Project title:	**Improved flowering of Rhododendron and other woody plant species**
Annual report:	**August 2001**
Project number:	**HNS 102**
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Location of Project:	**HRI-East Malling and Efford**
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Key words:	**hardy ornamental nursery stock, flowering, Rhododendron, controlled stress**

The results and conclusions of this report are based on an investigation conducted over one year. The conditions under which the experiments were carried out and the results obtained have been reported with detail and 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.

CONTENTS

PRACTICAL SECTION FOR GROWERS

Commercial Benefits of the Project

The potential benefits of this project can be applied both specifically to *Rhododendron* growers and to those nurserymen with a much wider crop range, where a more general understanding of flower initiation would be desirable. Key benefits are likely to include:

- Reduced time from propagation to sale, by promoting consistent, precocious flowering.
- Improved quality through more uniform flower bud development and higher numbers of flower buds.
- Enable nurserymen to compete with imports, especially from regions with warmer summers, where higher temperatures can help ensure good bud production.
- Develop protocols for 'stress-induced' flowering across a range of HNS crop types.
- Develop opportunities to better regulate flower initiation through environmental control, e.g. altering photoperiod through the use of low cost, tungsten lamps.

Background and Objectives

Inducing flower buds on finished plants is essential to maximise garden centre sales of many HNS lines. A number of important, high-value genera that fall within this category are *Rhododendron, Magnolia* and *Camellia*. However, flower bud formation in such species can often be limited within the first few years of production. Even in those cultivars that can form flower buds early in their lifespan (i.e. precocious), the actual numbers of buds induced can vary significantly from one year to the next. Such inconsistency in development can make scheduling and marketing of crops difficult. This project aims to identify reasons for poor flower initiation and development, and to devise simple protocols to ensure precocious flower production in container-grown HNS. *Rhododendron* is used as the primary model subject, but other species are incorporated in some experiments to determine how wide-spread some of the responses

to flowering are. One objective is to identify the key environmental stimuli responsible for flower bud initiation and to develop practical techniques to exploit these. Also, the use of controlled stress techniques (water stress, extra phosphate addition, root restriction) are being assessed to determine if they can alter the hormonal balance in the shoot tip and trigger floral development.

Summary of Results and Conclusions

The effects of daylength (photoperiod) and temperature on flowering were evaluated using approximately 2-year-old *Rhododendron* cvs Hoppy and Scintillation. Both cultivars responded positively to being placed under long-day photoperiods (18 hours light provided by tungsten bulbs) from mid-summer onwards, especially when this was combined with higher temperatures (i.e. in a polytunnel compared to outdoors) (Figure 1). Shoot age, however, is likely to be a critical factor in determining flowering potential, and the relatively hard pruning employed on *R*. cv. Hoppy at HRI-East Malling reduced the flowering potential (0.5 floral buds per plant) compared to equivalent non-pruned plants at HRI-Efford (5.6 floral buds per plant). One advantage of the long-day regime may be that it allows the shoot tips to develop more rapidly and thereby enable them to form floral tissues earlier.

A number of controlled stress treatments were tested using *R*. cvs Hoppy, Scintillation and Mrs T.H. Lowinsky. Interestingly greatest flower bud formation per plant was associated with the control plants in *R*. cvs Hoppy and Mrs T.H. Lowinsky, but the partial root drying technique (PRD) showed some promise in *R*. cv. Scintillation (although differences with other treatments were often not significant). Partial root drying was accomplished by alternating the position of drippers within the pots, leaving localised dry zones in the medium. It is also possible that some PRD occurred in the control plants. Experiments in year 2 will attempt to clarify if indeed PRD has a role in inducing flower initiation.

By examining buds of mature field-grown *Rhododendron*, it was apparent that flower bud formation naturally occurred in late June, relatively quickly after the previous

floral tissues had abscised their petals. By August, it was easy to differentiate between floral and vegetative buds in some, but not all, cultivars.

Action Points for Growers

- Nurserymen should always be aware of the compromise between pruning the plant for shape, and the loss of 'mature' shoot tissue that may have the potential to form flowers.

- These preliminary results imply that the newly-developing shoots on young *Rhododendron* plants need to be exposed to long-day photoperiods and possibly higher growing temperatures to optimise flower formation.

- The use of inexpensive tungsten bulbs may be a feasible technique to impose long-day photoperiods over the crop. However, the actual light level and spectrum required to induce a photoperiodic response in *Rhododendron* requires qualification.

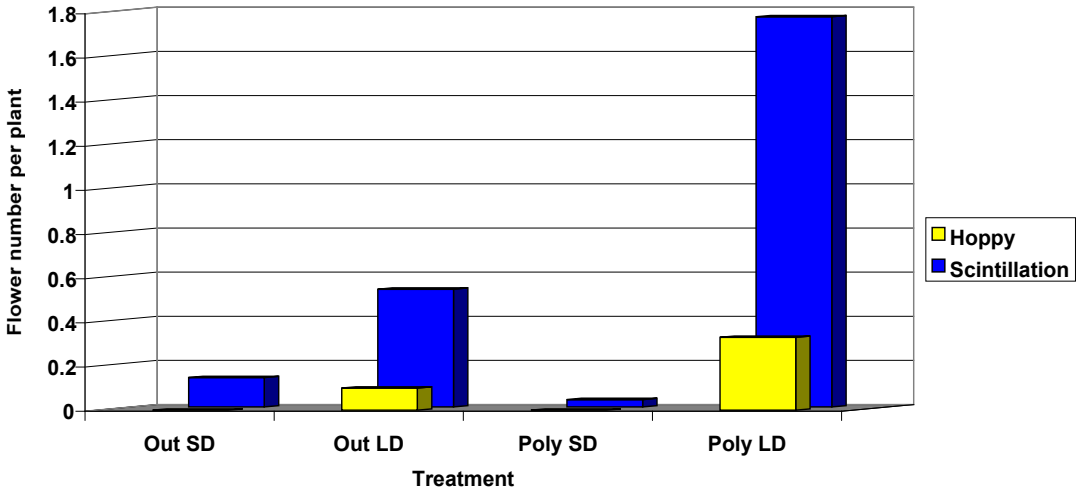
- If growing a Rhododendron crop within a polythene tunnel, beware that the high temperatures associated with this environment may result in leaf scorch in heat-sensitive cultivars.

Anticipated practical and financial benefits

- Although these are preliminary results, the use of a LD photoperiod and protected structures may have a role in:
    - Increasing the number of shoot tips that form flowers (better quality crop).
    - Reducing production time and hence costs, by enabling a given crop to flower at an earlier age.

- Assuming a 4 year production cycle could be reduced to 3 years and equate to a 25% saving in production costs, this would need to be offset against additional costs associated with implementing a long-day regime (in the experiment in the project, we estimated an initial capital cost of £300 per 30 m^2 of bed, plus running costs of £30 per 6 month period. However, the light levels required and the length of the illuminated period needed could be considerably less than we applied).

Figure 1. The effect of environment on flower numbers per plant of *R.* cvs Hoppy and Scintillation. (SD = Short day regime – 8 hours, LD = Long day regime – 16 hours, Out = Outdoors, Poly = Polytunnel).



SCIENCE SECTION

Introduction

Sales of *Rhododendron* and many other high value HONS lines rely strongly on plants being in bud /flower at the point of sale. Failure to initiate sufficient buds during production can result in retailers rejecting an entire crop. The consequence of which is that plants need to be retained on the nursery for a further 12 months, thereby increasing production costs and disrupting subsequent cropping schedules. The aim of this project is to improve numbers of flower buds initiated in young *Rhododendron* plants, and develop techniques that ensure consistency of bud production from one year to the next. Through a better understanding of the environmental stimuli involved in flower development the objective is to identify and promote practical mechanisms that enhance bud initiation and reliable cropping in both *Rhododendron* and other woody plant species.

There is some evidence to suggest that by applying water stress to certain species, flower initiation can be induced at an earlier stage in the lifecycle e.g. *Citrus* (Krajewski and Rabe, 1995), *Kalmia* (Carden, 1995), *Litchi* (Stern *et al.*, 1993), *Picea* (Ross, 1988) and *Pyrus* (Mitchell *et al.*, 1984). Previous research (DEFRA project HH 1608 SHN) indicated that water stress could enhance flower bud formation in *Rhododendron*, but that degree of stress applied and timing was critical in optimising the response - applying stress at an inappropriate time reduced flowering (Cameron *et al*, 1999). Similarly, there is evidence to suggest that flowering in some crops can be enhanced by the application of high levels of phosphate (Ticknor, 1969). How such stress factors work is unclear, although the interaction between the plant hormones abscisic acid (ABA) and gibberellin (GA) may have a regulating role in flower initiation. Certainly, plant growth regulating compounds (PGRs) such as paclobutrazol and chlormequat work by disrupting GA production and activation in the stem tissue. Such chemicals have been shown to reduce shoot growth and promote flower formation in a number of important genera (HNS 39), including *Rhododendron* (Scott, 1971). However, PGR use has a number of drawbacks (i.e. expense, inconsistent growth responses and the restriction on their use in future), and

alternative, practical mechanisms that induce early flower formation need to be sought.

In contrast to florist azaleas, relatively little information has been gained on the environmental stimuli involved in initiating flowers in the large-leaved *Rhododendron* hybrids. Whereas flower initiation in the florist azalea appears to be optimal under 4-6 weeks of short day (SD) photoperiods, preferably at 18-20ºC, it has been suggested that hybrid *Rhododendron* cultivars require long day photoperiods (LD) for flower initiation and short days for flower development (Davidson and Watson, 1959). This requires verification however, as other authors have suggested that shoot age is more important in determining flower initiation than photoperiod (Criley, 1985). Certainly there is evidence to suggest that at least a degree of shoot development is required before the meristem becomes responsive to any photoperiodic stimulus (Adams and Roberts, 1968; Purohit and Dunham, 1979). Unlike azaleas, the requirement of a minimum temperature does not appear essential for floral initiation in the large-leaved *Rhododendron*. In species such as *R. carolinianum* though, greater numbers of flower buds have been recorded after initiation at higher temperatures (24-27ºC), (Criley, 1985). Whether sub-optimal temperatures during initiation are a cause of poor flowering in some of the garden hybrids remains undetermined.

The research outlined below is a collaborative project involving HRI (East Malling and Efford) and Lancaster University. It combines a range of experiments, both to investigate some of the environmental factors responsible for flower initiation and to develop practical protocols that can be used on nurseries to promote more consistent cropping.

Materials and methods - General

Plant material

East Malling

- *R*. cv. Hoppy – bought in as well-established plants in 2 l pots (approx. 2-year-old) and potted on into 3 l pots in April 2000. Grown in a medium of 80:20 peat: cambark 100, 2 g l^{-1} Osmocote Plus, 0.9 g l^{-1} Mg CO_3, 0.15 g l^{-1} Fongaride 25 WP and 0.6 g l^{-1} Suscon Green. The previous growth flush was pruned back hard at potting, reducing the plant height by 1/3 (i.e. approx. 25-30 cm high).

- *R*. cv. Scintillation - bought in as recently-potted plants in 7.5 l pots. Re-potted back into 7.5 l containers using growing medium described for *R.* cv. Hoppy. These plants had only one previous main growth flush with very large internode sections, so pruning in April 2000 only involved removing existing dormant or newly expanding buds.

Efford

- *R*. cv. Hoppy – bought in as well-established plants in 2 l pots and potted on into 7.5 l pots in November 2000. Grown in a media of 80:20 peat: cambark 100, 2 g l^{-1} Osmocote Plus, 0.9 g l^{-1} Mg CO_3, 0.15 g l^{-1} Fongaride 25 WP and 0.6 g l^{-1} Suscon Green. Plants were un-pruned during the trial.

- *R*. cv. Scintillation - bought in as recently-potted plants in 7.5 l pots. Plants were un-pruned during the trial.

- *R*. cv. Mrs T.H. Lowinsky - bought in as recently-potted plants in 7.5 l pots. Plants were un-pruned during the trial.

Statistical analyses

Plants were divided on the basis of positional block and plots, and mean values calculated for each plot. Data analysis was carried out using a Genstat V computer programme, and comparison between mean values compared using least

significant difference (LSD). Significant differences were assessed at the 5 % level ($P<0.05$), i.e. a 95 % probability that results are due to treatment effects.

Experiments and Results

Timing of flower bud initiation

Mature plants (8 year-old) of *R.* cv. Hoppy grown under natural conditions were examined for floral bud development at fortnightly intervals using a binocular light microscope (Leica x 50 mag.). Approximately 10 buds were harvested at random at each time interval and cut longitudinally to allow inspection of the primary vegetative meristem and sub-apical, axilliary buds. First visible floral tissues (floral meristems) were identified on 26 June 2001, at which point it was estimated that approximately 50% of the terminal buds had initiated floral tissues (i.e. positive identification of floral meristems occurred in 5 out of the 10 buds examined). At the previous sampling date i.e. 14 June, no floral tissues had been able to be identified. These results agree with previous sampling of *R.* cv. Hoppy plants when first floral buds were identified on 26 June (2000) and 3 July (1997).

The effect of temperature and photoperiod on flowering – Comparisons between polytunnel and outdoor conditions

Materials and methods

From May 2000 both *R.* cv. Hoppy and *R.* cv. Scintillation plants were grown outdoors or within a polythene tunnel to represent grower relevant environments. Plants in both environments were maintained under natural daylength (long-days) until mid-summer at which point they were sub-divided into 2 photoperiod treatments - continued long days (16h - LD) or short days (8h - SD). Artificial LD photoperiods were provided by placing a bank of 60 x 25 W tungsten lamps at 1.5 m above part of the crop. This provided irradiance of 2.36 W m^{-2} at the crop canopy; the precise irradiance required to maintain a LD signal is undetermined for *Rhododendron*, however, other species have been quoted as requiring a 0.06-0.30 W m^{-2} (Salisbury

and Ross, 1985). Tungsten lamps were illuminated from 6pm-10pm and 6am-8am every day. The SD conditions were implemented by placing a reflective screen (XLS Obscura A/B +B – Svenson) over the other half (from 5pm until 9am). Treatments were in place from 21 June until 15 October 2000. Temperature data suggested that mean daily temperatures were 2-3ºC warmer in the tunnel that outdoors. There was a minimum of 30 plants per treatment combination.

Plants were monitored for shoot and bud development, and final flower counts recorded in May 2001.

Results

Plants of *R*. cv. Hoppy that were placed under LD treatment continued growth for longer during autumn 2000 and formed an extra vegetative flush compared to those grown under SD. The number of flowers induced in *R*. cv. Hoppy across all treatments were relatively low, possibly reflecting the hard pruning that had been carried out on this cultivar. Nevertheless, clear treatment effects were evident with flower set only occurring in those plants exposed to the LD treatment (Figure 3). Placing plants in the warmer conditions of the polytunnel also significantly increased the number of flowers that could form under the LD conditions.

Flowering responses in *R*. cv. Scintillation were very similar, with greatest numbers of flowers formed when plants were maintained under prolonged LD conditions in the polytunnel (Figure 4).

The formation of flower buds appeared to be at the expense of new lateral shoots, as the greatest number of terminal shoots during May 2001 was associated with the SD treatments, although differences were not always statistically different (Figure 5 and 6). It is interesting to note that in the *R*. cv. Scintillation (which had not been hard pruned) almost 60 % of terminal shoots had formed a flower bud when placed in the polytunnel LD regime.

Figure 3. The mean number of flowers per plant in *Rhododendron* cv. Hoppy after placement either outdoors (Out) or in a polytunnel (Poly) and under either 8 hour short-day (SD) or 16 hour long-day (LD) photoperiods.

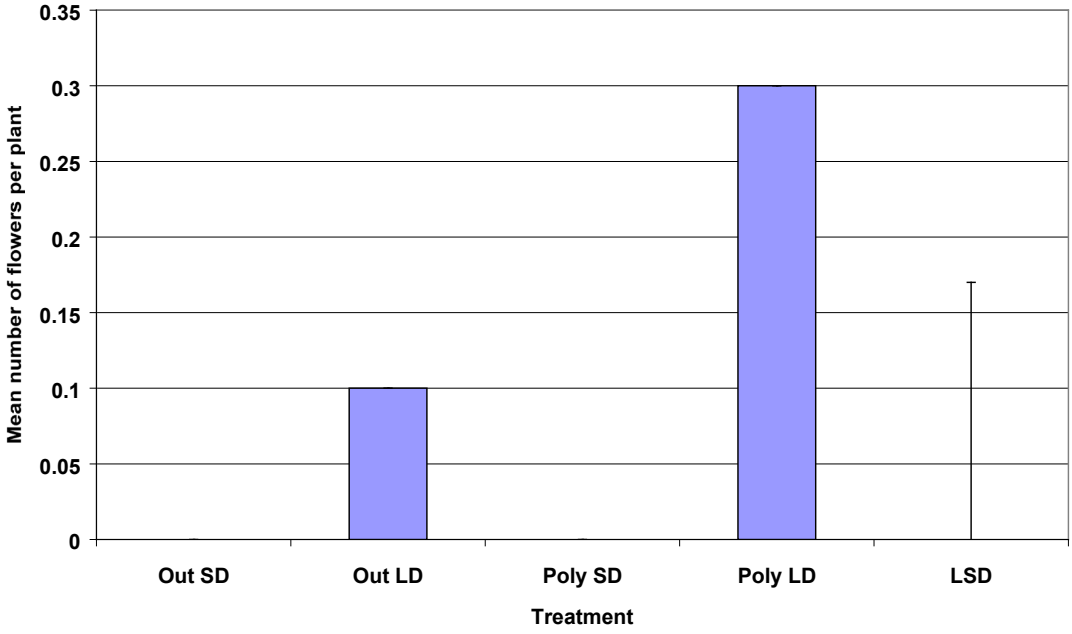


Figure 4. The mean number of flowers per plant in *Rhododendron* cv. Scintillation after placement either outdoors (Out) or in a polytunnel (Poly) and under either 8 hour short-day (SD) or 16 hour long-day (LD) photoperiods.

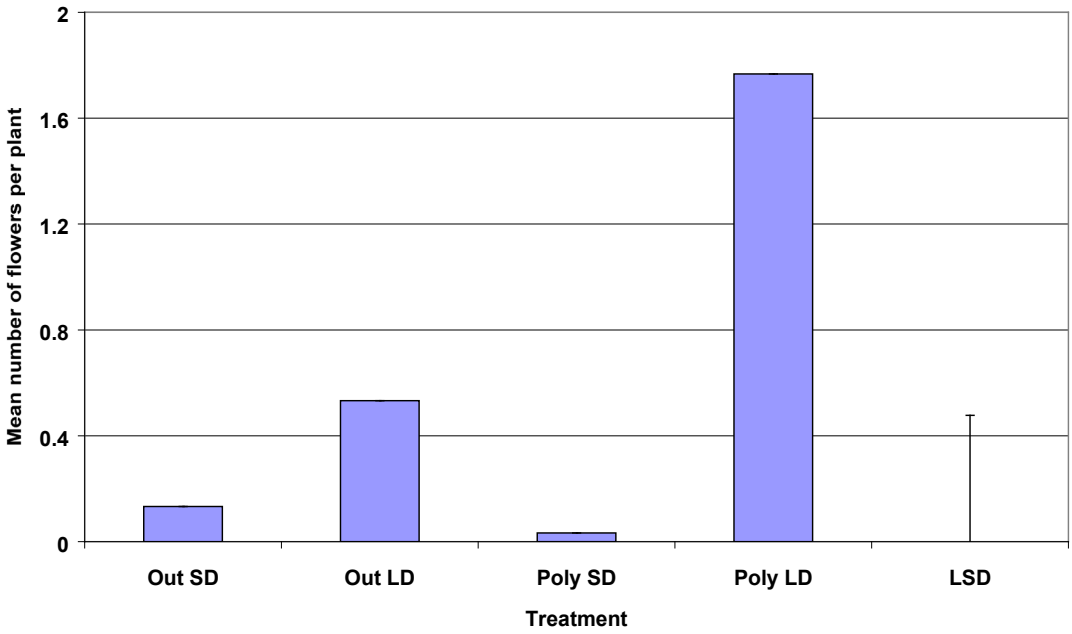


Figure 5. The mean number of terminal branches per plant and the percentage of those with flower buds as recorded in *Rhododendron* cv. Hoppy after placement either outdoors (Out) or in a polytunnel (Poly) and under either 8 hour short-day (SD) or 16 hour long-day (LD) photoperiods.

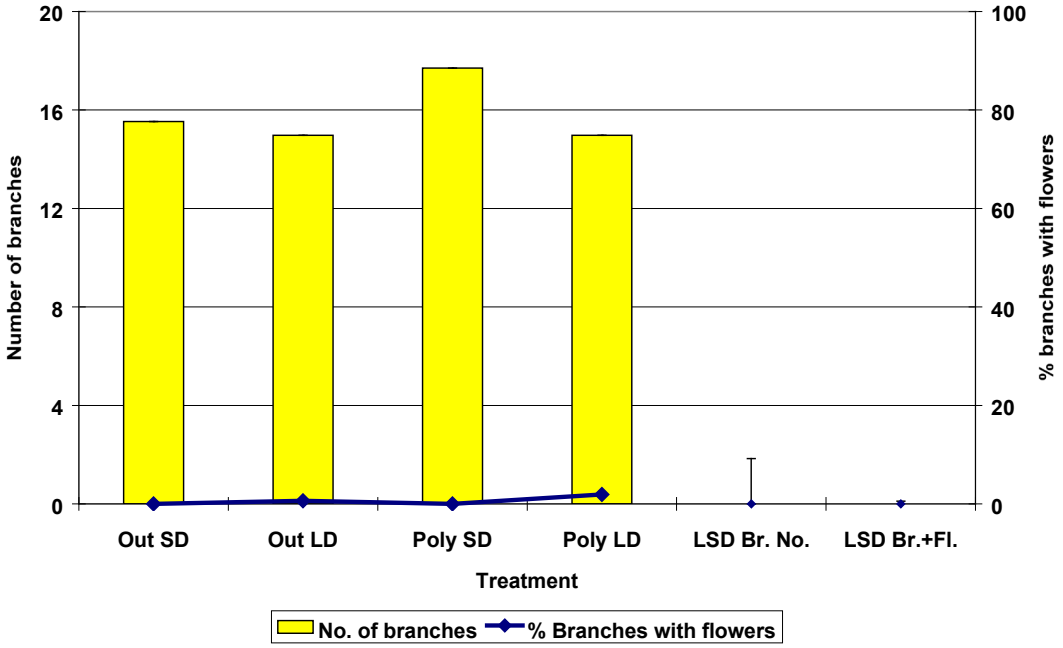
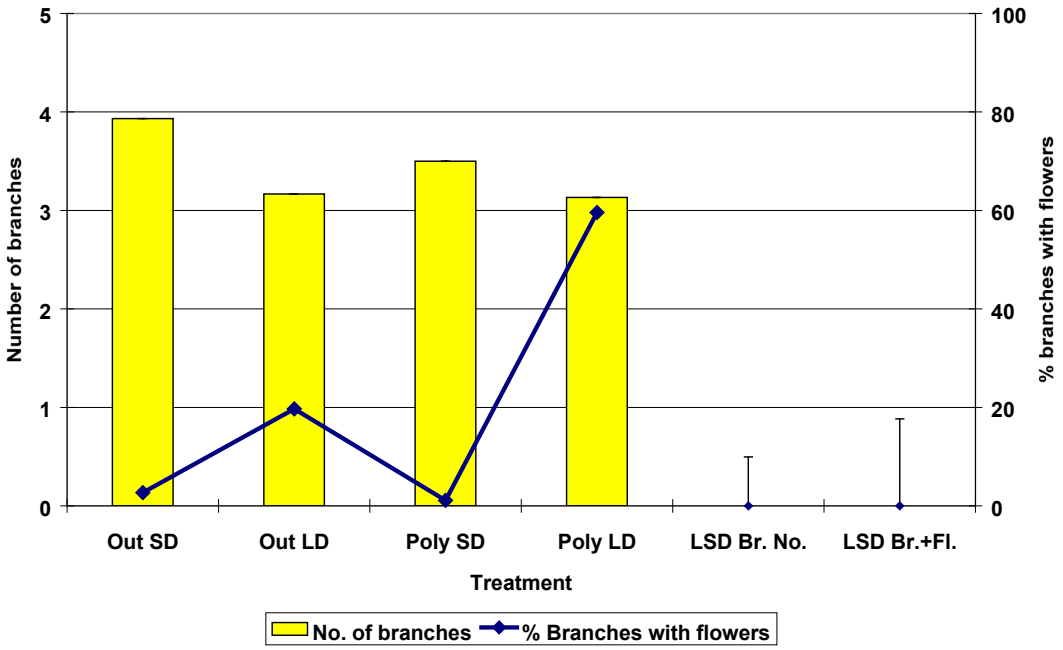


Figure 6. The mean number of terminal branches per plant and the percentage of those with flower buds as recorded in *Rhododendron* cv. Scintillation after placement either outdoors (Out) or in a polytunnel (Poly) and under either 8 hour short-day (SD) or 16 hour long-day (LD) photoperiods.



The effect of temperature and photoperiod on flowering – Comparisons using controlled environment conditions

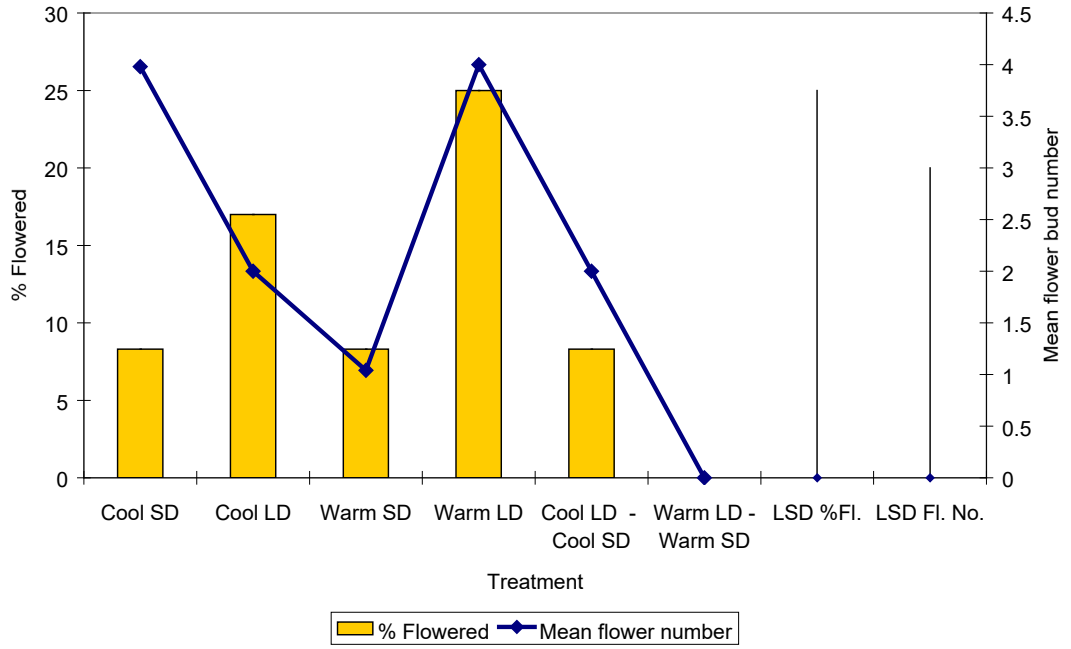
Materials and methods

Experiments were set up at East Malling in November 2000 using controlled environments to provide two temperature regimes: cool (16 +/- 4ºC), and warm (30 +/- 4ºC). In each environment plants of *R.* cv. Hoppy were either exposed to a short day (8 hours - SD) or a long day (16 hours) photoperiods. In the warm environment light was provided by natural irradiance supplemented by sodium lamps (500 μmol m^{-2} s^{-1}, approx. 108 W m^{-2}) whereas in the low temperature environment light was provided by sodium lamps with daylength extension being provided by tungsten lamps (in an attempt to avoid too much variation in photosynthetic active radiation between the LD and SD regimes). Plants that had been growing outside were re-pruned again by removing any resting buds. Due to the restricted space within the controlled environments there were only 12 plants in each treatment combination. Some plants were changed over from the LD to the SD treatment in both the warm and cool environments, after 8 weeks. Flower bud number was recorded after a further 12 weeks.

Results

The greatest number of *R.* cv. Hoppy plants to form flower buds occurred with the Warm LD treatment with 25 % of the population forming flower buds (Figure 7). Results were not statistically significant however, reflecting the relatively small population of plants that could be placed in the environments. The fact that not all the plants formed flower buds even under this regime, may again indicate that shoot age is having a significant effect on whether the meristem may change from a vegetative to a floral state. Similarly, placing plants under artificial conditions with relatively low light levels may not provide the right stimulus or energy levels to support floral initiation in all the shoots. Moving a number of the plants from the LD to SD regimes after 8 weeks did not enhance floral initiation compared to keeping the plants in the LD conditions.

Figure 7. The percentage of *Rhododendron* cv. Hoppy plants forming flower buds and mean number of buds per plant, after placing plants in controlled environments (warm v cool; long-day -LD v short day -SD) during winter.



The influence of controlled 'stress' treatments on flower formation

Materials and methods

Three cultivars, namely *R*. cvs Hoppy, Scintillation and Mrs T.H. Lowinsky were evaluated at Efford for their response to abiotic stress treatments in terms of flower production. Plants either received treatments for 8 weeks from 18th July to 11th September 2000 (Summer treatments) or for 9 weeks from 14th September to 15th November 2000 (Autumn treatments), and plants were monitored for bud and flower numbers, and foliar quality in the following spring - May 2001.

Treatments were as follows –
Control – Plants maintained on an Efford sand bed and hand-watered as required
Water Stress - Progressive drying of the growing media was implemented by using regulated deficit irrigation (RDI) to bring container weight to approximately 40 % of container capacity. RDI works on the principle of applying water in relation to evaporative demand, and allows the plant to adapt to a moderate degree of water stress. 5 plants per cultivar of the control treatment were designated at the start of the trial. The weight of plant and pot at full capacity was established at the start of the trial. These plants were weighed three times a week (Monday, Wednesday and Friday) to allow estimation of evapo-transpiration (ETp). The amount of water added to the water stress treatments was then calculated as 40% of the ETp figure. Due to observed water run-off from dried pots, water was applied daily as 20% ETp per day Monday - Thursday and 40% on Friday.

Partial Root Drying (PRD)-{Root signalling}: Drip irrigation was used to provide differential watering within an individual pot, where only half of the root system was watered, leaving the other half in drying soil. This may generate 'root signals' which alters stomata behaviour and slows vegetative growth. Plants often respond as if they were experiencing water stress, but actually avoid any desiccation of the shoot tissues. The portion of roots exposed to irrigation / drying was altered every two weeks by moving the dripper to the opposite side of the pot.

Phosphate addition (**P**) - Triple superphosphate - $Ca(H_2PO_4)_2$ was added to the growing medium as a liquid feed on a weekly basis. Bulk solution was made up in 100 l batches by dissolving triple superphosphate in warm water to give EC = 2.0 mS cm^{-1}. This solution was watered on to pots by hand once weekly (Wednesday). Plants were irrigated with mains water Monday and Friday to prevent scorching of roots.

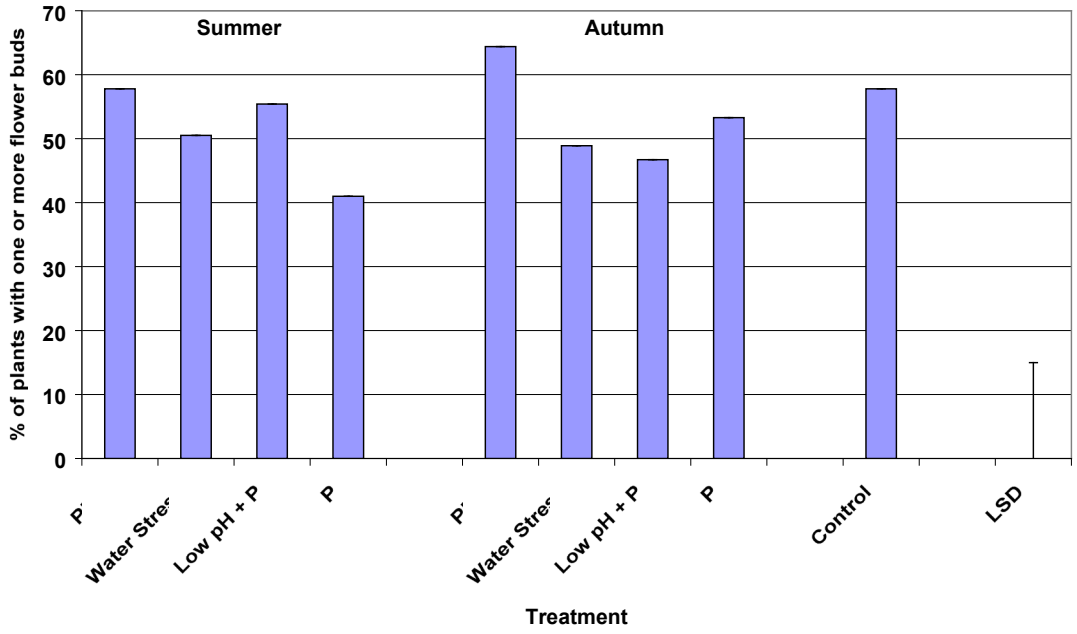
Phosphate addition + low pH (Low pH + P) - Phosphoric acid was added to the growing medium as a liquid feed on a weekly basis. Bulk solution was made up in 100 l batches by dissolving phosphoric acid in water to give pH = 3.5. This solution was watered on to pots by hand three times a week (Monday, Wednesday and Friday).

There were 15 replicates of each species per treatment.

Results

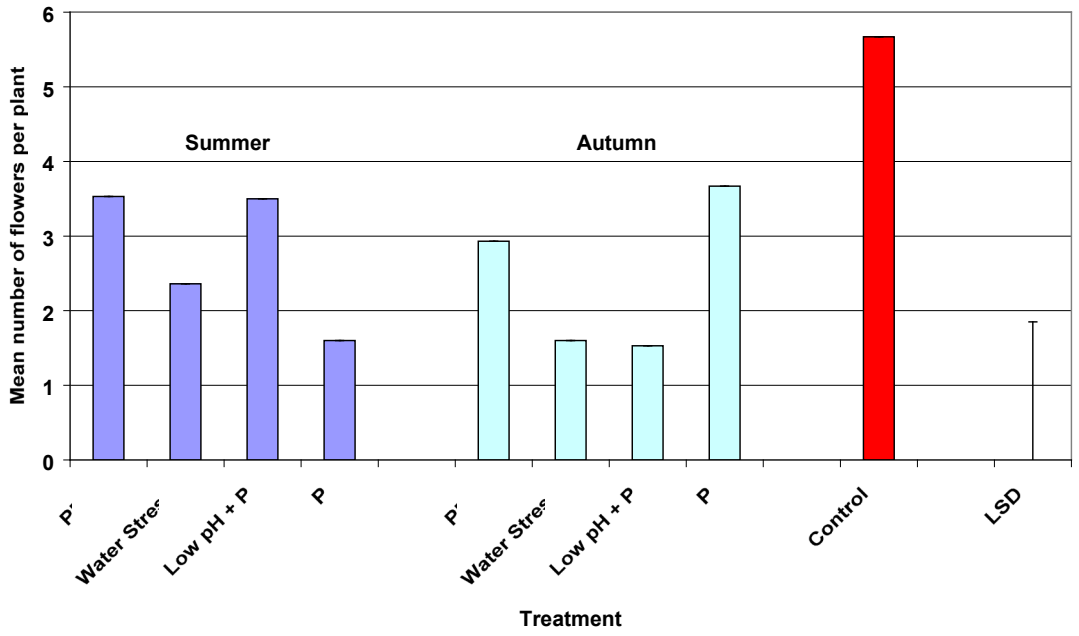
When results were based on number of plants (pooled across all three cultivars) that formed one or more flower buds (i.e. when no account was taken for number of buds per plant), the greatest number of flowering plants occurred when the PRD treatment was applied in autumn (Figure 8). Differences between treatments were rarely significantly different however, except that applying triple super phosphate during summer reduced the number of plants that flowered compared to the control treatment.

Figure 8. Treatment effects on the percentage of all plants that formed at least one flower bud (data for all three cultivars pooled).



When results were based on the numbers of flower buds per plant (a more commercially important parameter), *R*. cv. Hoppy proved to be a considerably more floriferous cultivar compared to the other varieties tested, with some individual plants having as many as 12 flower buds. However, meaned data shows that none of the stress treatments imposed increased flower initiation compared to the controls (Figure 9). Indeed some treatments, such as imposing water stress or adding phosphates at low pH in the autumn considerably reduced the number of flower buds that formed.

Figure 9. *Rhododendron* cv. Hoppy - The mean number of flower buds per plant after exposure to stress treatments.



In *R.* cv. Mrs T.H. Lowinsky, a shier flowering cultivar, a similar trend was apparent with the most flowers being induced on the control plants. In this case, however, there was large variation within treatments and no treatment gave statistically greater results than another (Figure 10).

There was a large degree of variance in the flowering results for *R.* cv. Scintillation as well (again reflected by a large LSD value), however in this case the PRD treatment and the application of phosphate fertiliser in autumn appeared to have some merit in improving flower bud formation (Figure 11). Interestingly, adding phosphates at low pH, and the water stress treatment resulted in the lowest number of flowers forming.

To assess if any of the treatments had a detrimental effect on plant quality, individual plants were scored (0-4) for any incidence of leaf necrosis, with 0 = no damage on any leaves and 4 = significant marginal necrosis on more than 1 leaf. Of

Figure 10. *Rhododendron* cv. Scintillation - The mean number of flower buds per plant after exposure to stress treatments.

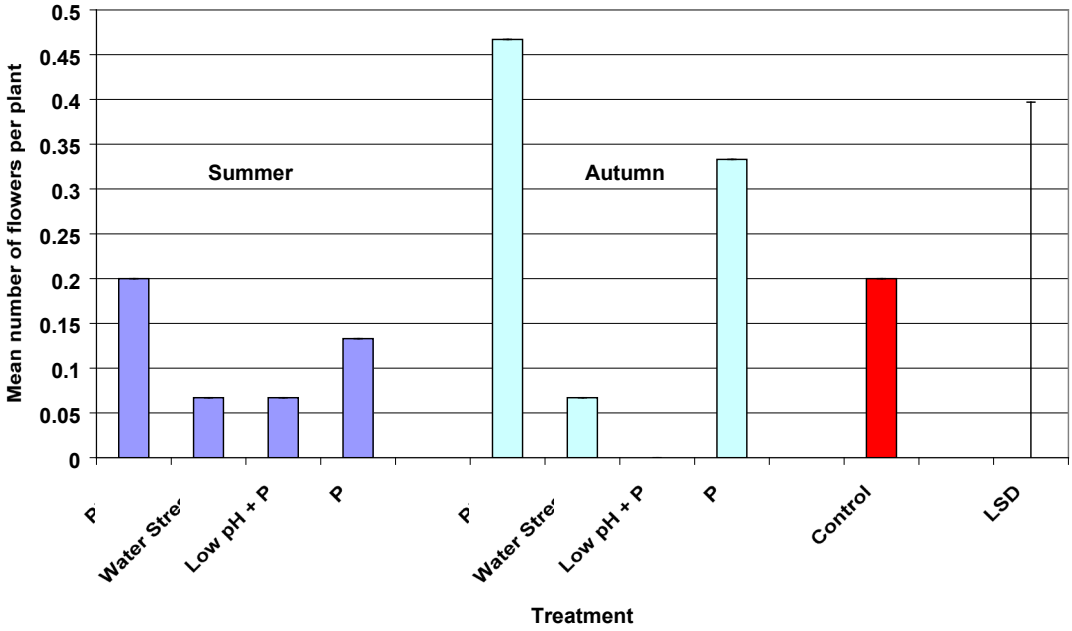
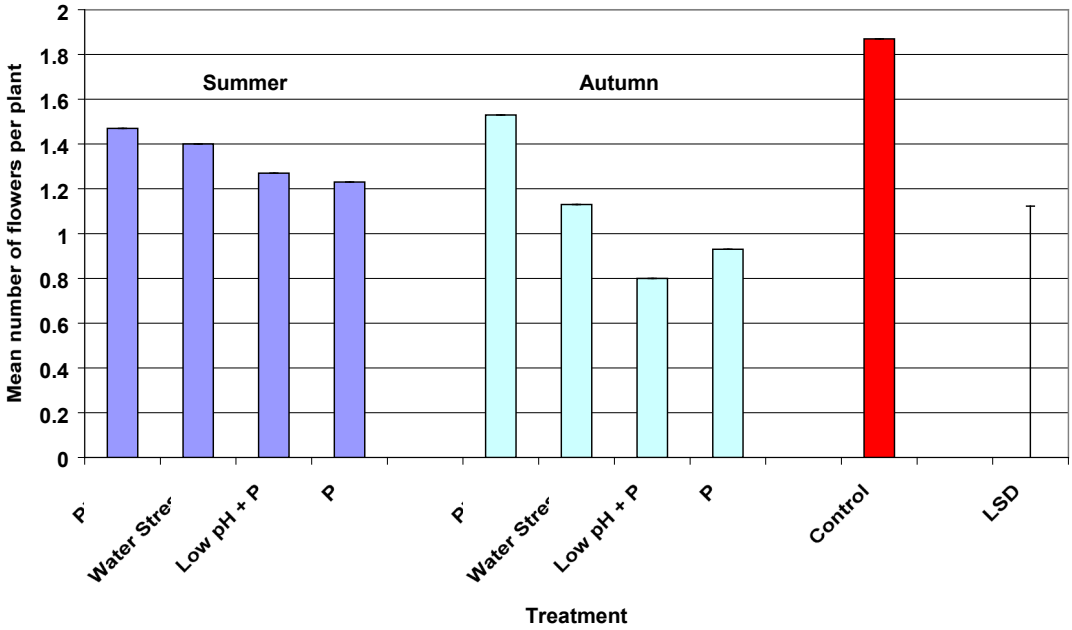


Figure 11. *Rhododendron* cv. Mrs T.H. Lowinsky - The mean number of flower buds per plant after exposure to stress treatments.



the three cultivars, *R*. cv. Scintillation was the most susceptible to leaf injury, but there were no significant effects due to treatment (Table 1). The large mature leaves of this cultivar suggest that it has been bred from species that have a degree of shade adaptation, and that leaf damage may occur after exposure to high light or high temperatures. Overall, there appeared to be slightly more leaf damage in *R*. cv. Hoppy when treatments were applied in summer compared to autumn. In particular, the application of phosphate (to both *R* cvs Hoppy and Mrs T.H. Lowinsky) resulted in more leaf necrosis.

Table 1. Mean scores for leaf necrosis (0 = none, 4 = severe) after the application of 'stress' treatments

		Rhododendron cultivar		
		Hoppy	Scintillation	Mrs T.H. Lowinsky
Control		0.27	1.47	0.13
Summer	PRD	1.00	1.13	0.20
	Water Stress	1.08	0.67	0.00
	Low pH + P	0.20	0.73	0.00
	P	1.20	1.33	0.43
Autumn	PRD	0.00	0.93	0.00
	Water Stress	0.33	0.60	0.00
	Low pH + P	0.53	1.07	0.20
	P	0.80	1.47	0.20
LSD		0.677	0.646	0.330

Development of protocols for hormone extraction and analysis

During this first year techniques to extract gibberellins (GAs) and abscisic acid (ABA) from floral have been developed at HRI- East Malling using *R*.cv. Hoppy and an evergreen azalea. *R*. cv. Hatsugiri. We estimate that 1 g of fresh bud tissue is required per replicate sample. The extraction process and sample 'clean-up' procedures are relatively complex however, and the number of samples that can be

run through a gas-chromatagraph –mass spectrometer is limited at each time. As such, we envisage using pooled samples from the different treatments carried out in year 2 to relate flower development to hormonal changes.

Conclusions

Although this project has just completed its first year some interesting results are becoming apparent. Comparing the data from Efford and East Malling sites strongly suggests that shoot age is likely to be the over-riding factor in allowing the meristem to form a flower bud. The *R*. cv. Hoppy plants used in both locations were from the same source, yet the more severe pruning employed at East Malling considerably reduced the number of flowers that could form (an average of 0.3 per plant), whereas in the Control plants at Efford which received no pruning there was an average of 5.6 flowers. Nevertheless, the environmental comparisons at East Malling were extremely useful in that they demonstrated that extending the daylength for longer during summer can increase flower bud initiation in the newly expanding shoots. Similarly, the effect is accentuated by placing plants within a polytunnel. The results for *R*. cv. Scintillation showed a similar pattern, with a stronger response in terms of actual flower numbers per plant – again a possible consequence of imposing a less severe pruning regime compared to *R*. cv. Hoppy.

The precise level of irradiation required and the appropriate light spectrum for maintaining the LD regime are undetermined. Further detailed research would be required to evaluate the most effective system to adopt and this costed against the likely financial benefits of improved flower bud formation. In our work, the infrastructure for the LD regime cost £300, with running costs for the period June-October of approximately £30. However, it is anticipated that costs could be lower with more effective light systems (we may have provided considerably more light than was required, but this remains to be determined).

The research confirmed that in *R*. cv. Hoppy at least, first flower initiation occurs by late June. Therefore, there is a relatively short time period (3-4 weeks) between petal drop of the previous year's flowers and the development of a new vegetative flush

followed by flower initiation. It is not surprising that there is some anecdotal evidence to suggest that certain *Rhododendron* species and cultivars are prone to biennial flowering, as there may be competition between seed formation and the development of future floral buds.

The results associated with the controlled stress treatments gave rather inconsistent trends depending on which parameter was being measured. Greater numbers of plants (particularly in *R*. cvs Scintillation and Mrs T.H Lowinsky) flowered after the PRD treatment, but actual flower numbers per plant was often greatest in non-treated control plants (i.e. *R*. cvs Hoppy and Mrs T.H. Lowinsky).

A similar phenomenon for flower bud numbers was noticed in the previous DEFRA project (HH 1608 SHN), when guard plants gave relatively high flower bud counts. This may be partially due to the plants being maintained on capillary systems with occasional hand watering (similar to the maintenance regime for control plants at Efford). It is conceivable that some degree of partial root drying can occur under these conditions and this aspect requires further investigation. The fact that the results for PRD and controls were frequently similar may suggest that the hormonal signalling mechanism from the root system is relatively subtle. Future work in the project will attempt to clarify how widespread and effective PRD signals may be.

Based on the results on flower numbers for *R*. cvs Hoppy and Scintillation, applying additional phosphate fertiliser in the autumn, (i.e. after the main vegetative growth flush) also may have some merit. Generally, it was more desirable to apply triple super-phosphate rather than the phosphoric acid to the medium, so if lowering the pH was influencing any flowering response, it was in a negative direction. The effects of phosphate addition over a broader range of plant species will be evaluated at Efford in year 2.

Technology transfer

- Aspects of the work have been presented at the nursery stock conference, Contact 2001 – Bromesgrove, January 2001.

- It is anticipated that parts of the project will be on view at the HDC Efford Open Day in October 2001.

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