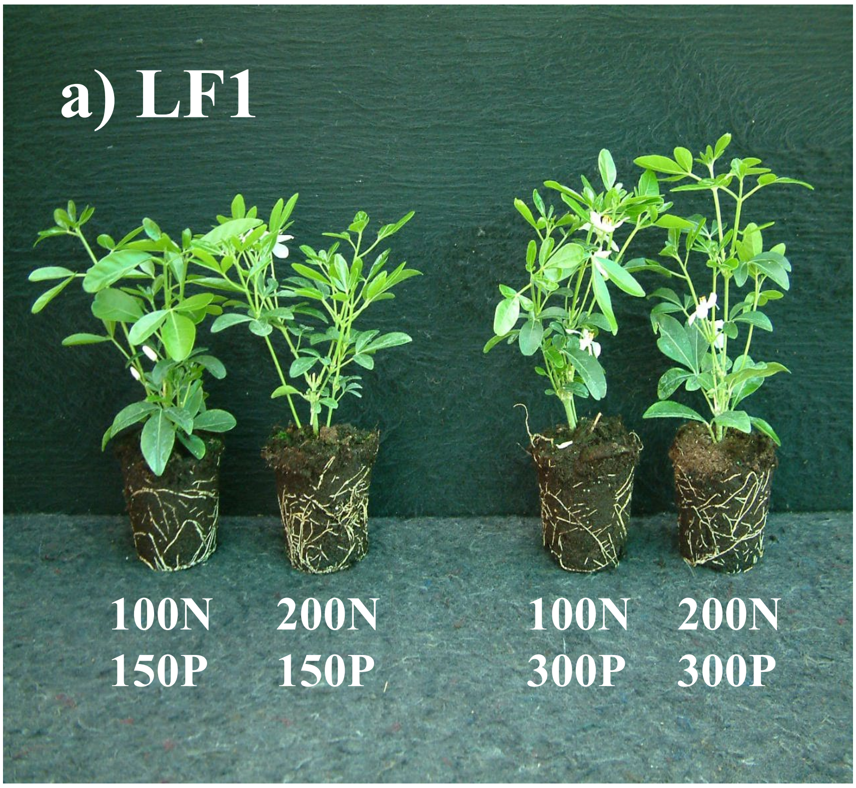
Ad. Rooted cuttings potted on into 90 mm pots, standing on capillary matting

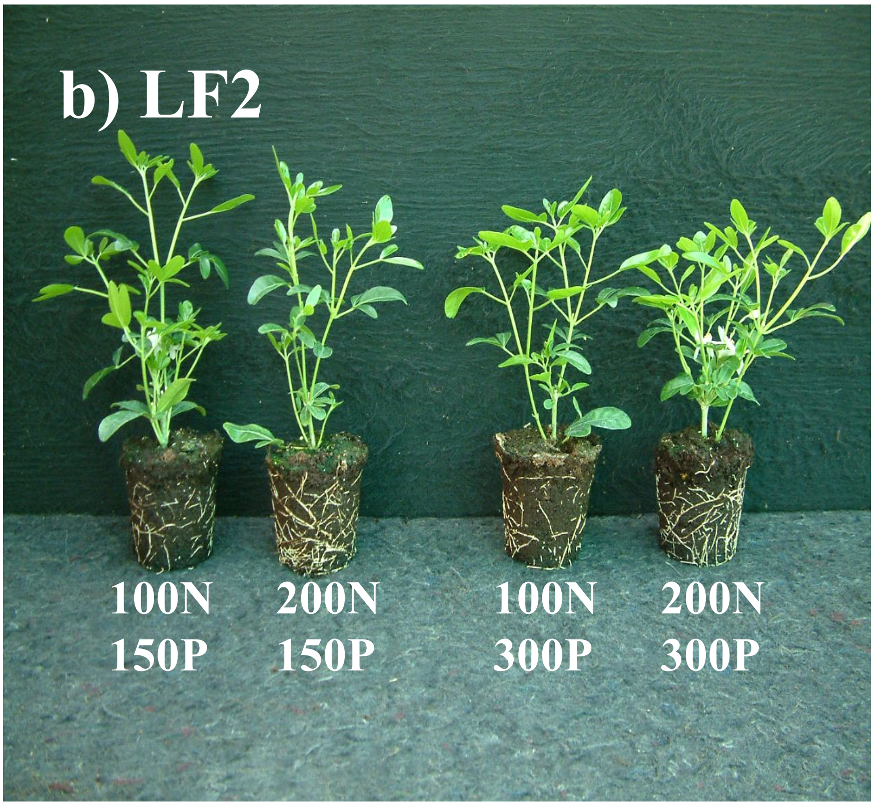
Appendix Fig. B. Reference photograph of root score scale for *Choisya ternata*: L-R, scores 1,3,5.

Appendix Fig. C. Effects of maintenance nutrition on ultimate growth after potting and growing on of *Choisya ternata*: NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O; CRF, Controlled release fertiliser treatment. a) trigger nutrition of 100 : 150 ppm N : P_2O_5; b) trigger nutrition of 200 : 150 ppm N : P_2O_5; c) trigger nutrition of 100 : 300 ppm N : P_2O_5; d) trigger nutrition of 200 : 300 ppm N : P_2O_5



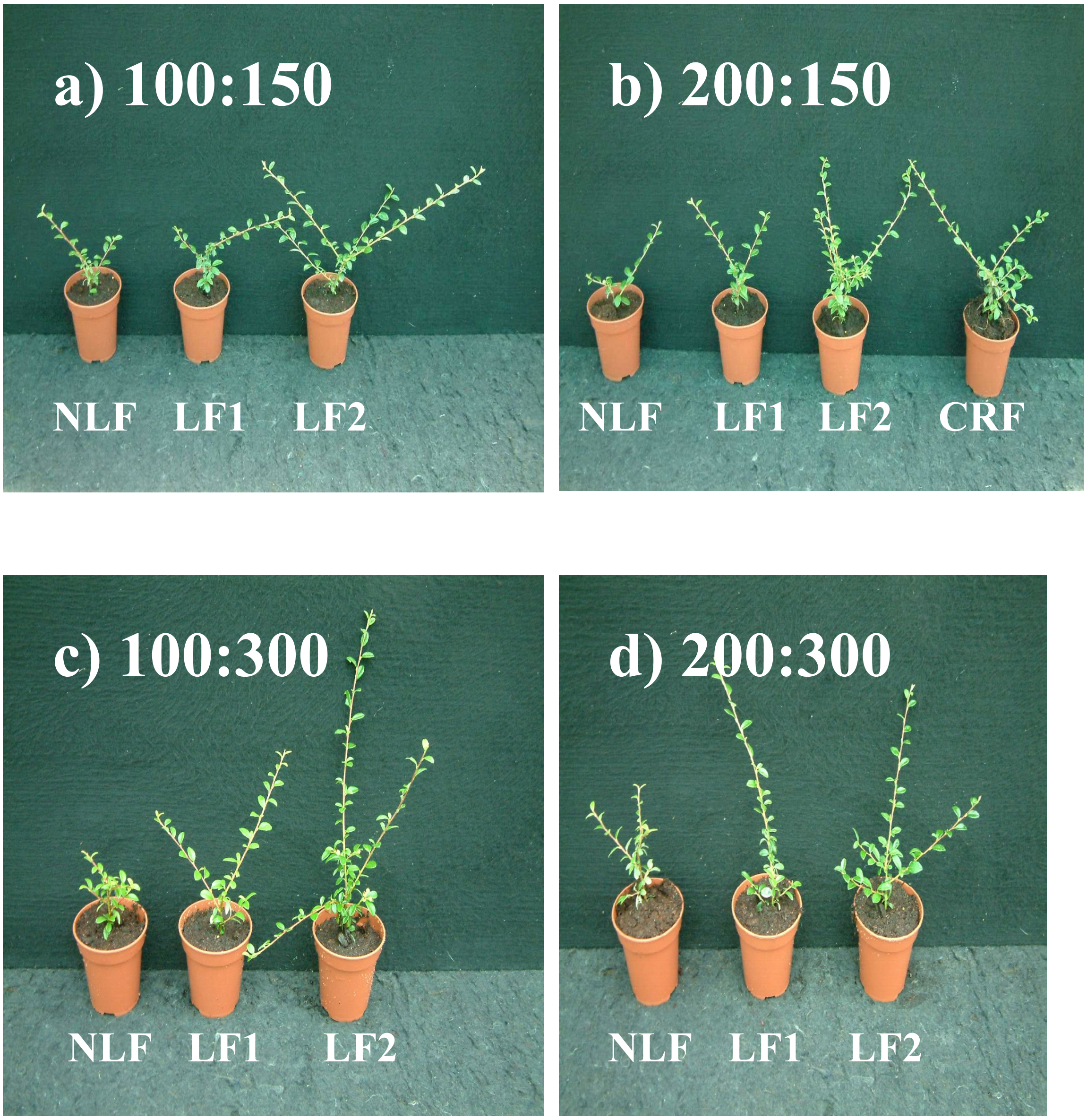
Appendix Fig. D. Effects of trigger nutrition treatment on ultimate growth after potting and growing on of *Choisya ternata*: a) maintenance feed LF1; b) maintenance feed LF2



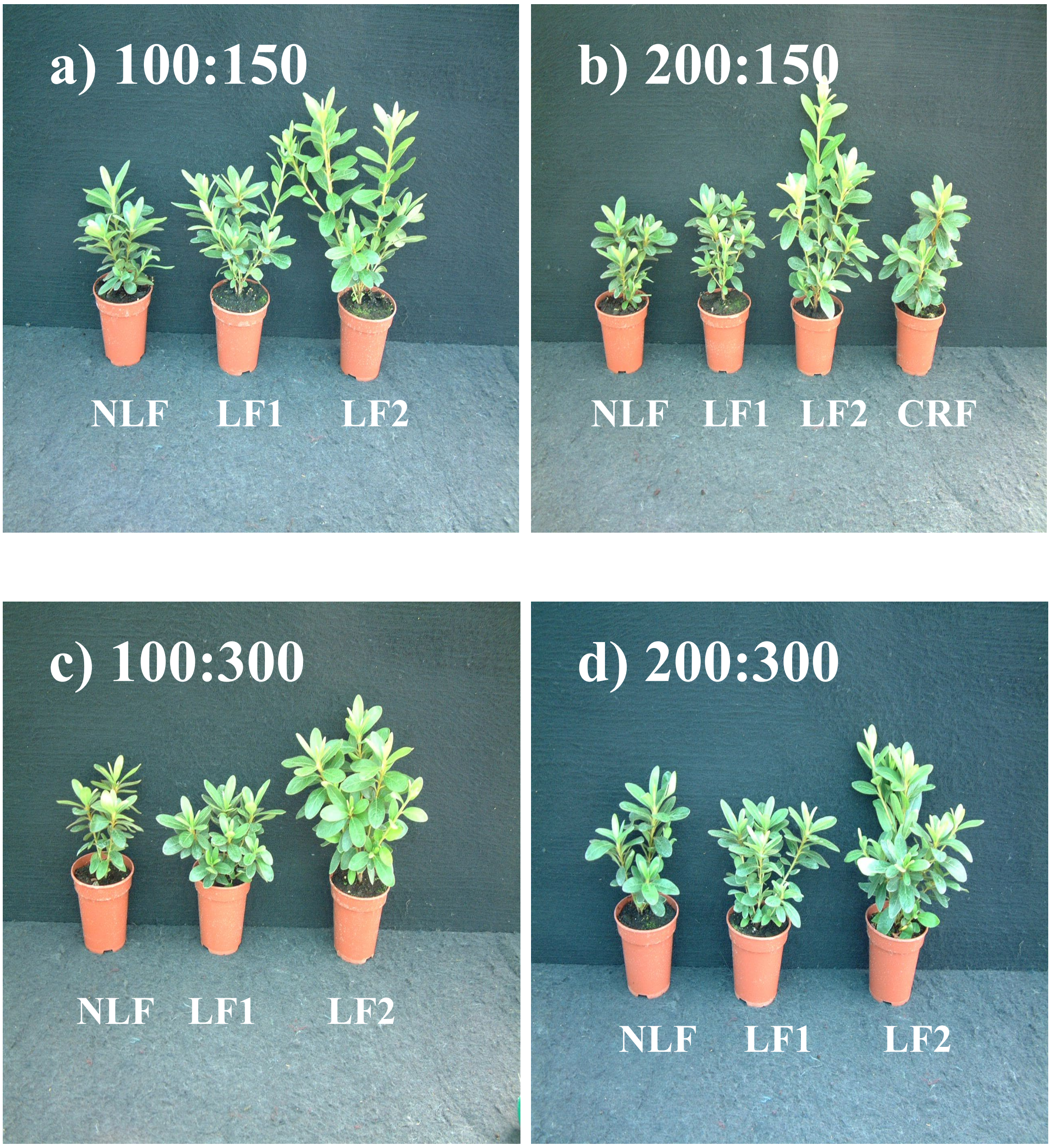


Appendix Fig. E. Effects of maintenance nutrition on ultimate growth after potting and growing on of *Juniperus* 'Repanda': NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O; CRF, Controlled release fertiliser treatment. The plants that are shown were triggered with 200 ppm N : 150 ppm P_2O_5 and received 2 trigger applications, two-weeks apart, starting 6 weeks before potting.

Appendix Fig. F. Effects of maintenance nutrition on ultimate growth after potting and growing on of *Cotoneaster* 'Coral Beauty': NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O; CRF, Controlled release fertiliser treatment. a) trigger nutrition of 100 : 150 ppm N : P_2O_5; b) trigger nutrition of 200 : 150 ppm N : P_2O_5; c) trigger nutrition of 100 : 300 ppm N : P_2O_5; d) trigger nutrition of 200 : 300 ppm N : P_2O_5

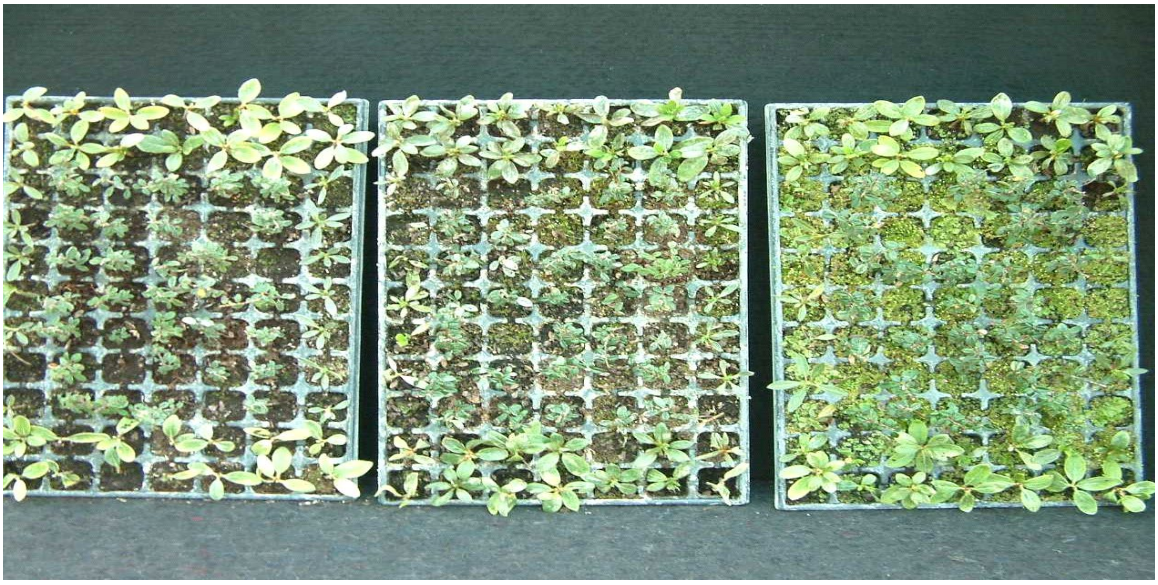


Appendix Fig. G. Effects of maintenance nutrition on ultimate growth after potting and growing on of *Azalea* 'Rose Greeley': NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O; CRF, Controlled release fertiliser treatment. a) trigger nutrition of 100 : 150 ppm N : P_2O_5; b) trigger nutrition of 200 : 150 ppm N : P_2O_5; c) trigger nutrition of 100 : 300 ppm N : P_2O_5; d) trigger nutrition of 200 : 300 ppm N : P_2O_5



Appendix Fig. Ha. Scores used to assess moss/liverwort cover on the surface of trays immediately prior to the application of trigger treatments

L-R, 1- little cover: 2- moderate cover: 3- high level of cover



Appendix Fig. Hb. Effects of maintenance nutrition treatments on the growth of moss/liverwort on the surface of rooting trays, immediately prior to the application of trigger treatments: NLF, no liquid feed; LF1, 50 ppm N : 50 ppm K_2O; LF2, 50 ppm N : 25 ppm P_2O_5 : 50 ppm K_2O; CRF, Controlled release fertiliser treatment.