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FACTORS AFFECTING BLINDNESS AND QUALITY IN PRIMROSE

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REPORT TO THE HORTICULTURAL DEVELOPMENT COUNCIL

PC105

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FACTORS AFFECTING BLINDNESS AND QUALITY IN PRIMROSE

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GROWER APPLICATION AND KEY FINDINGS

In this study, three experiments have been conducted to investigate the factors leading to blindness in primrose and factors affecting time to flowering, plant quality and shelf-life. The first experiment conducted at Wellesbourne examined 11 varieties of primrose and 3 of polyanthus grown in one of two environments (glasshouse or polytunnel) and sown on one of five different dates (weeks 29, 33, 38, 43 and 48). Records included the proportion of the plants that were blind, and the proportion of plants with polyanthus type stems. Plants from this experiment were dispatched to HRI Efford for shelf-life assessment. Further plants were also sent to Reading for apical dissection in order to assess the causes of blindness. At Reading two experiments were also conducted, the first examined the effects of temperature (6 to 26°C) on the time to flowering and leaf production of three primrose varieties sown on one of three dates (week 33, 38 and 43). The second experiment examined the effects of four fixed photoperiod (8 to 17hd^{-1}) combined with six temperatures (6 to 26°C) on time to flowering and leaf production.

Potential Benefits

This study may increase the potential for growers to extend the marketing season into Easter/ Mothers Day, which is currently limited by the fact that a number of late sown primrose tend to go blind. Primrose crops often suffer from poor plant quality, and understanding the factors that affect problems such as excess leaf production and polyanthus stem reversion would have clear benefits. Little is known regarding the factors affecting time to flowering, and increasing our understanding of primrose's environmental responses may help growers schedule production and reduce wastage. Shortening the time to flowering would increase through-put, which would reduce overhead costs whilst increasing productivity and allow crop programming.

Grower Application

The results have shown the following points for current commercial application;

- Blindness is due to the failure of the plant to initiate flowers and not flower abortion.

- Blindness increases with sowings later than between weeks 33-38.

- Blindness was dependent on cultivar. The worst varieties for blindness, averaged over the two compartments were Finesse, Corona and Husky.

- Polyanthus stem reversion increases with later sowing date.

- The colour mixes in individual varieties tended to be poorly matched, with blue flowers typically emerging ahead of other colours. Thus, to achieve a good blend of colours growers should either use a range of varieties or use a number of different sowing dates for the same variety.

- Primrose and polyanthus have a short shelf-life, a maximum of 7 days.

- For cv. Danova, experiments at Reading showed that there was an interaction between daylength and temperature in time to flowering, thus at temperature greater than 16°C, time to flowering is delayed if days are long (>approx 12h). At cooler temperatures flowering is unaffected by daylength. Therefore, for early sowings and until late September temperatures should be kept below 16°C to prevent a delay in maturity.

- There is little evidence of an interaction between variety, sowing date and temperature in terms of leaf size or number. Thus, leafy varieties will always be relatively leafy, compared to others at any sowing date/growing temperature. Thus, to reduce leafiness select plants that have inherently small leaf areas.

- Leafiness is related to temperature and photoperiod. With long day lengths leaf area increases, it is also maximised at 12°C.

- There are key varietal differences in the sensitivity of plants to blindness, polyanthus stem reversion, shelf-life and production quality. For current commercial specification, varieties with good all round performance were Danova, Wanda, Finale, Dania and Riviera.

1.0 INTRODUCTION

The UK Primrose crop has been estimated to have an annual UK value of up to £35M per annum. It represents one of the most important winter/spring crops, and is sold both as a pot plant for bowl work and for bedding. It has great potential for a plant which can be purchased as a flowering pot plant and subsequently planted outside for 'added value'. The season for Primrose is quite short with sales centred between October and March. It is thought that considerable potential exists for the market to be expanded either earlier or later in the season; with notable opportunities for sales of Primrose on Mothers Day or even at Easter. Currently these market opportunities are not exploited, since late sown primrose, that may flower around Mothers Day, become blind, where blindness represents a failure of the plant to flower.

However, recent research at the University of Reading (see Pearson *et al.*, 1995) suggested that the sowing of typically early maturing varieties at late times of the year may reduce the levels of blindness. Blindness appeared to be reduced by plants grown at a set point of 10°C, compared to warmer or cooler temperature regimes. Unfortunately only one cultivar was examined, in one pot size and with only three sowing dates. A literature search revealed no other publications that described the causes of blindness in primrose.

There is little information on the factors affecting quality in primrose, especially in terms of leaf production, leaf area and shelf-life. Leaf production is thought important, since highly vegetative (leafy) plants are considered to be of low value, except for ground cover work. A further disorder noted in primrose is the formation of polyanthus type stems. These again lower the quality of the plant and factors affecting both these disorders are not understood. Even the extent of differences between varieties in the incidence of these quality defects are unknown. In terms of shelf-life, we are aware of no previous studies on the shelf-life of primrose. This is clearly a key area of particular importance to the supermarket buyers of primrose.

Consequently, in an attempt to increase our understanding of the factors affecting blindness in Primrose an HDC funded study was conducted that examined flowering in 14 cultivars of primrose and polyanthus sown on one of five dates and grown in either packs or pots, and at one of two different temperatures. More fundamental studies were also conducted in order to establish the environmental factors that affect time to flowering in primrose, since blindness and flowering appear to be inextricably linked. Studies were also conducted at Reading to establish whether blindness was attributed to a failure of the flower to initiate or the result of flower abortion, and to assess factors affecting plant quality, in terms of leaf production (especially total area). Shelf-life studies were also conducted to provide growers with guidelines regarding the durability of a range of primrose varieties.

Thus, the outcome of this research would be information that would allow commercial growers of primrose to help schedule production of quality crops, whilst minimising losses from blindness.

2.0 Materials and Methods

Experiment 1. HRI Wellesbourne

2.1 The effect of sowing date, pot size, temperature and variety on the incidence of blindness in primrose.

Treatments

This experiment was conducted at HRI Wellesbourne. On five occasions (week 29, 33, 38, 43 and 48) 11 and 3 varieties of mixed colour primroses and polyanthus, respectively, were sown, by Four Oaks (Nurseries) Ltd in standard polystyrene seed trays. A list of the varieties used is shown in table I.

Table I. A list of the varieties used in the experiment.

Type	Variety
Polyanthus	Casino
	Crescendo
	Rainbow
Primrose	Pageant
	Danova
	Riviera
	Finesse
	Dania
	Finale
	Husky
	Saga
	Wanda
	Lira
	Corona

Plants were pricked out into one of two containers, a 9cm pot (9C, with 72 replicate plants per cultivar) or a standard commercial six pack (24 replicate six packs per variety). Thus, the design was an unreplicated blocked experiment comprising;

14 varieties

x

5 sowing dates

x

2 containers

x

2 temperatures

The potting compost used was a special primrose mix prepared by Bulrush (Danish pot plant compost: Primula mix). Half of the plants were then grown on in a polytunnel greenhouse maintained frost free (4°C), or in a glasshouse compartment maintained at a minimum temperature of 8°C. Plants were fed with a 20:10:20 feed diluted 1 in 100 to give 100ppm N, commencing three weeks from potting. Plants were sprayed at regular intervals with Rovral to control botrytis. Filex was applied as a routine spray 2 weeks after potting.

Data Collection

To examine when primrose initiate flowers, and whether blindness is a function of a failure of plants to initiate or flower abortion *per se*, at approximately two weekly intervals six plants each from the varieties Wanda, Saga, Crescendo, Pageant, Danova, Finale and Husky were sampled for apical dissection at the University of Reading. Only plants grown in the 9C pots were sampled. During apical dissection, each plant was examined under a binocular microscope to establish whether the plant was vegetative or reproductive; leaf numbers below the flower were also determined.

30 weeks after planting the proportion of the crop that was blind was assessed for each crop, the proportion of the stems which showed a 'polyanthus' morphology (i.e. primrose varieties

where the flowers were borne on atypically elongated stems) were also assessed. To quantify variety differences, on first flowering a batch of plants (5) from the following representative varieties Wanda, Saga, Crescendo, Pageant, Danova, Finale and Husky were sampled and dispatched to the University of Reading, where leaf areas and leaf numbers below the flower were assessed.

On flowering a further 4 to 8 plants were sent to HRI Efford for shelf life assessments. Only plants in 9cm pots were examined, since six-pack production is a bedding/outdoor subject. Plants were placed in trays, 15 plants per tray, but were not sleeved or boxed. Plants were then transported 130 miles to Efford in an uncontrolled environment where temperature and humidity were able to fluctuate. Upon receipt, plants were placed in drip trays in a simulated shelf-life room. Plants were immediately watered from below by hand, and thereafter as necessary. The shelf-life room was controlled to achieve a minimum temperature of 18°C, day and night, not rising above 22°C. Relative humidity was maintained at 65%± 5%. Florescent tubes provided 800lux light level at plant canopy height. Plants were lit from 06:00 to 18:00 each day. Plants were recorded upon receipt, and at 7, 14 and 21 days in the shelf-life room. Records included; flower number, flower drop, foliage colour score, overall plant quality, flower colour and size and photographs where appropriate.

Experiment 2. University of Reading

Experiments were conducted at Reading in order to increase our understanding of the factors affecting flowering and quality in primrose. These were an adjunct to the large scale experiment at Wellesbourne and were conducted in small semi-controlled environment facilities.

2.2 Experiment 2a. The effect of temperature and sowing date on the time to flowering and quality of six primrose varieties.

Excess plants of the varieties Pageant, Finale and Danova from the week 33, 38 and 43 sowings were sent from Wellesbourne to Reading in order to investigate the effects of temperature and sowing date on overall plant growth and time to flowering. Plants were potted up in 9C pots containing the same compost as used at Wellesbourne. From each sowing date, six plants of each variety were placed in one of six temperature controlled glasshouse compartments with set point heating temperatures of 6, 10, 14, 18, 22 and 26°C. Plants were watered as necessary with a nutrient solution made from sangral 1:1:1 diluted to a conductivity of 1500μS, acidified with nitric acid to a pH of 5.8. Plants were grown on until flowering and as individual plants flowered they were destructively sampled in order to measure leaf number below the flower and leaf area. Actual temperatures were recorded from PT100 temperature sensors mounted within aspirated screens inside each greenhouse compartment.

2.3 Experiment 2b. The effect of temperature and photoperiod on the flowering of primrose cv. Danova.

The effects of both controlled temperature and photoperiod were investigated with plants from the week 38, cv Danova. Thus, 4 plants from each variety were placed inside one of four photoperiod controlled compartments built inside the temperature controlled compartments used in the first Reading experiment. Space is very limited inside each compartment, hence the small number of replicates. The photoperiod treatments were provided by maintaining the plants in the open greenhouse for eight hours of the day (08:00 to 16:00), where they received natural solar radiation. At 16:00 plants were placed inside the compartments, which are completely sealed from exterior light sources. Photoperiods were then extended inside the compartments using low light intensity day length extension lighting; 11μmol m^{-2} s^{-1} provided from a 40W tungsten and an 18W compact florescent bulb. The daylength treatments used were 8, 11, 14 and 17hd^{-1}. Plants remained in the compartments all night and were removed at 08:00 for placement back inside the greenhouse. The experiment was a 4 photoperiod x 6 temperature factorial with 4 replicate plants per treatment. Time to flowering, leaf area and leaf number were measured. Plants were grown using the same protocol as described for the first Reading experiment.

3.0 RESULTS

3.1 Wellesbourne Experiments: General Layout

Plate 1 shows the general layout of the experiment at Wellesbourne.

Plate 1. The layout of the plants in the tunnel greenhouse at Wellesbourne

3.2 The Cause of Plant Blindness

Plants from all sowings, including 'blind' plants, were sent from Wellesbourne to Reading for apical dissection. A total of 220 plants were dissected. From all those dissections, only a single plant was found to have aborted a flower. Of the 'blind' plants examined the principal cause of blindness was found to be either a total failure of the plant to initiate a flower (see Plate 2), or late flowering, such that the flower had not had sufficient time to develop visible buds (see Plate 3). It is not clear whether the plants that had failed to initiate would ever had done so in the same season. Thus, this study has shown clear evidence that blindness is related to factors that affect the ability of the plant to initiate flowers, not abortion of flowers post initiation.

This finding is important, since it shows where future research effort should be devoted in order to solve this problem.

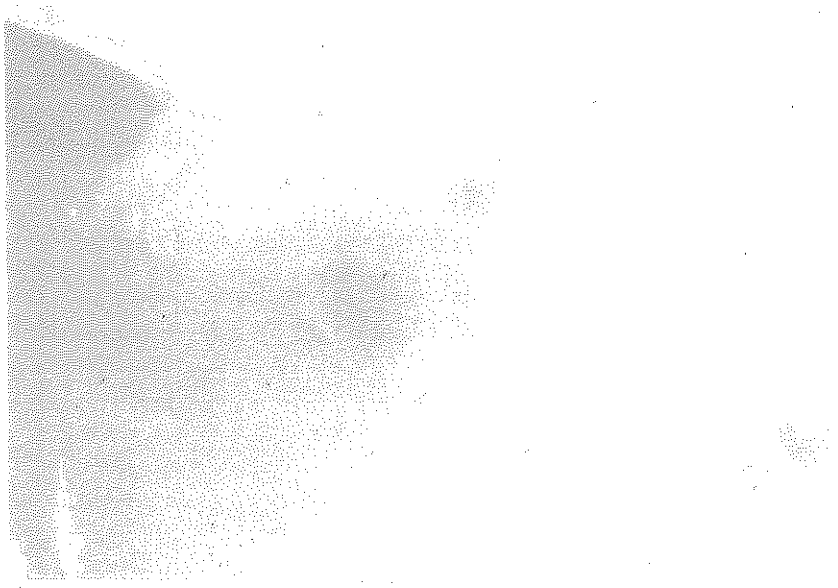

Plate 2. A photograph of the apex of blind plant, that failed to initiate

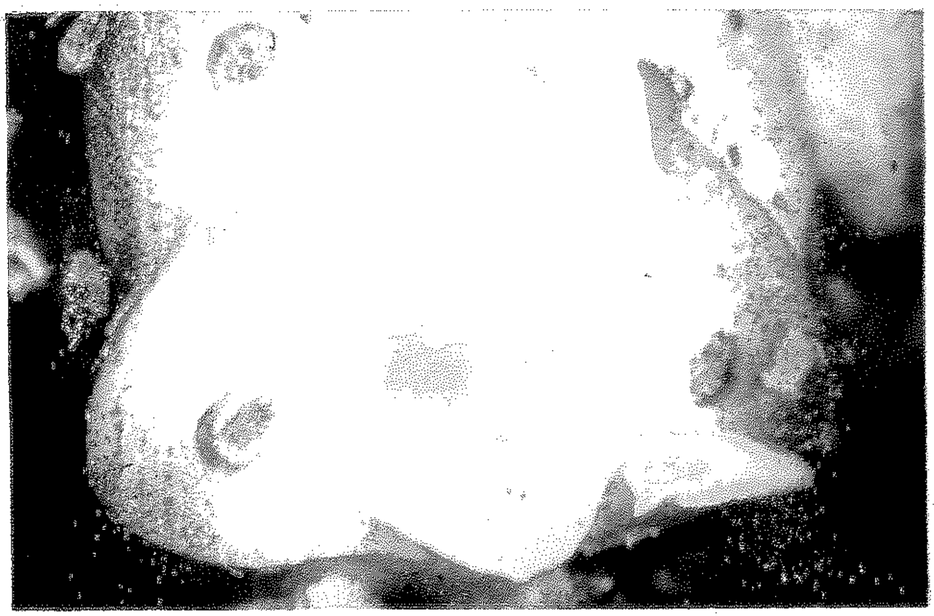

Plate 3. A photograph of an apex of a blind plant that had initiated, but had insufficient time to develop visible buds.

3.3 The Time to Initiation

Figure 1 shows the leaf numbers initiated below the flower bud of the dissected plants (blind plants were excluded from the analysis).

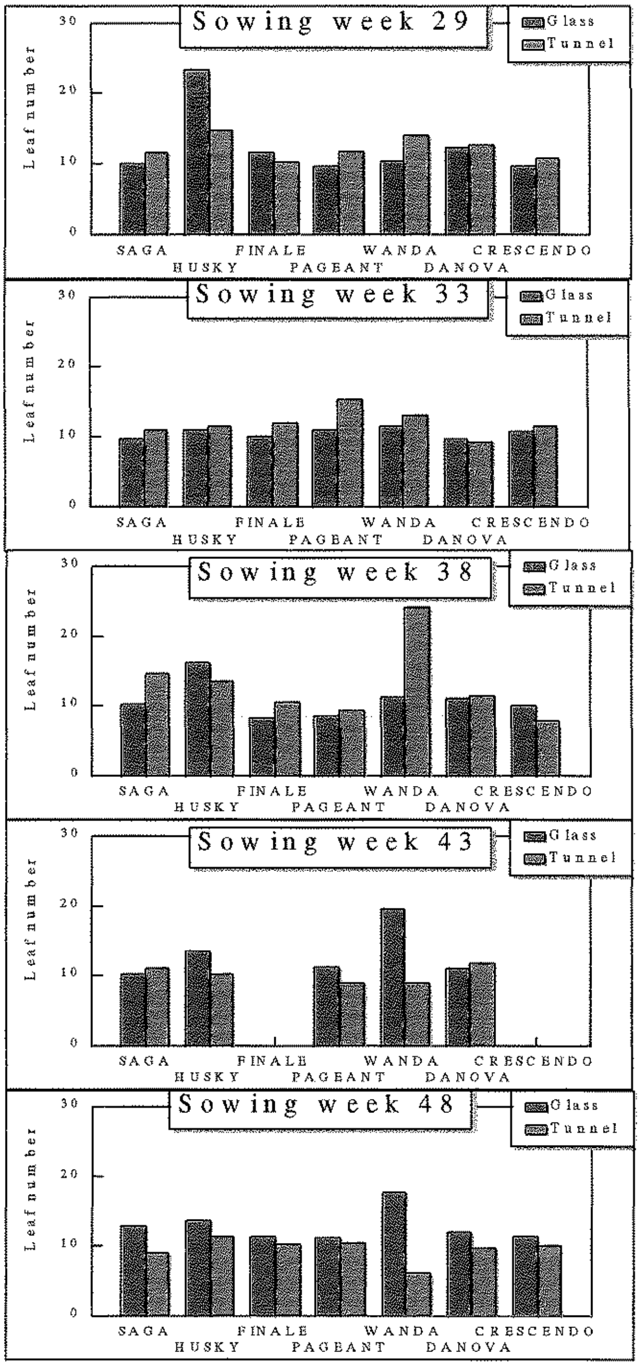

Figure 1. The leaf numbers below the flower bud of the dissected primrose varieties, blind plants were excluded from the analysis.

In terms of leaf number below the flower (blind plants were excluded from the analysis), figure 1 shows that, with few exceptions, sowing date, variety, and greenhouse type had no significant effect. Thus, plants from all varieties and sowing dates had initiated 8 to 14 leaves prior to flowering. Thus, leaf numbers greater than 14 may provide an indication that plants will be, and remain, blind. However, more analysis on a greater number of blind plants is required to confirm this.

Figure 2 shows the time to initiation of plants from each of the varieties and sowings dissected at Reading.

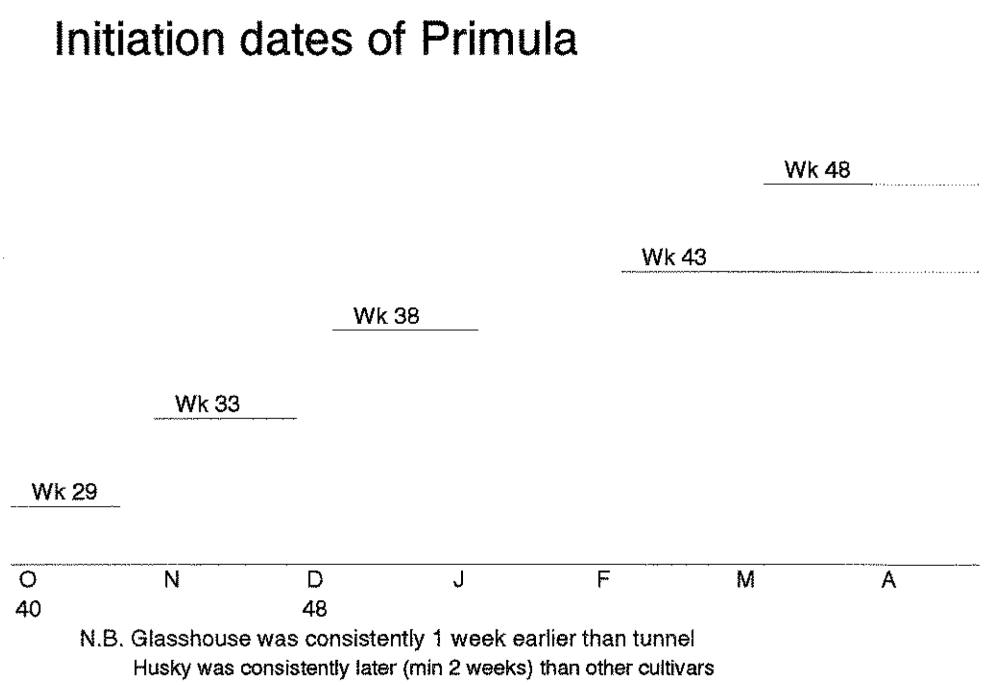

Figure 2. Estimated time to initiation of the primrose sowing, due to the small number of replicates and the plant to plant variability more precise estimates for individual varieties was not possible. Letters on the lower axis represents different months.

This shows that by week 29, varieties in both the tunnel and glasshouse were initiating during October, with November, December, February and March for the week 33, 38, 43 and 48 sowings, respectively. More precise estimates of the initiation dates could not be given due to the large variability in time to initiation amongst the crops. Notably, however, sowings later than week 38 (i.e. 43 and 48) took a longer period to initiate than those sown earlier. Furthermore, the variability in the time to initiation amongst the crop was greater in the weeks 43 and 48 compared to earlier sowings. This also suggests that blindness with later sowings may be due to increased variability in the time to initiation amongst the crop.

3.4 The Proportion of Blind Plants at Wellesbourne

Figure 3 shows a summary of the data on the proportions of plants that were blind from different sowing dates.

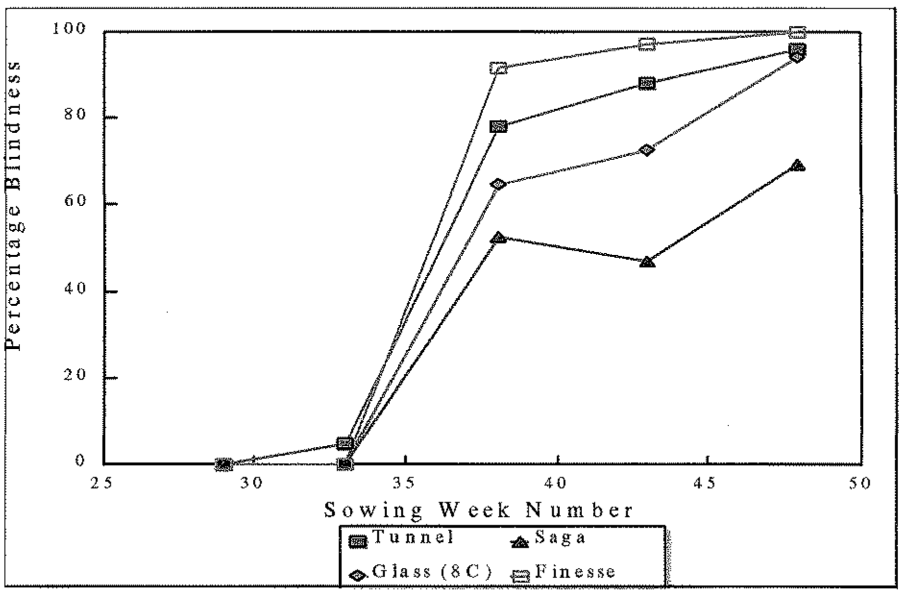

Figure 3. The relationship between the proportion of blind plants against sowing week number.

When data from all varieties were combined, the results showed that sowings, grown on in both the tunnel and glasshouse, during weeks 29 and 33 showed very low proportions of blindness, whilst blindness increased dramatically with later sowings. There were, however, important varietal differences, such that at all sowings of cv. Finesse had a higher proportion of blindness than other cultivars, whereas Saga an early variety, consistently had a lower proportion of blindness. Blindness was found to be 11% lower, overall, in the glasshouse compared to the tunnel (56% compared to 45%). To give a more detailed comparison of the performance of the varieties, Table II shows the percentage blindness (from the most representative sowing weeks; 33, 38 and 43) of each of the varieties.

Table II. The percentage blindness of each of the varieties averaged from the week 33, 38 and 43 sowings, P = polyanthus, and the percentage of plants from all sowings with polyanthus stems.

Variety	% Blind Tunnel	% Blind Glass	% Poly' Tunnel	%Poly' Glass
Saga	33.3	33.3	25.4	27.7
Crescendo (P)	51.8	35.2	100	100
Wanda	53.7	55.5	6.9	0
Lira	54.8	50.9	13.1	17.4
Rainbow (P)	55.5	35.1	100	100
Finale	56.5	41.6	2.4	7.1
Pageant	57.4	29.6	6.1	24.8
Husky	57.4	60.2	0	2.5
Casino (P)	58.3	50.0	100	100
Riviera	58.3	41.6	12.9	5.8
Danova	61.1	46.2	0	1.1
Corona	64.8	62.0	13.3	11.7
Dania	65.7	36.1	2.7	1.9
Finesse	69.4	62.9	7.2	7.9
Average	**56.8**	**45.7**	**27.9**	**29.1**

This table confirms that Saga had a considerably lower proportion of blind plants than the other varieties, which all had relatively high proportions of blindness from the week 33, 38 and 43 sowings. There were also notable interactions between greenhouse type and cultivar, such that Pageant, Rainbow, Dania and Crescendo showed a high degree of blindness in the tunnel (53-64%), but considerably lower blindness in the glasshouse (30-36%) maintained at a minimum of 8°C.

3.5 Proportion of the Primrose Varieties with 'Polyanthus' Type Flowers

Figure 4 shows how the proportion of primrose plants that had polyanthus type flower stems varied with different sowing date.

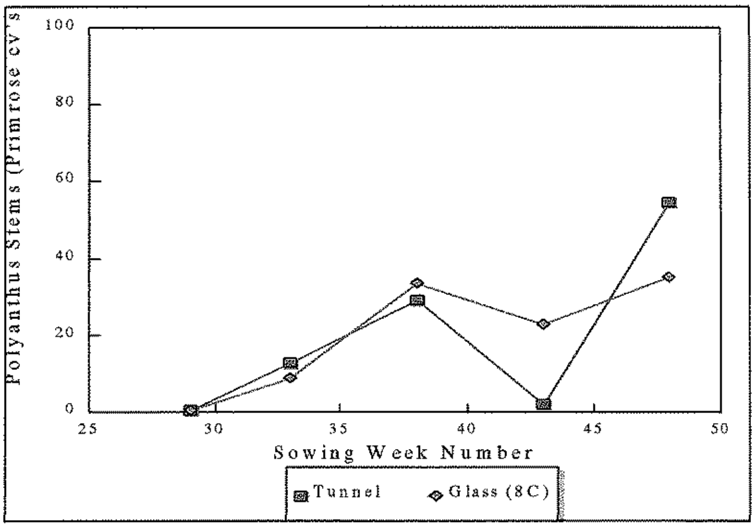

Figure 4. The effect of sowing date and greenhouse type on the percentage of polyanthus type flower stems amongst the eleven primrose varieties tested.

For the earliest sowings, week 29, no plants were found to have polyanthus stems. However, with later sowings the proportion of polyanthus stems varied between 5 to 55%. There was no evidence of any clear differences between the glasshouse or tunnel treatments. There were, however, key differences between varieties (Table II), such that Saga, Lira, Corona, and Pageant showed an undesirably high proportion of polyanthus stems.

varietal performances are described below in the shelf-life observations. One further notable feature was that many of the varieties had a poor mix of colours in terms of uniformity of flowering within the mix. For example, blue flowers of Saga and Danova always tended to emerge ahead of the yellows, reds and pinks. In Pageant, yellows tended to emerge earliest.

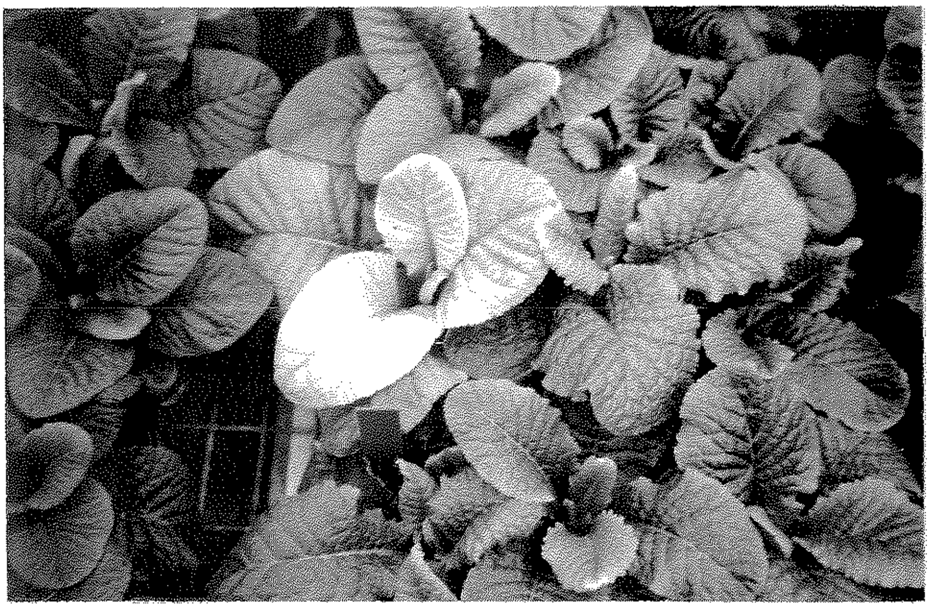

Plate 4. Leaf yellowing in variety Husky

Plate 5. Plant to plant variation in variety Wanda.

3.7 Shelf-Life Studies at HRI Efford

Plants from each of the batches and environments were dispatched to Efford for shelf-life tests. Unfortunately, inherent problems were faced with shelf-life evaluation due to the random flowering habit and growth of many of the varieties. Difficulty in the selection of plant material also meant that plant maturity varied at the marketing/shelf-life stage, and, due to blindness, no plant material was received from the week 43 and 48 sowings. As a consequence, it was impossible to conduct detailed and comprehensive shelf-life evaluation on all varieties x sowing dates x temperatures. However, an attempt has been made to highlight varietal differences and the effect of the two growing temperatures on the shelf-life of a number of the varieties.

3.7.1 General Observations Prior To and During Shelf-Life: By Variety

Casino (P)

At receipt, glasshouse grown plants were larger with greater foliage (size) and larger flowers than the plants grown in the polytunnel. Foliage colour of the polytunnel plants was poorer with leaf edge yellowing noticeable. After 7 days in shelf-life, leaf yellowing was obvious on both sets of plants but worse on plants produced in the polytunnel. Each plant had at least 9 open flowers with only 2-3 individual dead flowers per plant. Flower colour was fading but overall plant quality was average. At 2 weeks, plant quality had deteriorated substantially with greater flower colour loss on plants produced in the greenhouse. Although all plants had on average 7 open flowers, there were a greater number of dead flowers, 6 per plant, which greatly detracted from the overall plant appearance. Foliage was paling on both sets of plants. Production of new flowers became distorted and flower size reduced. Leaves became 'strap-like'. Overall rating poor.

Crescendo

Glasshouse grown plants were larger than those grown in the polytunnel upon receipt. Foliage colour was good for both sets of plants and each plant had between 3 and 9 open flowers. Glasshouse grown plants had more flowers at receipt. Although flower buds developed and open flower number increased in shelf-life, their size was much smaller for both sets of plants and flower colour began to fade after 7 days. Plants grown in the greenhouse had a greater number of dead flowers and both flower and foliage colour was reduced. Foliage colour progressively worsened as leaf edge yellowing became more pronounced on both sets of plants. After 21 days there were very few open flowers on either set of plants and plant quality overall was poor. Leaf colour was pale and plants' appearance had become straggly and `old'. Overall rating - moderate/poor.

Rainbow (P)

Plants from the earlier sowing (week 28) from both production temperatures were of good quality. However, plants received from later sowings and grown in the greenhouse were of only moderate quality with spindly foliage and weak flower pedicels which were unable to support the flowers. Foliage colour was also paler. All plants had large numbers of open flowers which lasted for approximately 14 days. However, flowers produced during shelf-life were much smaller in size and not as vivid in colour. Plant foliage became untidy and yellowing developed quickly. Plant quality was worst after 21 days from plants grown at in the greenhouse. Overall rating moderate/poor.

Pageant

Plants at receipt were all of good quality. Plants grown in the glasshouse had more open flowers, on average 7, compared to 4 on the polytunnel grown plants. Plants continued to flower for 7-14 days, by which time a greater number of dead flowers were recorded. Plants grown in the greenhouse tended to have a shorter shelf-life, where earlier and increased flowering reduced plant quality more rapidly than plants grown in the polytunnel. Overall plant quality remained good for 14 days. A number of plants reverted to polyanthus status, particularly the yellow flowered plants. Leaf yellowing became more obvious after 14 days on the glasshouse grown plants. Overall moderate.

Riviera

All plants were of good quality at receipt. Glasshouse grown plants were slightly larger and had larger flower size. The pastel shades faded quickly in shelf-life. Although greenhouse grown plants had on average more flowers than plants grown in the polytunnel grown plants, their colour and number faded quickly and plant quality deteriorated more rapidly. Foliage colour became pale more quickly where plants had been grown in the glasshouse. Overall plants grown in the polytunnel had an improved shelf-life lasting for 14 days.

Danova

Overall, this variety had good shelf-life and although the number of open flowers was reduced after 21 days, plant quality remained good. Plants at receipt were of good quality with glasshouse grown plants having more flowers and darker foliage. Overall - good.

Finesse

Plants were of good quality at receipt with the glasshouse grown plants having larger flowers. Flower colour quickly faded - worse so on plants grown in the glasshouse. Number of open flowers was consistent over the 3 week shelf-life assessment with between 4 and 8 flowers per plant. The average number of dead flowers did not rise above 4 per plant until the final week. One or two plants grown in the polytunnel became 'polyanthus' type in their flowering habit. Leaves tended to yellow more on plants grown in the glasshouse and leaves became strap-like. Overall - moderate.

Dania

All plants were of good quality at receipt. Plants grown in the glasshouse were slightly larger in size. Plants averaged 7 open flowers for the first 14 days, whilst the average number of dead flowers did not rise to above 2 per plant until 21 days. Flower colour loss was pronounced after 14 days and foliage colour was poor. Leaf edge yellowing was apparent from both sets of plants and leaves became strap-like and upright in habit. Overall plant shelf-life was moderate/poor, not exceeding 14 days.

Finale

All plants were of good quality at receipt with little difference between the two growing environments. The average number of open flowers per plant remained above 6 until the final week when a greater proportion of dead flowers were recorded. Plants remained neat and compact, although new leaves produced were strap-like and upright. Plant quality remained good until 14 days. By the third week all plants were of poor quality, with flower colour loss and yellowing of the lower leaves. Overall good/moderate.

Husky

Plants grown in the glasshouse continued to produce flowers until day 14. Flower colour remained good and although slight leaf yellowing was visible, plant quality was moderate/good throughout. Greater leaf yellowing and flower drop after 14 and 21 days was found on plants grown in the glasshouse. Overall - moderate/good.

Saga

Quality of plants at receipt was variable. Generally plants grown in the glasshouse were of a higher quality than those grown in the polytunnel. However, plants grown in the greenhouse reverted to polyanthus status during shelf-life. Foliage colour was worse at plants grown in the greenhouse, whereas flower colour loss was greatest from plants grown in the polytunnel. With the later sowings, plant size was smaller and the plant canopy appeared sparse. New leaves were produced after 14 days in shelf-life which increased plant size, although average number of open flowers was reduced. Overall - moderate/poor.

Wanda

With its characteristic darker foliage, no significant paling of the foliage was recorded in shelf-life from any of the sowings received. Plant quality remained good throughout shelf-life, although one plant from week 38 sowing did revert to polyanthus status. There was little flower colour loss throughout shelf-life. Overall - good.

Corona

All plants were of good quality at receipt. Foliage colour deteriorated more on plants grown in the glasshouse and after 21 days, severe leaf edge yellowing was apparent. Flower colour remained good on plants which had been grown in the polytunnel until the third week, whereas flower had deteriorated after only 7 days from plants grown in the glasshouse. The later sowings did not have such a good shelf-life. Overall, plant quality remained good

Lira

Greater number of plants reverted to polyanthus status in this variety. Plants grown in both environments were of good quality at receipt and little difference in the average number of open flowers was recorded each week. Flower colour loss was greater from plants which had been grown in the glasshouse. Flowers were prominent and displayed well on the plant. Overall, plant shelf-life was good/moderate throughout.

3.7.2 Analysis of Shelf-life Studies

Plate 6 shows the appearance of plants at receipt and after they had been in shelf-life for 21 days.

Plate 6. Variety Dania, the left photograph shows plants at the start of shelf-life and on the right after 21 days.

Plates 7 a and b show flower loss and distortion, and 'strap-like' leaves characteristic of plants held in shelf-life conditions for >14 days.

Plate 7. a (left) cv Finesse showing flower distortion and colour loss. b (right) cv Finale showing 'strap-like' leaves.

A more detailed quantitative summary of the data is shown in Figures 5 and 6, which show data from plants of varieties Pageant and Crescendo sown during week 29, and grown in either the greenhouse or the tunnel. Data from other varieties are shown in the appendices, and are similar to that shown in figures 5 and 6. Thus, for all varieties total flower number tended to increase up day 7 and declined thereafter, with a resultant increase in the number of dead flowers per plant. Plants grown in the glasshouse (8°C) tended to produce slightly more flowers than those grown in the tunnel (4°C). Flower colour and size for all varieties tended to deteriorate soon after entry into shelf life. It was also observed that foliage faded slightly and new leaf production was strap-like and upright, inhibiting the display of flowers. Overall plant quality deteriorated rapidly after 14 days and at final records, after 21 days, plants were judged to be of poor quality. The analysis also showed that there were no consistent differences between the sowing dates examined (see appendix for data).

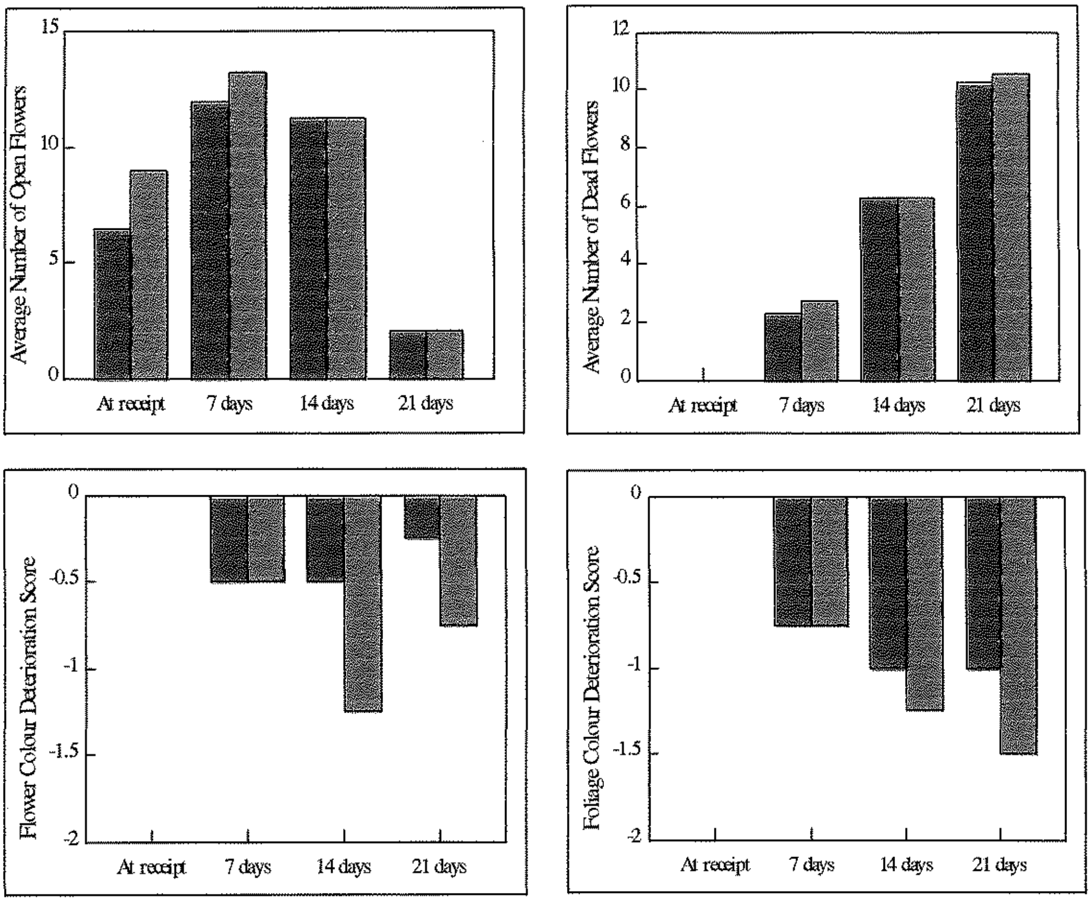

Figure 5. The changes in number of open flowers, number of dead flowers, flower and foliage colour deterioration during shelf-life for polyanthus cv. Crescendo sown during week 29. Red bars represent plants grown in the tunnel (4C), green bars represent plants from the glasshouse (8C).

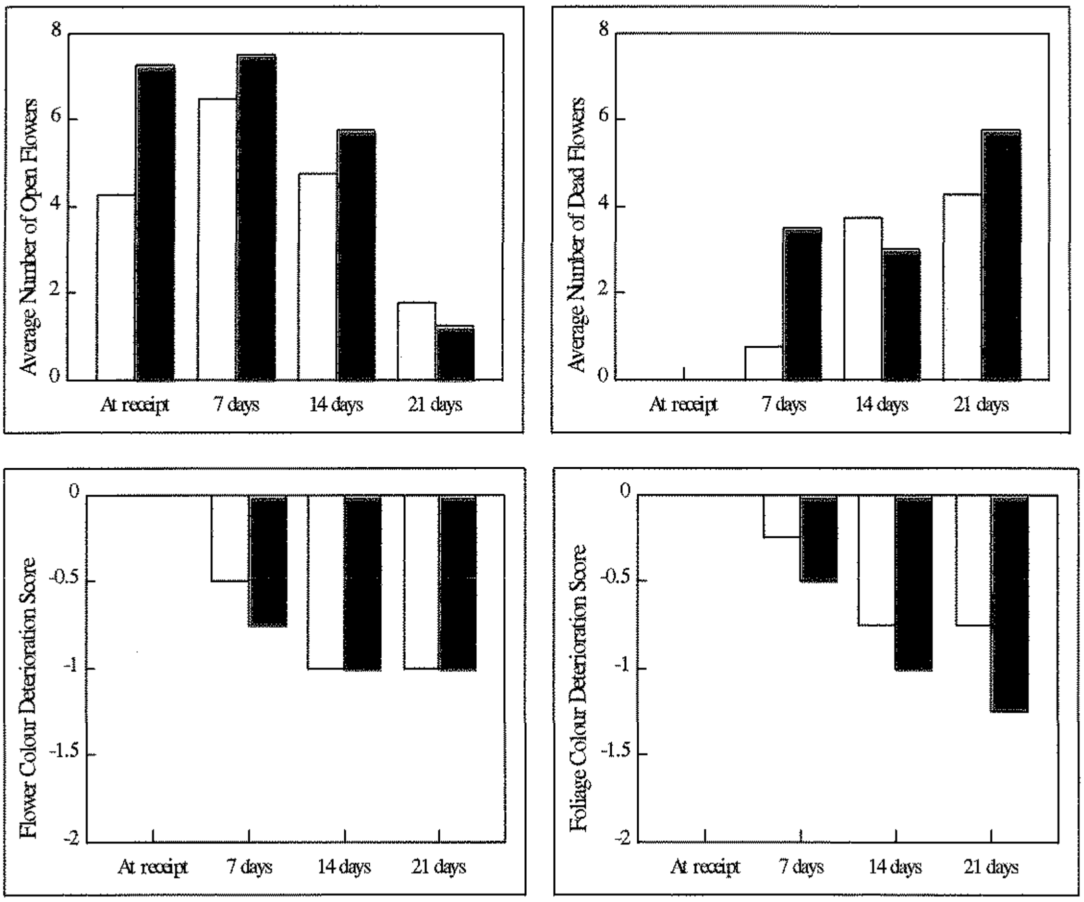

Figure 6. The changes in number of open flowers, number of dead flowers, flower and foliage colour deterioration during shelf-life for primrose cv. Pageant sown during week 29.Yellow bars represent plants grown in the tunnel (4C), blue bars represent plants from the glasshouse (8C).

3.7.3 Conclusions from Shelf-Life Studies

To summarise, production from the glasshouse (8°C) produced larger plants at marketing with increased flowering and flower size. In contrast plants grown at 4°C (tunnel) were generally smaller and a greater proportion of plants showed leaf edge yellowing. In shelf-life plant quality deteriorated rapidly for plants produced which had been produced in the greenhouse. Flower colour quickly faded, and flower size was reduced. Plants grown in the polytunnel did not deteriorate as quickly in shelf-life although after 21 days their overall quality was also poor. Best plant quality for the consumer would be attained with a maximum of 7 days shelf-life. Furthermore, any increase in the length of time a plant is displayed in shelf-life will subsequently effect its longevity and quality in the consumers home. Varieties with improved shelf-life performance were Danova, Finale, Wanda and Lira. Poorest varieties were Casino, Dania and Saga. However, these results are observations on only one set of plants, and further investigations to examine shelf-life performance are required.

3.8 Reading Experiments. The Effects of Temperature on Time to Flowering

In the first Reading experiment, 3 varieties of primrose were sown on one of 3 dates (weeks 33, 38 and 43) and grown at one of six set point temperatures between 6 and 26°C. The very extensive temperature regime was used in order to gain a complete understanding of the plants response to temperature. Plants grown at 22 and 26°C did not flower. However, of the remaining treatments Figure 7 shows the effects of temperature on time to flowering.

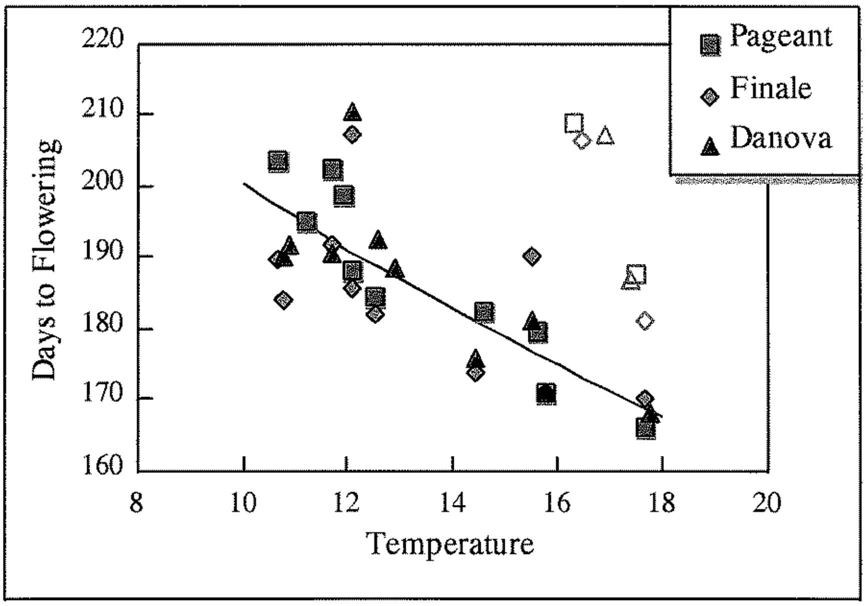

Figure 7. The effect of temperature on the time to flowering of three primrose varieties, combined data from plants sown on three different dates. The line was fitted by regression where time to flowering = 1/(0.00378 + 0.000121T), r^2 = 0.64, 28 d.f. Points with colours not filled in were excluded from the analysis..

This shows that as mean recorded temperature increased from 10 to 18°C time to flowering decreased from 200 to 170 days. Thus, an 8°C temperature change brought maturity forward by one month. However, figure 7 shows at least 6 outlier points (colours not filled in on figure 7). These were data from plants sown during weeks 33 and 38, and grown at the highest temperatures. Thus, relatively early sowing combined with high temperatures may delay flowering. Possible reasons for this are discussed below.

There were also significant difference between cultivars and effects of temperature on the final leaf area (Figure 8).

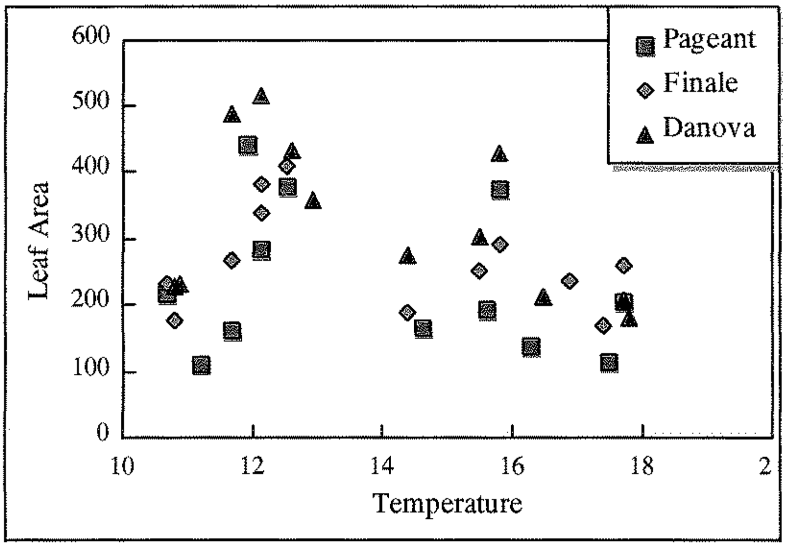

Figure 8. The effects of temperature on the final leaf area of plants of 3 primrose varieties. Each point is the mean of 6 plants.

The most leafy plants were Danova, followed by Finale and Pageant. Thus, plants of cv. Pageant had an average leaf area 33% smaller than Danova. Furthermore, plants grown at an average recorded temperature of 12°C were significantly leafier (total leaf area) than those at cooler or warmer temperatures.

Generally, in primrose, higher quality is associated with small leaf areas. 'Cabbagy' (leafy) plants that have high leaf areas are considered undesirable. These results have demonstrated that this phenomenon is highly dependent on, and sensitive to, temperature. Thus, careful temperature control may partially help control the incidence of 'Cabbagy' plants.

3.9 Reading Experiments. The Effect of Temperature and Photoperiod on Time to Flowering

Plants were grown at set-point temperatures between 6 and 26°C, combined factorially with 4 day-lengths (8 to $17hd^{-1}$). Plants grown at 22 and 26°C did not flower. For plants grown at the cooler temperatures, figure 9 shows the relationship between the days to flowering and photoperiod and temperature.

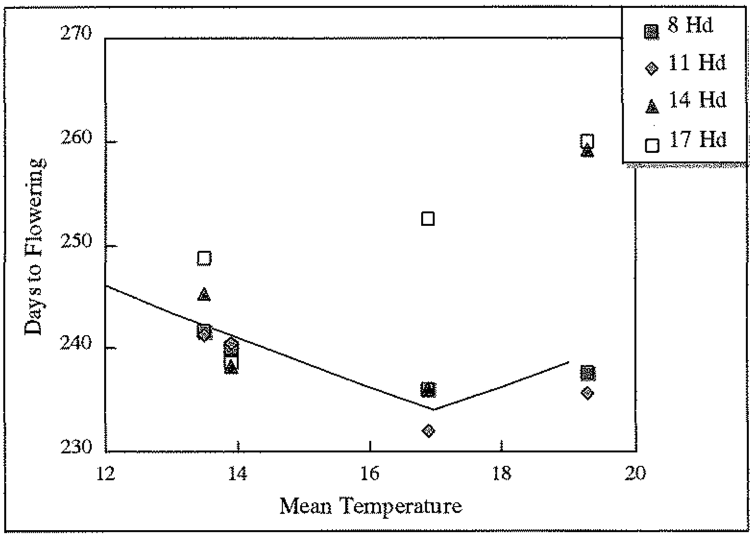

Figure 9. The effect of photoperiod and temperature on the time to flowering Primrose cv. Danova.

Thus, for plants grown at cool temperatures (<16°C) photoperiod had very little effect. However, as temperature increased plants grown under long days were significantly ($P>0.01$) delayed in their time to flowering. Note that the two points in the top right of the figure represent plants grown in long-days. Thus, at warm temperatures (>16°C), it is apparent that short days are required for early flowering. These data explain the apparently aberrant points on figure 7, where at temperatures greater than 16°C early sown (week 33 and 38) primrose under natural day lengths, took longer than expected to flower, whilst later sowings (week 43) at high temperatures flowered relatively quickly. These effects are presumably due to the fact that natural day lengths during week 33 and 38 are long (14 and 12.6hd^{-1}, respectively), compared to 9.5hd^{-1} in week 43. Consequently, the combination of long-days and high temperatures delayed time to flowering.

These data on photoperiod/temperature interaction affecting time to flowering are also confirmed by data on leaf numbers formed below the flower for plants grown at different photoperiods (Figure 10).

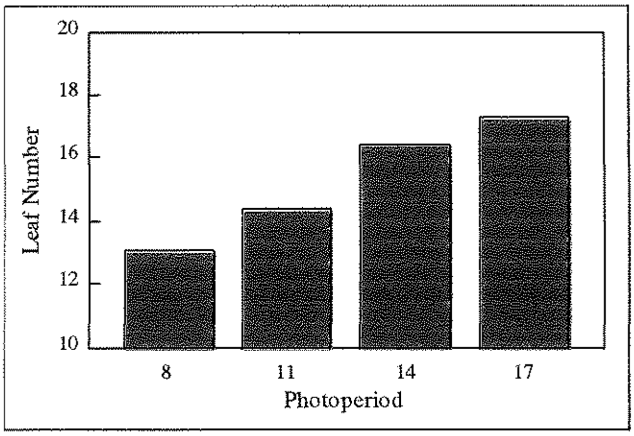

Figure 10. The effect of photoperiod on leaf number initiated below the flower of primrose cv. Danova. (s.e.d. = 0.6, 61d.f.).

Thus, plants grown at 17hd^{-1} had significantly more leaves than those grown at 8hd^{1} . This difference reflects the likelihood that flowering is delayed by long photoperiods.

Generally, this mechanism probably explains why Primula are naturally a winter/spring flowering plant, since when temperatures are cold (<14°C) they can flower at any photoperiod. However, flowering is prevented during the warmer summer months because the daylength is too long. Similar responses were noted in *Primula malacoides* by Runger and Wehr (1971), who showed that as temperature exceeded 12°C flowering was delayed at long photoperiods, whilst at cooler temperatures photoperiod had no effect on time to flowering/

Photoperiod treatments also had a significant ($P<0.05$) effect on leaf area (Figure 11). Thus plants grown under long days had nearly twice the leaf area as those grown under short days ($8hd^{-1}$). This response is partially due to increased leaf number with long-photoperiods, and may partially explain the observation that early sowings tend to be more 'Cabbagy' (vegetative) than later sowings, since sowings in late June will be initiating and growing leaves when photoperiods are long.

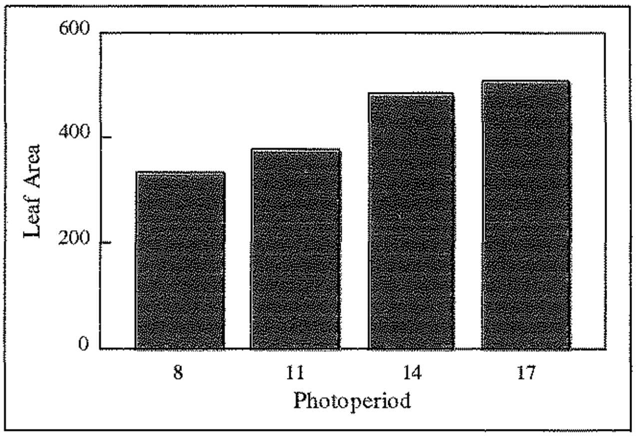

Figure 11. The effects of photoperiod on leaf area (cm^2) of primrose cv. Danova (s.e.d. = 28 cm^2, 61.d.f.).

4.0 Discussion and Conclusions

This study has considerably advanced our understanding on the effects of environment and sowing date on the flowering, blindness, quality and shelf-life of primrose and polyanthus. The key findings can be summarised as;

Understanding of Blindness

The experiment has shown that blindness is associated with the failure of the plant to initiate flowers rather than flower abortion. Thus, to understand blindness a deeper understanding of the factors affecting time to flower initiation is required, in order to reduce the incidence of blindness. However, it was clear from this study that sowing later and between weeks 33-38 are likely to suffer from a high proportion of blindness. It should, however, remembered that these results were from only a single experiment, and therefore the work need repeating to definitively confirm the latest sowing date that does not result in blindness.

Shelf-life

This study has shown that primrose have a relatively short shelf-life, and that shelf-lives later than about 7 days should not be recommended. There were, however, considerable differences between varieties, summarised below.

Varietal Differences

Table III attempts to summarise the key differences between the cultivars tested.

Table III. A summary of the attributes of the different varieties

Type	*Variety*	*Blindness*	*Polyanthus Reversion*	*Shelf-life*	*Quality Prior to Shelf-life*
Polyanthus	Casino	Poor	-----	Poor	Good
	Crescendo	Average	-----	Moderate/ Poor	Average
	Rainbow	Average	-----	Moderate/ Poor	Average
Primrose	Pageant	Average/ Good	Poor	Moderate	Good
	Danova	Average	Good	Good	Good
	Riviera	Average	Average	Moderate	Good
	Finesse	Poor	Average	Moderate	Good
	Dania	Average	Good	Moderate/ Poor	Good
	Finale	Average	Good	Good/ Moderate	Good
	Husky	Poor	Good	Moderate/ Good	Average
	Saga	Good	Poor	Moderate/ Poor	Poor
	Wanda	Poor/ Average	Good	Good	Good
	Lira	Poor/ Average	Poor	Moderate/ Good	Good
	Corona	Poor	Poor	Good	Good

Of the primrose varieties, Saga showed the least blindness but, suffered from a high degree of polyanthus stem reversion and poor shelf-life. The varieties that appeared to have a good all - round performance were Danova, Wanda, Finale, Dania and Riviera. Of the polyanthus varieties all were similar, however, Casino had good quality prior to shelf-life, but its shelf life performance was poor. The other two varieties, Crescendo and Rainbow, were considered to have average all round performance.

Factors Affecting Time to Flowering

This project has established that a number of factors affect time to flowering in primrose. Firstly, observations showed that mixed varieties were generally poorly matched, such that blue flowering plants tend to flower earlier than the others colours. This will present growers with considerable problems if they aim to sell the product as mixed colours. Clearly further work is required to identify better techniques to match colour mixes. The work has also shown that there is a clear interaction between photoperiod and temperature on the time to flowering of primrose. Thus, at temperatures below 16C flowering is unaffected by daylength, however, at higher temperatures the plants require short-days to flower. This information could be of considerable benefit in the long term for devising improved scheduling techniques, and for manipulating crop maturity to predefined dates e.g. production of crop for the Easter or Mothers Day market. It also has practical implications for present production, since it shows that to hasten production, and therefore increase throughput, during the summer (up to late September) growers should strive to keep temperatures below 16C. It is clear, therefore, from the work on time to flowering and plant quality that in primrose production careful attention should be given to the accurate monitoring of greenhouse temperatures.

Factors Affecting Plant Quality

This study has also indicated some of the factors affecting plant quality, in terms of leafiness and the reversion to polyanthus type stems. In terms of leaf production, this is dependent on photoperiod, and hence sowing date, since earlier sowings will be developing under long days. Leaf area is also temperature dependent, and that to reduce cabbagyness temperatures should be greater or lower than 12C. If leafiness is a common occupance then growers could also swap to different varieties in subsequent years, since for example Pageant was found to be less leafy than Finale at all temperatures and sowing dates.

5.0 Future Work

As discussed above, the production of primrose could be improved considerably by investigations into a number of key areas;

1) Further work is required to understand the relationship between blindness and factors affecting flowering, in particular the effect of light integral has not been examined. Changes in light level (integral) may explain why blindness increased with later sowing dates. Furthermore, the latter factor has been implicated in blindness in a range of other plant species.

2) Sowing date schedules could be developed for primrose with further work on the effects of environment variables on time to flowering, particularly with a greater range of cultivars.

3) Further work is required to develop protocols to determine the optimum match of colour strains in a mixed flowering variety. This would involve understanding factors that affect the variability in time to flowering of different colours.

4) Examination of the effects of environment on the variability of seed germination may also help explain, and therefore help growers reduce, plant to plant variability in the crop at the time of flowering.

Such a study would, however, need to be comprehensive and run over a number of growing seasons to investigate year to year differences. This study would therefore be particularly well suited to a PhD student.

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