REPORT FOR HDC
DOUBLE NARCISSUS VARIETIES:
BUD NECROSIS PROBLEMS IN FORCED CROPS

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AUTHENTICATION

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

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DOUBLE NARCISSUS VARIETIES: BUD NECROSIS PROBLEMS IN FORCED CROPS

SUMMARY

Some double narcissus cultivars, such as Golden Ducat, have a tendency for the buds to die during forcing. Little is known of the factors causing this necrosis or blasting, although it has been linked with low humidity or high temperatures in the glasshouse. A series of experiments was undertaken with six double cultivars (including Golden Ducat) with a view to (a) describing the course of the disorder and (b) evaluating simple possible remedial treatments.

1. Over the main experiments, losses due to blasting in untreated (control) plants, averaged 98 per cent in Golden Ducat, 30 to 36 per cent in Ice King, Texas and Cheerfulness, 23 per cent in Dick Wilden, and only 15 per cent in Tahiti.

2. From the time plants were moved to the glasshouse until flowering, plant dissections showed that the growth patterns of the leaves, stem and spathe (flower sheath) were similar in the six double cultivars, and in cultivar Carlton included for comparison. In Golden Ducat, however, pedicel and flower growth failed after the first week, while the water content of leaves fell, possibly indicating a failure in water uptake.

3. From an experiment in which the spathe was punctured, removed or enveloped in a light-tight cover, it appeared that it affects development by shading the pedicel, preventing its goose-necking by interfering with the normal response to light.

4. Sprays of gibberellic acid (GA) over the developing bud reduced blasting slightly in Golden Ducat and more in Ice King and Dick Wilden. A spray of 6-benzylaminopurine reduced blasting to some extent in cv Texas. Treatments with GA by bud injection or topical application of auxin paste failed to reduce blasting.

5. A benomyl spray treatment reduced bud blasting in Ice King and Dick Wilden only.

6. Calcium nitrate drenches reduced bud blasting in Ice King and Dick Wilden only.

7. Treatment with the retardant ethephon did not reduce blasting.

8. In Cheerfulness, blasting increased markedly as glasshouse temperature was increased from 14 to 18°C, and blasting was least at 14°C in Dick Wilden, Golden Ducat and Tahiti. At 16°C, only in Cheerfulness and Texas was bud blasting increased by growing at an atypically low humidity.

9. In bulbs cool-stored for an additional period of 6 weeks at 1°C before forcing, flower losses were lower (except in cv Texas) than in the bulbs forced earlier. Losses were 90 per cent in Golden Ducat and 42 per cent in Texas, but only 2 to 5 per cent in the other four varieties. When grown at only 10°C, blasting was still 73 and 20 per cent in Golden Ducat and Texas, respectively. Calcium nitrate and GA treatments reduced losses slightly in cv Texas.

INTRODUCTION

Double narcissus varieties have considerable appeal because of the interesting combinations of colour and form which are available. At present there appears to be increasing interest in forcing these varieties. In The Netherlands, the area of field-grown double cultivars has about doubled in the last ten years, from 92 ha in 1980/81 to 189 ha in 1990/91 (PVS/BKD, 1991). A number of double varieties, however, have a propensity for floral disorders during forcing. The highly attractive cultivar Golden Ducat is especially prone to a bud necrosis which occurs late during forcing. This results in a dry, non-splitting spathe (flower sheath) containing the withered remains of the floral bud. The stem and dead bud resembles a drumstick. Other varieties, including singles, may exhibit similar disorders sporadically. While the condition has not been extensively studied, it has been linked with low humidity in the glasshouse, presumably resulting in desiccation of the spathe, which in turn could limit the growth of the floral parts within or perhaps restrict gaseous exchange. In American advisory literature the condition, described as a failure of the flower to proceed beyond the 'goose-neck' stage of development, and called 'bull-nosing', was related to high (above 18°C) glasshouse temperatures (De Hertogh, 1989).

Similar disorders, in field-grown crops, include 'bullhead' in variety Cheerfulness (Rees, 1972). This most usually affects single-flowered stems, the plants showing perianth segment doubling, corona dissection and poor ovary development, and the stems failing to elongate. Marked 'bullhead' plants produce affected plants the next season, so the condition may be viral or genetic in origin. Flower bud death is also well known in *N. poeticus* 'Flore Pleno', where it appears in field-grown crops to be most common on warmer slopes, and the condition is exacerbated by temperature extremes, hot, dry growing seasons and wet autumns (Rees, 1972). Although this suggests a connection with adverse water relations aggravated by a poor root system, treatments involving irrigation, mulching and shading did not prevent it (Tompsett, 1972).

The breeding and selection of double cultivars free of a tendency for bud necrosis is a very long-term solution to these problems. Using only those non-susceptible cultivars available at present would mean that other excellent features, of varieties like Golden Ducat, would be lost. The objectives of the present project were, therefore, to investigate possible causes of the disorder, and attempt simple possible remedial treatments.

In the case of forced varieties like Golden Ducat, widespread bud death in a crop which produced flowers normally in the field the previous season suggests that a viral or genetic cause is unlikely. Usually, glasshouse humidity and temperature can be sufficiently managed to maintain cool, adequately moist conditions, while water relations should be easily maintained at near optimum levels under good husbandry. A literature search failed to reveal any connection between diseases and these disorders in narcissus, although there is an unconfirmed report that the bullhead condition may be related to the presence of a mycoplasma. The crowded nature of double flowers could be expected to result in increased incidence of disease or water stress, due to humidity or other aspects of microclimate (Reynolds and Tampion, 1983).

The possible role of the spathe has already been referred to. In normal development, the spathe appears to have an important function in regulating growth and bending of the pedicel ('goose-necking'). The experimental removal of the spathe in narcissus resulted in earlier goose-necking and flower opening, before the normal amount of stem extension had taken place (Hanks and Rees, 1975). Responses such as goose-necking in narcissus, and pre- and post-anthesis hooking in *Fritillaria*, are controlled by auxin produced by the gynoecium (carpels) (Kaldewy, 1957; Hanks and Rees, 1975). The spathe may function, during stem extension, by blocking the photo-inactivation of auxin diffusing down the pedicel; only when the spathe dies, could auxin be destroyed preferentially on the lit side, giving the uneven growth which leads to bending of the pedicel. Replacing the excised spathe with a light-tight (aluminium foil or black polythene) cover only partly restored the anthesis-delaying effect of the spathe itself, however, so other factors must be involved (Hanks and Rees, 1975, 1977). Plants with punctured spathes behaved like intact ones, so the spathe presumably does not regulate the gaseous exchange of the floral parts within (Hanks and Rees, 1975). When the excised spathe was 'replaced' by a ring of lanolin paste containing auxin, the hormone application was without effect, suggesting that the spathe is not itself a source of auxin (Hanks and Rees, 1977).

The experiments described here were conducted with six double narcissus cultivars, a selection arrived at after discussion with HDC Bulbs and Outdoor Flower Panel members, and representing both susceptible and resilient varieties. In the first part of the work, the course of flower bud development was followed by means of dissections, and a further experiment on the role of the spathe was carried out, in an attempt to discover key stages at which 'things go wrong' in flower development. In the second part, possible remedial treatments were tested. These treatments involved several approaches:

1. that glasshouse temperature and humidity are related to flower losses, as suggested in the advisory literature (De Hertogh, 1989);

2. that using plant growth regulators could form the basis of a simple treatment; these might, for example, delay spathe or flower senescence (gibberellins or cytokinins) (Ballentyne, 1965; Choudhary and Verma, 1986), increase the sink-strength of the bud (gibberellins) (de Munk and Gijzenberg, 1977), or promote growth of the flower parts (auxins) (Hanks and Rees, 1975);

3. that the crowded bud of double flowers might conceivably produce a humid internal micro-climate encouraging disease or preventing transpiration; a broad-spectrum fungicide treatment was applied in relation to the first possibility, while (by analogy with disorders such as topple or blossom end rot) calcium was applied to correct possible deficiencies relating to impaired water movement (Battey, 1990). The growth retardant ethephon was also used as a treatment since it can reduce topple in other bulbous species (De Hertogh, 1989).

METHODS

Plant material

Bulbs of the following double cultivars were obtained from various commercial sources in August to September 1991 and used in all experiments: Cheerfulness, Dick Wilden, Golden Ducat, Ice King, Tahiti and Texas. For comparative purposes, bulbs of cultivar Carlton, taken from HRI-Kirton stocks, were used in experiments 1 and 2. Bulbs used were of grade 12-15 cm.

Bulbs were pre-cooled at 9°C from 24 September 1991. On 5 November 1991, bulbs were planted in 14 cm-diameter half-pots of unamended medium-grade sphagnum peat, five bulbs per pot, watered well, and returned to the 9°C store.

For experiments 1 to 5, bulbs were transferred to a glasshouse on 7 January 1992. Unless otherwise stated, a minimum maintained glasshouse temperature of 16°C, with ventilation at 18°C and typical humid conditions used for bulb forcing, with pots kept well watered, were used. In order to carry out a further experiment (experiment 6) later in the season, however, one batch of pots was held at 1°C from 7 January until 20 February 1992 before housing. Where a bulb produced more than one flower stem, only the dominant one was treated or recorded.

Experimental treatments

Experiment 1: the course of flower development For Carlton and each of the six double cultivars, ten bulbs (two pots) were dissected at housing and at one to two weekly intervals until the median flowering date for the cultivar. The following were recorded: exposed stem (scape) length (bulb top to base of bud), bud length, bud volume, stage of floral development, stem (scape) length (basal plate to base of bud), length of longest leaf, and the fresh and oven-dry weights of leaves, stem, spathe, pedicel and flower/flower bud.

Experiment 2: effects of the spathe For Carlton and the six double cultivars, four treatments were applied: (1) tip of spathe punctured; (2) spathe removed entirely; (3) spathe wrapped in aluminium foil to exclude light; and (4) control, spathe left intact. Treatments were applied as soon after housing as the floral buds were sufficiently accessible, ie on 13 January (Carlton, Dick Wilden and Ice King), 16 January (Texas), 20 January (Tahiti and Golden Ducat and 28 January (Cheerfulness). Foil covers were removed individually once flowers had begun to goose-neck. The following records were taken on individual stems: date flower fully open, and overall flower diameter and stem length (bulb tip to base of spathe) on that date; for cv Cheerfulness, records were taken on the first floret. Where buds failed to open, the length of the dead bud was noted.

Experiment 3: effect of growth regulators Using the six double cultivars, a range of treatments was applied once the floral bud was sufficiently accessible, ie on 14 January (Dick Wilden, Ice King), 16 January (Texas), 20 January (Golden Ducat, Tahiti) and 28 January (Cheerfulness). The following treatments were applied as sprays to run-off over the bud and surrounding area: gibberellic acid (GA) or 6-benzylaminopurine (BA), each at 10, 50 or 100 mg ai/litre, and benomyl at 2.75 g ai/litre (as Benlate Fungicide). The following were applied as 1 ml injections into the spathe: GA at 10, 50 or 100 mg ai/litre. Indol-3-ylacetic acid (IAA) was applied as a 0.1% ai lanolin paste around the base of the spathe. GA and BA were made up with 5 ml dimethyl sulphoxide and 0.5 ml non-ionic wetter/litre, benomyl with 0.5 ml non-ionic wetter/litre, and IAA with 5 ml dimethyl sulphoxide/100 g lanolin. Appropriate controls received applications (sprays, injections or paste) containing co-solvents or plain water only, and a further batch of controls was entirely untreated. The same records were kept as for experiment 2 (see above).

Experiment 4: effect of calcium and ethephon treatments Bulbs of the six double cultivars were either sprayed (to run-off) or received a substrate drench, once or three-times a week, with aqueous calcium nitrate. For the spray the concentration was 2.4 g/litre, and for the drench 12 g/litre, 0.5 ml/litre non-ionic wetter being added in each case. Drench and spray treatments were started on 8 January and continued for each cultivar until the end of flowering. A further set of pots was treated with ethephon (as 1 ml Ethrel C/litre, using 80 ml solution per pot) when shoot length averaged 10 cm (on 13 January). Control plants were untreated. The same records were kept as for experiment 2 (see above).

Experiment 5: effect of glasshouse temperature and humidity Pots of each of the six double cultivars were placed in glasshouses heated to 14, 16 or 18°C with typical high humidity, or 16°C with humidity kept low by restricting watering, all glasshouses being ventilated 2°C above the stated temperatures. The same records were kept as above.

Experiment 6: further trial of selected treatments Pots of each of the six double varieties, after further storage at 1°C, were housed at glasshouse temperatures of 10, 16 or 20°C (each ventilated 2°C above) with typical humidity. At 16°C only, in addition to 'untreated' plants, the following treatments were given three times weekly, following methods described above: calcium nitrate drench, GA spray (100 mg ai/litre), benomyl spray and water ('control') spray. The same records were kept as above.

Statistical design and analysis

All experiments were of a randomised block design, with three to six replicate blocks. Data were subjected as appropriate to the analysis of variance, cultivars being treated separately.

RESULTS AND DISCUSSION

Experiment 1: the course of flower development

The general progress of plant development from housing to flowering is illustrated by graphs of scape length (Fig. 1) and bud length (Fig. 2). In all seven varieties examined (including the single cultivar Carlton, studied for comparative purposes), a similar pattern of scape extension was seen, although, under the conditions of the experiment, Carlton flowered within 2 weeks of housing, flowering in Cheerfulness was relatively protracted, and the other five cultivars flowered about together. For the main group of double cultivars, little difference was seen between the scape length curves for susceptible varieties (Golden Ducat, Texas and Ice King) and those resistant to flower blasting (Dick Wilden and Tahiti). The pattern of bud growth (Fig. 2) for the main five double cultivars was similar, except that

Tahiti was relatively slow developing. Curves for Dick Wilden and Texas, varieties with very different proportions of flowers lost through blasting, were very similar.

Graphs showing the growth of individual components of the bud - spathe, pedicel and the flower itself - are shown in Figs. 3 to 5, respectively. Although spathe fresh weight peaks at different times and weights in the seven cultivars, there were no clearly distinguishable features between, say, cultivars Golden Ducat and Dick Wilden. Considering pedicel and flower fresh weights, it was seen that Cheerfulness and Tahiti were relatively late in developing, but the striking feature was that in Golden Ducat growth failed after the first glasshouse week. In Golden Ducat, the failure of the flower in particular to grow was reflected in the low ratio of flower dry weight : whole bud dry weight in this cultivar (Fig. 6). The propensity for a cultivar to lose a high percentage of buds did not appear to be related to bud density (weight/volume), a measure of the degree of doubling: Golden Ducat had an about average bud density for the varieties studied, similar to that of Tahiti which showed little bud necrosis.

Fresh weight : dry weight ratios were considered, and it was noticeable that the relatively large spathe of Golden Ducat showed a rapid loss of water in the third glasshouse week, in comparison with other varieties. Possibly of more significance, however, was the consideration of water content in other parts of the plant. Leaf fresh weight : dry weight ratio (Fig. 7) showed a marked fall in the second glasshouse week in Golden Ducat only. This may indicate a failure of water uptake to keep up with rapid glasshouse growth in this vigorous cultivar, and suggests that flower blasting in this variety may be related to water stress. Root growth appeared normal.

Experiment 2: effects of the spathe

The results are given in Table 1. In this experiment, among control (untreated) plants, all flowers blasted in Golden Ducat, percentage losses in the other double cultivars ranging from 11 to 55. In Carlton, a single cultivar included for comparative purposes, no bud blasting was observed.

Puncturing the spathe had little effect on the course of flower development, the sole instance of a significant effect being a slight shortening of stem length (measured at flowering) in cv Dick Wilden. In Golden Ducat, puncturing the spathe reduced bud blasting to 90 per cent, although statistically this effect just failed to achieve significance. In general, it seems there is little evidence for the spathe functioning by regulating gaseous exchange.

Spathe removal also had relatively little effect. In Tahiti, removal led to a reduction in the percentage of buds lost (from 23 to 7%), but there was no corresponding effect in other varieties. In Dick Wilden, spathe removal led to earlier flowering on shorter stems, reinforcing the idea that the loss or death of the spathe allows more light to reach the pedicel and promote goose-necking. There were corresponding suggestions of such effects on stem length at flowering in Carlton and Cheerfulness, but not in Ice King, Tahiti or Texas.

Covering the bud with light-tight foil had the most profound effect on flower development. Bud blasting was greatly increased by this treatment in cultivars Dick Wilden, Ice King, Tahiti and Texas, but not in Cheerfulness (in Golden Ducat blasting was 100% even in controls, while in Carlton no blasting was seen in any treatment). Bud covering also delayed flowering in Carlton, Dick Wilden and Texas (and not quite significantly in Cheerfulness), but these delays were not accompanied by significant increases in stem length by the date of flowering. These results reinforce the idea that the spathe acts by regulating the effects of light on pedicel growth, the supplementary foil covering markedly inhibiting goose-necking (and apparently slowing stem extension since stems were not taller when the flowers eventually opened). Effects of these treatments on flower diameter were generally small or non-significant.

In general, these results confirm a subtle role for the spathe in regulating flower development, but except in Tahiti, and possibly Golden Ducat, there was no evidence that the spathe exhibited an adverse effect on flower survival in double cultivars.

<u>Experiment 3: effect of growth regulators</u>

Table 2 summarises the results of this experiment. Among untreated control plants, all buds blasted in Golden Ducat and only 9 per cent in Tahiti. In Golden Ducat, the high-rate GA spray was the only treatment to reduce the incidence of blasting significantly, and then only to 88 per cent. In Tahiti, the amount of blasting in controls was too low to permit clear detection of beneficial effects, although several treatments increased blasting.

In the remaining four varieties, percentage blasting in controls varied from 21 (Cheerfulness) to 44 (Texas). Considering first GA and BA sprays, in Cheerfulness no beneficial effects were seen, and the results with spray controls suggested that the spray treatments themselves encouraged bud blasting. In the other three varieties, some GA and BA treatments reduced blasting by about half, although different treatments were effective in different cultivars. Dick Wilden responded well to GA sprays (the highest rate reducing percentage blasting from 30 to 3). Ice King and Texas showed some response to high concentration sprays of GA and BA, respectively.

Bud injection is a useful experimental tool for studying floral development, possibly serving to provide pointers to eventual practical treatments. Except in Dick Wilden, which appeared to respond differently to GA from other cultivars, control injections (plain water) increased bud blasting compared with non-injected controls. This tends to confirm the suggestion that an adverse internal environment in the bud encourages blasting. Auxin paste treatments did not have any useful effects, in some cases increasing bud losses, perhaps by interfering with normal gaseous exchange across the plant epidermis.

A benomyl spray treatment reduced bud blasting in two cultivars: in Ice King from 40 to 15 per cent, and in Dick Wilden from 30 to 4 per cent. There were no useful effects in other varieties. Typical shrivelled buds of various cultivars were examined for possible pathogens. *Penicillium* sp. and *Botrytis* sp. were isolated, but these were not thought to be primary pathogens, but rather typical of secondary infections of already damaged tissue.

Those treatments which decreased bud blasting in Dick Wilden, Ice King or Texas did not adversely affect flowering date, stem length or flower diameter (Table 2).

Experiment 4: effect of calcium and ethephon treatments

Table 3 shows the results of calcium and ethephon treatments. With Ice King, the most extreme calcium nitrate treatment (three drenches per week) reduced flower blasting from 19 to 6 per cent, but other calcium treatments were ineffective. In Dick Wilden, both drench treatments were similarly effective. In Golden Ducat, Cheerfulness, Tahiti and Texas, calcium treatments were either relatively ineffective or actually increased blasting. Treatments effective with Ice King and Dick Wilden did not have other adverse effects on flowering.

Ethephon treatments increased flower blasting in all varieties, but particularly in Cheerfulness, Ice King and Tahiti. It is known that different cultivars respond differently to this material, not all being suitable for dwarfing. In Dick Wilden and Texas, a good retarding effect was obtained.

Experiment 5: effect of glasshouse temperature and humidity

Table 4 shows that only in cv Cheerfulness was there a strong response of flower blasting to increased temperature, with only 13 per cent flowers being lost at a growing temperature of 14°C but 96 per cent at 18°C. Lowest blasting at 14°C was also seen in Dick Wilden, Golden Ducat and Tahiti (in Golden Ducat 90% of flowers blasted even at 14°C). The temperature optimum for flower survival may vary between cultivars, however, as Ice King showed minimum losses at 18°C and Texas at 16°C. Growing at 16°C, only Cheerfulness and Texas showed an increase in bud blasting when grown at atypically low humidity. As expected, flowering occurred faster, but on shorter stems, as glasshouse temperature increased. The effects of humidity (at 16°C) on flowering date and stem length were not consistent between cultivars, nor were effects of temperature and humidity on flower size.

Experiment 6: further trial of selected treatments

The results of testing the most promising treatments on a second forcing round of the six double cultivars are presented in Table 5. In untreated controls growing at 16°C, the percentage flower losses (except in Texas) were lower than those obtained in the earlier series of experiments. In experiment 6, control losses remained high in Golden Ducat (90%) and Texas (42%), but varied only between 2 and 5 per cent in the other varieties. Whether this improved performance was a result of later forcing, more extreme cold treatment, or other factors, cannot be determined.

Among untreated plants growing at 10, 16 and 20°C, the beneficial effect of lower glasshouse temperatures was confirmed. However, even with a glasshouse heated only to 10°C, 73 per cent of Golden Ducat and 20 per cent of Texas buds were lost.

Because of the overall lower bud blasting in this experiment, possible beneficial effects of chemical treatments were difficult to determine, except for Golden Ducat and Texas. The calcium nitrate, GA and benomyl treatments had no beneficial effect in Golden Ducat, although there was a suggestion of reduced blasting in Texas when calcium nitrate and GA were used.

Flowering date was delayed by growing at lower temperatures, but appeared unaffected by the chemical treatments. Tahiti produced longer stems at the lowest growing temperature, while other varieties showed no marked response to temperature. Chemical treatments were generally without significant effects on stem length at flowering, although calcium nitrate drench treatment reduced extension in Cheerfulness. Flower size showed little clear response to temperature or chemical treatments.

GENERAL DISCUSSION

Conditions such as bullhead, bull-nosing and bud necrosis in narcissus have been little studied, probably because they are of sporadic occurrence or only occur in specific cultivars. In the present project, various possible causes and potential cures were tested. It was thought unlikely at the outset that a comprehensive remedy would be found in the course of a single season's work on a possibly complex subject, but hoped that further guides for future investigations might be obtained: this was indeed the case.

It has been suggested earlier (see Introduction) that glasshouse and field conditions which lead to water stress (eg, high temperatures) may cause loss of buds in double varieties. Plant dissections carried out as part of the present study tend to support this view for Golden Ducat, a specially sensitive cultivar: in this case, a fall in relative water content was observed in the leaves at about the time flower growth was failing. As growing conditions in the glasshouse are easily maintained at apparently optimum levels during this time, it is difficult to see how practical improvements could be made to an extent likely to achieve a high flower yield. As the spathe appears important in regulating proper development of the flower and pedicel, flower losses may be exacerbated in Golden Ducat by the rapid water loss observed in the spathe during glasshouse forcing. In theory, a reduced leaf area might relieve the demands on water uptake, but ethephon treatment reduces leaf length less than scape length (Briggs, 1975), while using cold-storage temperatures lower than 9°C reduces the extension of both leaves and scapes (de Greef, 1986).

Single sprays of GA or benomyl, or calcium nitrate drenches, reduced bud blasting in Ice King and Dick Wilden. In the absence of more information on the nature of the disorder, it is not possible to suggest a basis for varietal sensitivity to these treatments, which were less effective in cv Texas and ineffective in Cheerfulness, although these cultivars had similar levels of flower losses in control plants. The mechanisms by which these potentially useful treatments work are not known, but the partial effectiveness of all three suggests a multifactorial nature to the disorder. The cytokinin BA was effective in reducing flower loss only in the earlier experiment with Texas.

High glasshouse temperatures (and to a lesser extent low glasshouse humidity) are clearly a factor which, in general, increased bud necrosis in double varieties. In Golden Ducat, however, control plants showed 73 per cent blasting even when grown at 10°C and late in the forcing season, so environmental control is unlikely to form the basis of useful control.

Flower losses were much reduced in the late-forced crop, suggesting that vulnerable double cultivars are best forced late in the season. As bulbs in this trial were held for an additional period of cold storage before being housed, it is possible that flower survival is influenced by duration of cold storage rather than late forcing *per se*. It would be useful to investigate these interactions of cold storage and forcing date more fully.

Ideally, these experiments should be repeated in a further season, for confirmation of results. The dose-responses curves of a range of cultivars to GA, calcium nitrate and benomyl should be examined more closely. The interaction of forcing date and glasshouse environment should be examined. It would be useful to determine whether bulbs of Golden Ducat can produce viable flowers under controlled environment conditions using hydroponic culture to eliminate imposed water stress. The disease factor should be examined more comprehensively, and bulbs which had produced blasting and viable flowers should be marked and grown-on separately to determine any persistent effect which might indicate a genetic or viral cause. It would be useful to investigate floral structure (including degree of doubling) in a range of cultivars in relation to susceptibility to flower losses.

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Fig. 1 Scape length (experiment 1)

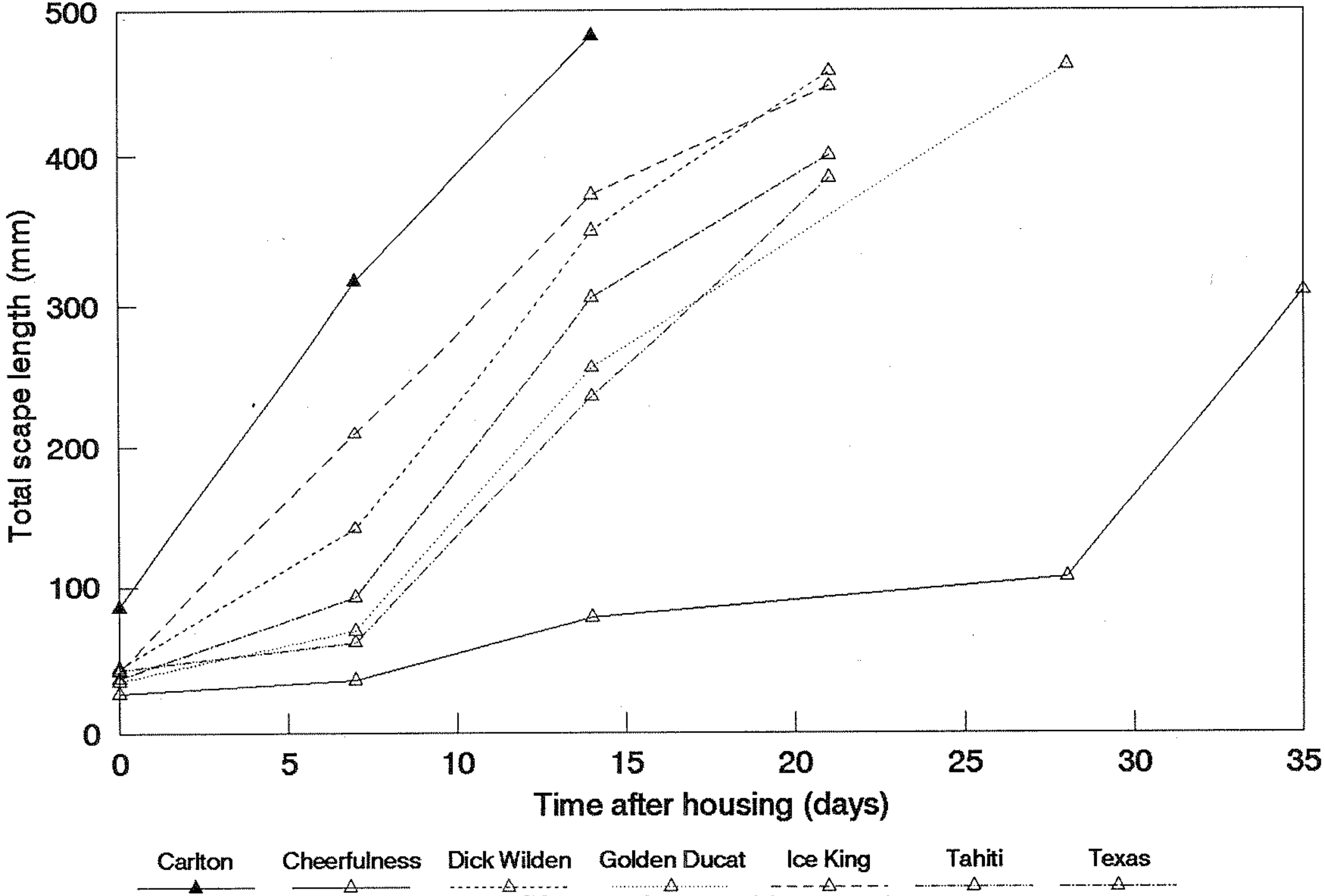

Fig. 2 Bud length (experiment 1)

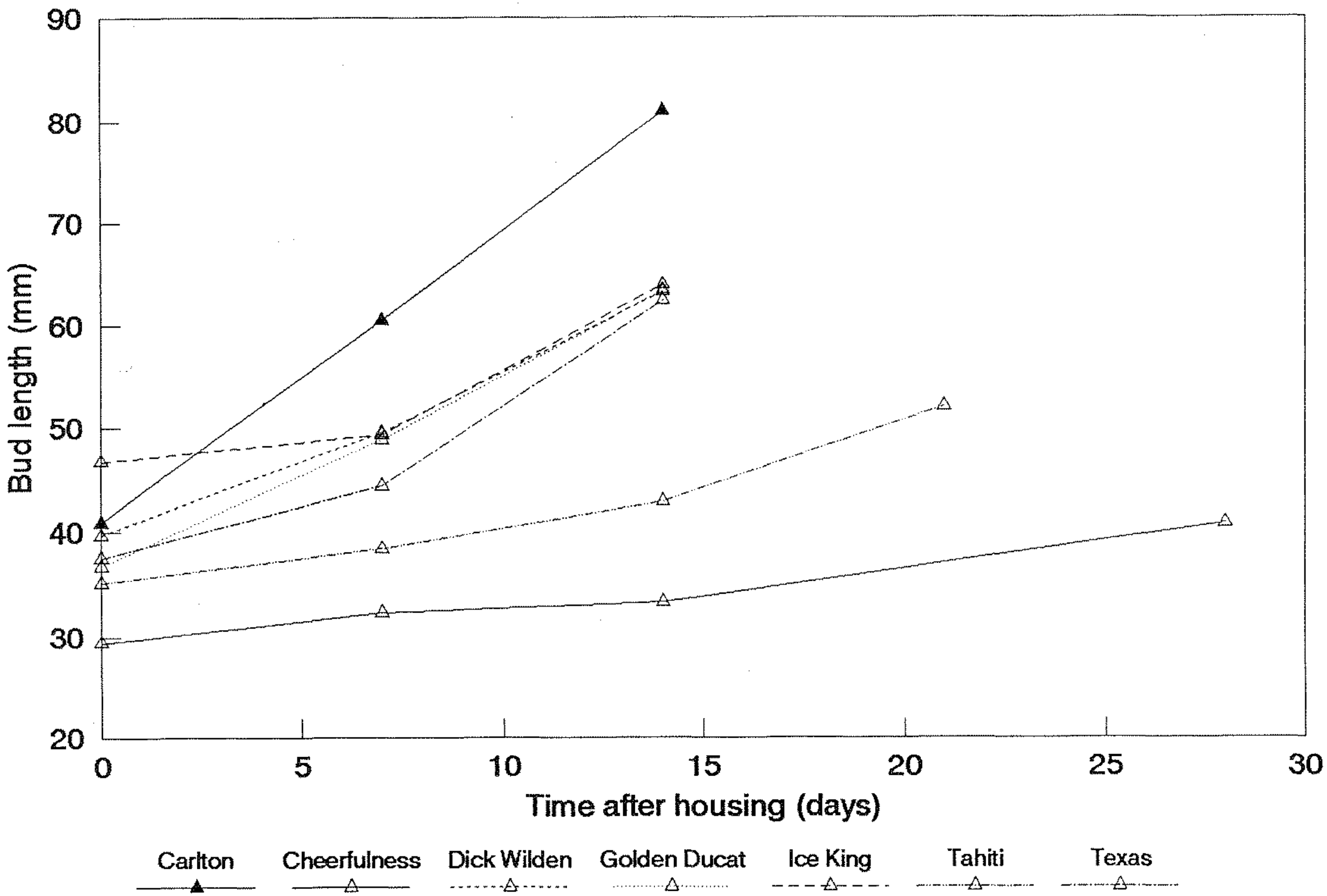

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Fig. 3 Spathe fresh weight (experiment 1)

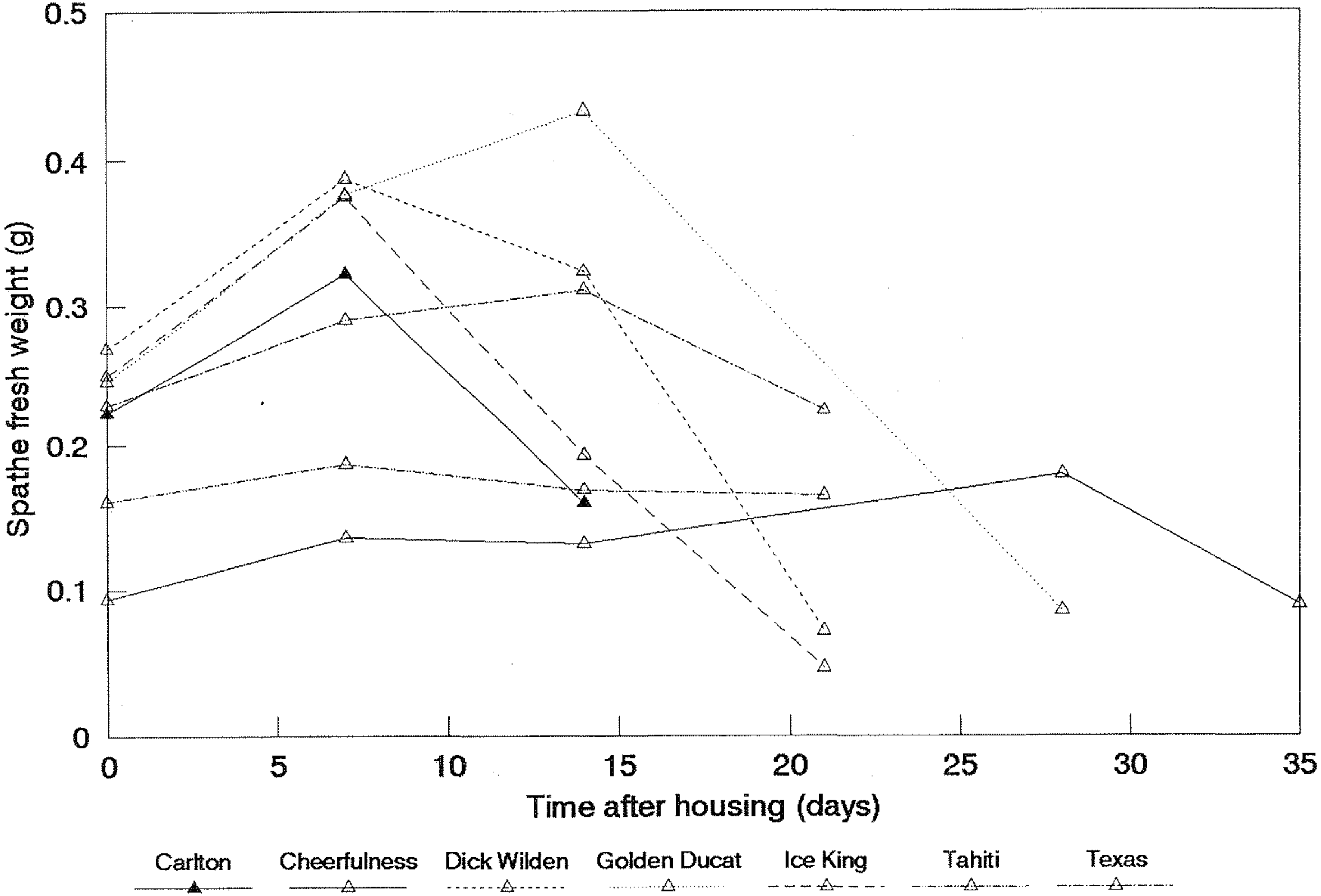

Fig. 4 Pedicel fresh weight (experiment 1)

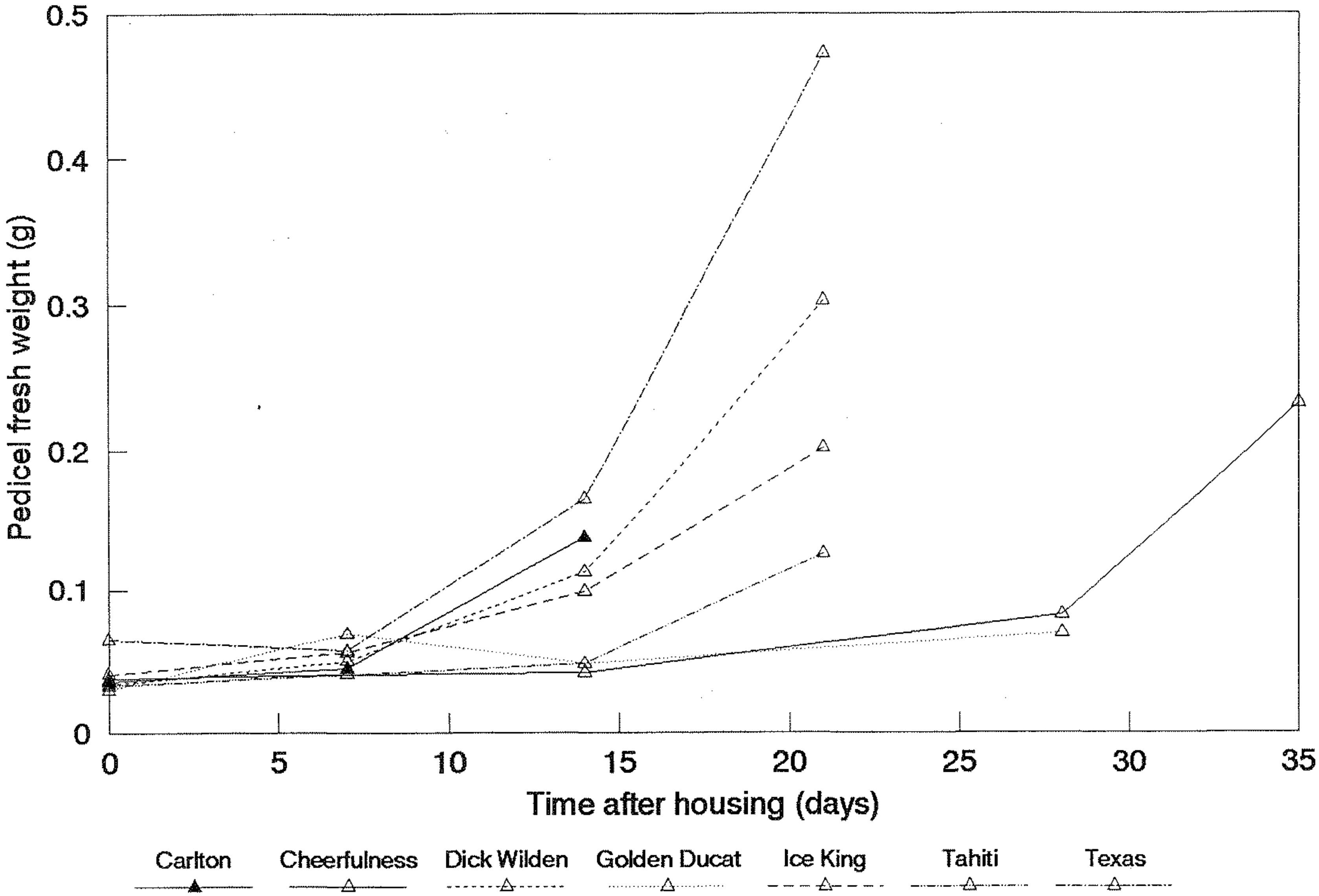

Fig. 5 Flower fresh weight (experiment 1)

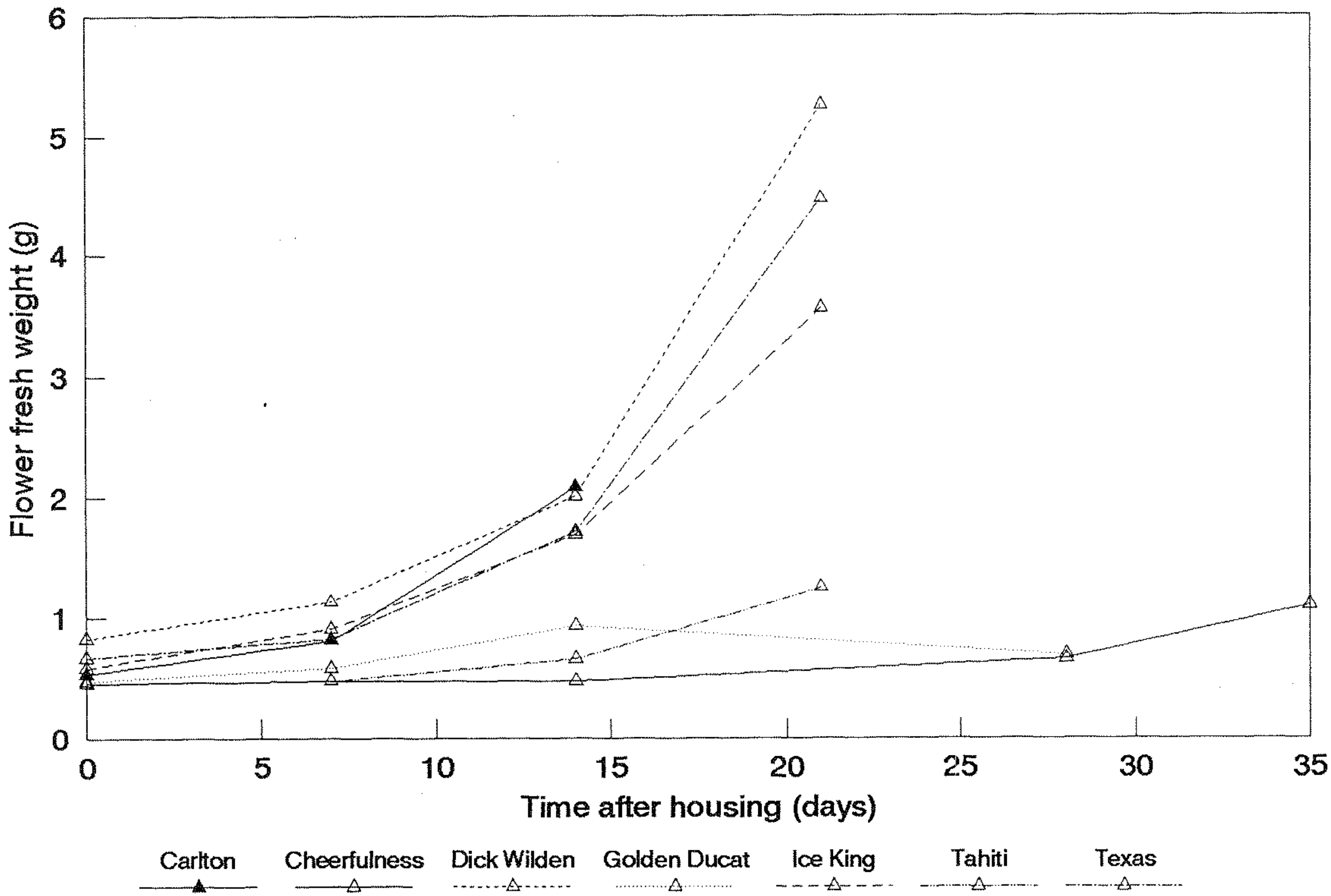

Fig. 6 Flower DW : bud DW ratio (experiment 1)

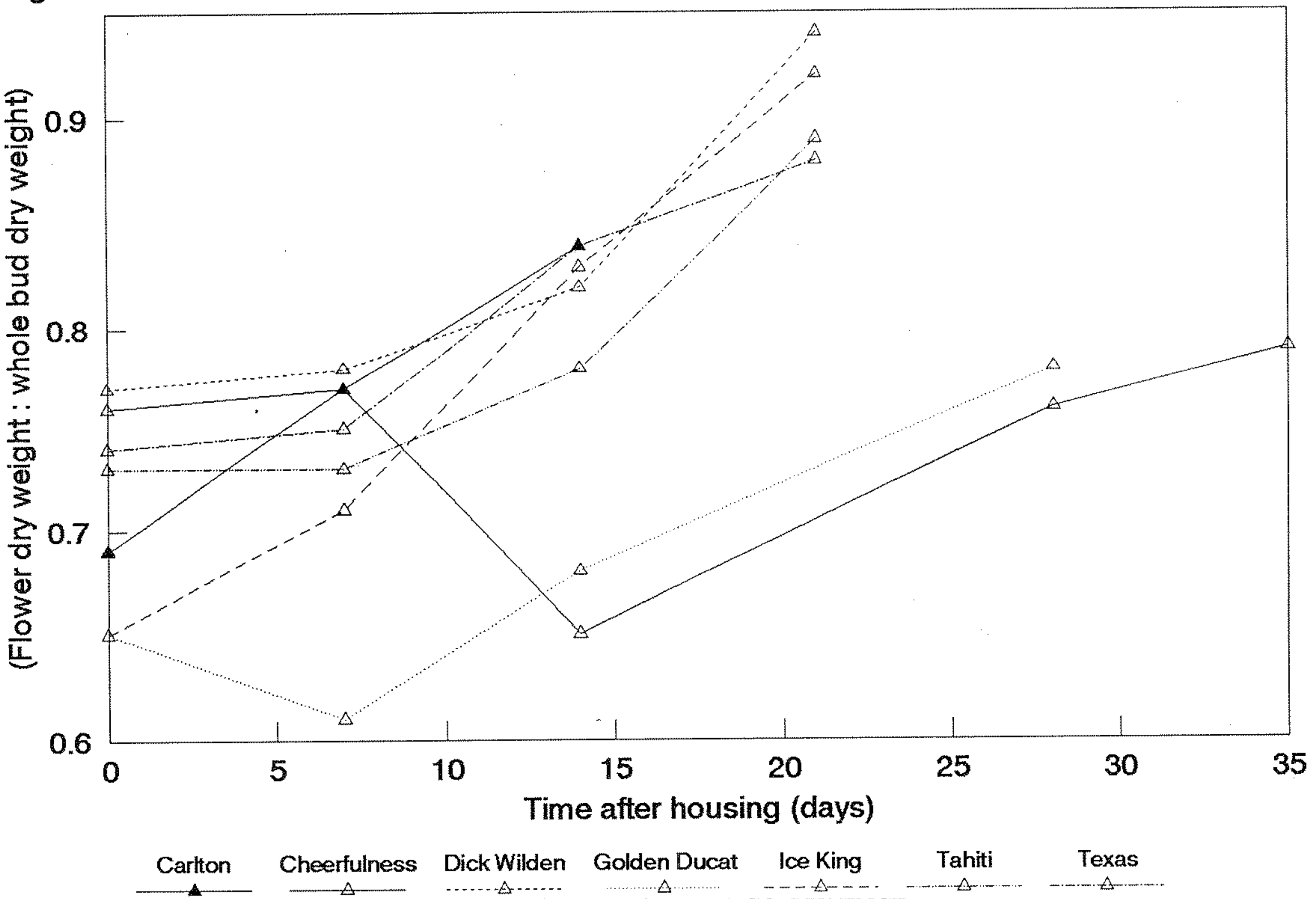

Fig. 7 Leaf FW : DW ratio (experiment 1)

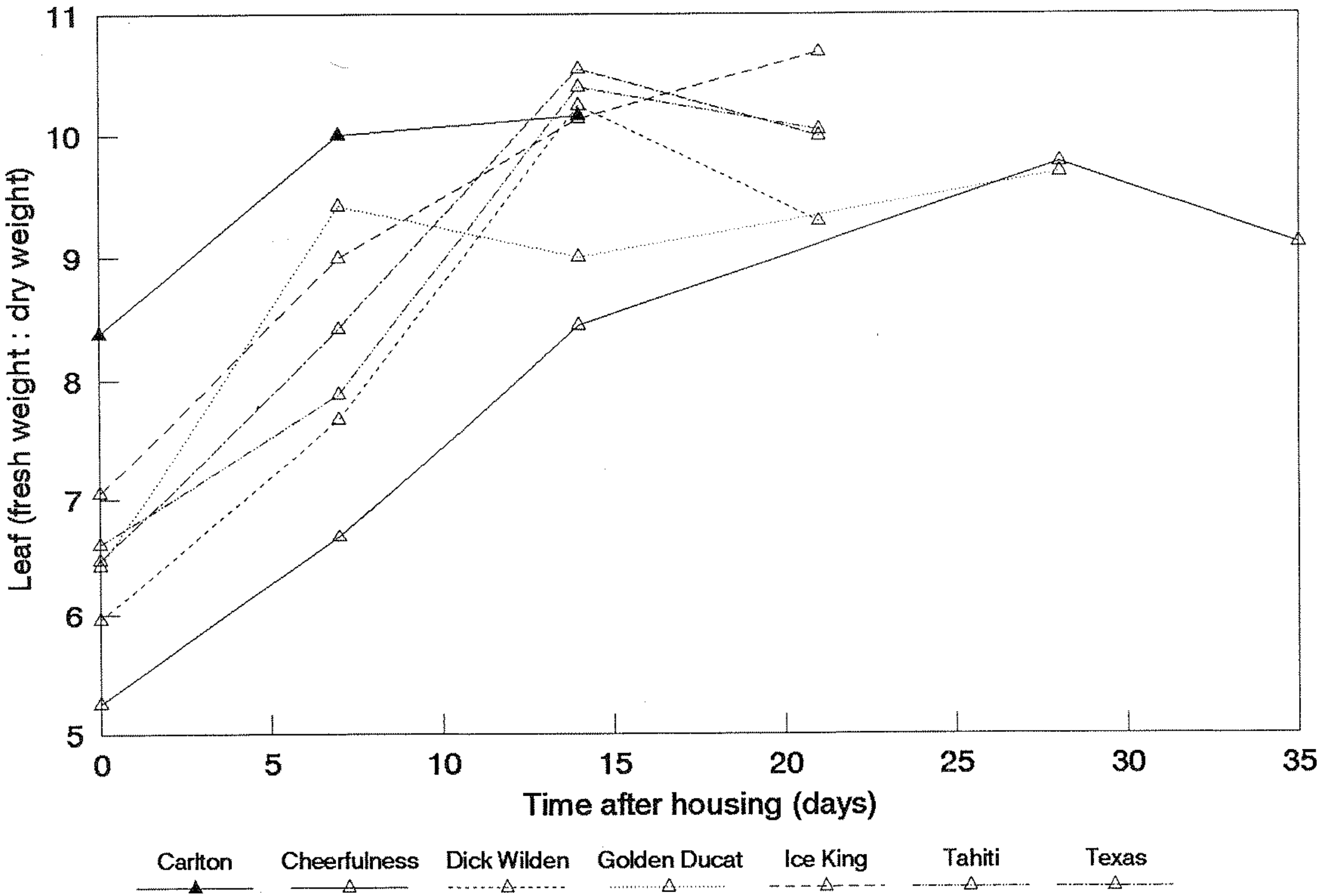

Table 1 Effect of spathe treatments on flower production in Carlton and six double cultivars

Treatment	Carlton	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
	% buds blasted						
Punctured	0	11	0	90	55	22	44
Removed	0	35	22	96	14	7	45
Covered	0	18	59	100	77	93	93
Control	0	22	11	100	30	23	55
SED (9 df)	-	9	16.4	4.6	19.9	na	11.7
Significance	-	NS	*	NS	*	***	**
	Flowering date (day no.)						
Punctured	23.0	38.5	31.5	-	26.3	35.5	30.3
Removed	22.5	37.0	28.0	-	25.8	34.0	29.0
Covered	27.8	40.5	34.0	-	24.9	37.0	35.9
Control	23.3	37.8	31.3	-	26.3	36.0	29.5
SED (9 df)	0.92	1.42	0.93		1.33	1.85	0.76
Significance	***	NS	***		NS	NS	***
	Stem length (cm)						
Punctured	45.2	31.1	37.8	-	39.9	39.7	32.5
Removed	42.8	25.5	39.1	-	37.6	39.4	29.9
Covered	46.4	33.8	47.0	-	42.8	43.3	30.9
Control	45.6	31.1	45.0	-	39.8	36.7	30.4
SED (9 df)	1.36	3.69	2.45		1.86	2.89	3.71
Significance	NS	NS	*		NS	NS	NS
	Flower diameter (cm)						
Punctured	9.2	4.5	9.4	-	8.9	7.9	8.9
Removed	9.0	4.1	9.0	-	8.6	7.7	8.1
Covered	8.5	4.4	9.5	-	9.4	8.0	9.6
Control	9.0	4.5	9.6	-	9.1	7.6	8.8
SED (9 df)	0.23	0.16	0.40		0.18	0.31	0.32
Significance	NS	NS	NS		*	NS	*

na, SED for non-transformed data not applicable

Table 2 Effect of growth regulator treatments on flowering in six double cultivars (a) buds blasted

Treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
Untreated	21	30	100	40	9	44
Spray treatments						
GA (10)	29	18	95	43	8	32
GA (50)	37	12	100	39	15	40
GA (100)	32	3	88	22	25	43
BA (10)	36	20	100	50	7	34
BA (50)	25	25	100	26	14	43
BA (100)	20	20	100	33	17	28
Benomyl	44	4	92	15	5	53
Water control	17	23	100	28	8	32
Water & solvents control	32	8	96	47	8	44
Bud injection treatments						
GA (10)	20	12	100	47	27	93
GA (50)	41	35	93	43	4	76
GA (100)	31	33	100	67	19	61
Water control	88	16	100	38	23	77
Water & solvents control	43	35	97	57	47	64
Topical applications, base of bud						
IAA paste	45	19	100	40	7	50
Plain lanolin control	56	34	100	27	30	38
SED (32 df)	17.1	14.5	4.3	17.9	13.0	13.9
Significance	*	NS	NS	NS	NS	**

Table 2 cont. (b) Flowering date (day no.)

Treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
Untreated	38.0	29.7	-	25.3	37.0	29.7
Spray treatments						
GA (10)	39.0	30.0	-	27.7	35.7	30.0
GA (50)	41.3	29.7	-	26.0	38.3	29.7
GA (100)	43.0	29.7	-	27.3	35.3	29.3
BA (10)	45.7	29.3	-	26.7	36.3	29.0
BA (50)	37.7	29.0	-	25.3	38.0	29.3
BA (100)	40.3	29.7	-	26.7	36.7	28.7
Benomyl	36.3	29.0	-	26.3	37.3	30.3
Water control	40.3	28.7	-	25.2	36.3	30.3
Water & solvents control	37.3	29.7	-	25.7	34.3	31.3
Bud injection treatments						
GA (10)	36.7	29.7	-	28.4	36.7	30.1
GA (50)	39.0	28.7	-	26.3	34.0	31.0
GA (100)	37.0	32.0	-	29.7	35.7	31.7
Water control	34.2	29.7	-	26.7	35.7	30.3
Water & solvents control	36.7	30.0	-	28.0	35.0	31.7
Topical applications, base of bud						
IAA paste	44.0	30.3	-	27.0	35.3	32.0
Plain lanolin control	42.7	30.0	-	27.7	37.3	29.7
SED (32 df)	4.62	1.04		1.15	1.83	1.46
Significance	NS	NS		*	NS	NS

Table 2 cont. (c) Stem length (cm)

Treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
Untreated	29.7	41.0	-	38.9	36.5	34.8
Spray treatments						
GA (10)	31.2	40.6	-	39.7	39.8	35.5
GA (50)	32.2	41.3	-	40.4	37.3	34.0
GA (100)	30.9	42.1	-	41.9	36.0	35.4
BA (10)	33.1	41.8	-	42.0	37.0	36.7
BA (50)	32.7	41.2	-	39.5	39.3	34.8
BA (100)	33.8	39.9	-	41.3	40.4	36.1
Benomyl	33.3	40.3	-	40.9	38.5	35.1
Water control	31.7	42.0	-	39.6	38.8	34.2
Water & solvents control	33.8	41.3	-	38.9	40.3	35.0
Bud injection treatments						
GA (10)	35.3	40.7	-	38.5	41.3	36.5
GA (50)	30.5	41.9	-	42.3	40.3	31.6
GA (100)	34.6	38.6	-	36.2	39.2	31.8
Water control	35.9	40.2	-	42.1	35.7	32.2
Water & solvents control	33.1	41.8	-	39.8	37.6	33.2
Topical applications, base of bud						
IAA paste	27.4	40.2	-	43.4	38.3	30.9
Plain lanolin control	28.6	41.4	-	39.7	34.6	34.2
SED (32 df)	2.43	1.67		2.17	1.95	3.05
Significance	NS	NS		NS	*	NS

Table 2 cont. (d) Flower diameter (cm)

Treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
Untreated	4.4	9.3	-	8.3	7.6	9.0
Spray treatments						
GA (10)	4.7	9.4	-	9.2	7.8	8.6
GA (50)	4.3	9.4	-	8.7	7.6	8.6
GA (100)	4.6	9.5	-	8.9	7.6	9.0
BA (10)	4.3	9.3	-	8.6	7.7	8.7
BA (50)	4.5	9.4	-	9.0	8.1	8.6
BA (100)	4.4	9.8	-	9.2	8.1	8.8
Benomyl	4.7	9.0	-	8.9	7.7	9.0
Water control	4.5	9.4	-	8.6	7.6	8.8
Water & solvents control	4.3	9.5	-	9.0	7.8	8.9
Bud injection treatments						
GA (10)	4.2	9.6	-	8.5	7.9	8.7
GA (50)	4.4	9.1	-	8.7	7.9	8.6
GA (100)	4.1	9.5	-	9.2	8.1	8.6
Water control	4.5	9.3	-	9.0	7.6	8.8
Water & solvents control	3.8	9.0	-	8.6	7.3	8.8
Topical applications, base of bud						
IAA paste	4.7	9.7	-	9.2	7.7	8.7
Plain lanolin control	4.6	9.5	-	8.9	7.9	8.7
SED (32 df)	0.23	0.24		0.28	0.24	0.35
Significance	*	NS		NS	NS	NS

Table 3 Effect of calcium drench or spray and ethephon treatments on flowering in six double cultivars

Treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
	% buds blasted					
Control	25	21	94	19	9	16
Drench (3/week)	19	7	100	6	3	47
Drench (1/week)	18	6	94	31	17	45
Spray (3/week)	37	13	97	42	12	41
Spray (1/week)	29	18	100	33	9	33
Ethephon	100+	35	100	54	100+	34
SED (12 df)	17.8	-	-	-	8.9	-
(15 df)	-	10.1	3.1	12.7	-	10.7
Significance	NS	NS	NS	*	NS	*
	Flowering date (day no.)					
Control	38.8	28.5	-	25.8	35.0	28.8
Drench (3/week)	36.0	27.8	-	27.5	37.3	31.0
Drench (1/week)	35.3	28.5	-	25.8	36.0	29.3
Spray (3/week)	38.5	28.8	-	27.0	35.8	31.5
Spray (1/week)	36.0	29.0	-	26.5	37.0	30.5
Ethephon	-	29.8	-	25.5	-	29.5
SED (12 df)	2.83	-	-	-	1.09	-
(15 df)	-	0.80	-	1.34	-	1.05
Significance	NS	NS	-	NS	NS	NS

+ Data for these treatments excluded from statistical analyses presented below

Table 3 cont.

Treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
	Stem length (cm)					
Control	33.1	44.2	-	40.8	39.9	34.3
Drench (3/week)	31.8	37.7	-	40.3	38.0	31.6
Drench (1/week)	33.2	42.1	-	39.9	38.2	35.0
Spray (3/week)	31.7	40.5	-	41.5	39.3	33.0
Spray (1/week)	34.3	41.5	-	39.4	38.1	33.5
Ethephon	-	31.1	-	24.8	-	23.1
SED (12 df)	2.78	-	-	-	2.09	-
(15 df)	-	1.19	-	1.42	-	1.24
Significance	NS	***	-	***	NS	***
	Flower diameter (cm)					
Control	4.5	9.7	-	8.7	7.8	8.8
Drench (3/week)	4.4	9.0	-	8.5	7.4	8.5
Drench (1/week)	4.1	9.4	-	8.5	8.4	8.8
Spray (3/week)	4.4	9.4	-	9.1	7.8	8.8
Spray (1/week)	4.4	9.4	-	8.9	7.8	9.0
Ethephon	-	10.1	-	9.2	-	9.2
SED (12 df)	0.14	-	-	-	0.30	-
(15 df)	-	0.18	-	0.25	-	0.24
Significance	NS	***	-	NS	NS	NS

Table 4 Effect of glasshouse conditions on flower production in six double cultivars

Glasshouse temperature (°C)/ humidity	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
	% buds blasted					
14/ambient	13	11	90	52	17	49
16/ambient	50	29	96	54	20	20
16/low	86	24	100	48	28	43
18/ambient	96	30	100	35	29	40
SED (9 df)	na	11.2	4.6	8.9	10.1	10.2
Significance	**	NS	NS	NS	NS	NS
	Flowering date (day no.)					
14/ambient	48.0	33.8	-	29.5	43.0	35.5
16/ambient	51.7	30.5	-	28.5	38.3	30.8
16/low	69.9	27.8	-	24.0	35.0	27.5
18/ambient	33.9	25.8	-	21.3	29.3	26.5
SED (9 df)	3.25	0.45		0.96	1.40	0.73
Significance	**	***		***	***	***
	Stem length (cm)					
14/ambient	34.9	41.1	-	40.8	38.9	35.5
16/ambient	31.4	39.0	-	40.9	35.0	33.6
16/low	23.2	41.4	-	36.5	35.9	33.2
18/ambient	24.4	38.9	-	36.3	36.2	35.9
SED (9 df)	1.51	1.55		1.26	3.27	0.98
Significance	**	NS		**	NS	NS
	Flower diameter (cm)					
14/ambient	4.4	9.7	-	9.1	7.7	8.9
16/ambient	4.4	9.7	-	9.2	7.9	9.1
16/low	5.0	9.8	-	8.5	8.0	9.0
18/ambient	5.2	9.8	-	8.7	8.1	9.3
SED (9 df)	0.21	0.22		0.22	0.19	0.16
Significance	*	NS		*	NS	NS

na, SED for non-transformed data not applicable

Table 5 Effect of selected treatments on flower production in six double cultivars

Glasshouse temperature (°C)/ treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
	% buds blasted					
10/control	10	0	73	6	0	20
20/control	15	4	97	2	6	42
16/control	5	2	90	3	2	42
16/calcium	0	2	93	2	0	29
16/GA	10	0	98	4	3	24
16/benomyl	16	1	91	5	2	32
16/water	13	0	90	3	0	27
SED (30 df)	7.9	2.5	5.9	5.1	3.0	10.7
Significance	NS	NS	**	NS	NS	NS
	Flowering date (day no.)					
10/control	74.5	69.2	-	67.0	74.8	73.2
20/control	64.0	61.7	-	59.8	64.7	63.5
16/control	66.8	64.5	-	62.2	68.5	67.0
16/calcium	68.3	64.3	-	62.3	68.0	67.0
16/GA	67.7	64.2	-	63.3	68.7	67.2
16/benomyl	68.7	64.3	-	62.3	68.8	67.5
16/water	68.5	64.2	-	62.5	67.7	67.2
SED (30 df)	0.58	0.46		0.44	0.63	0.74
Significance	***	***		***	***	***

Table 5 cont.

Glasshouse temperature (°C)/ treatment	Cheerfulness	Dick Wilden	Golden Ducat	Ice King	Tahiti	Texas
	Stem length (cm)					
10/control	34.2	34.4	-	36.2	39.4	31.5
20/control	36.0	35.4	-	36.2	31.9	33.6
16/control	35.6	35.9	-	37.3	34.7	33.3
16/calcium	31.5	33.8	-	36.3	34.0	31.2
16/GA	36.2	35.6	-	37.4	36.8	33.4
16/benomyl	34.3	35.1	-	36.8	35.7	32.7
16/water	34.8	36.4	-	35.9	36.8	31.3
SED (30 df)	1.21	0.93		1.06	0.98	1.49
Significance	**	NS		NS	***	NS
	Flower diameter (cm)					
10/control	4.6	9.5	-	9.3	8.1	9.0
20/control	4.5	9.4	-	9.3	8.1	9.0
16/control	4.6	9.3	-	9.4	7.9	8.9
16/calcium	4.4	9.2	-	8.8	7.7	8.6
16/GA	4.5	9.6	-	9.5	8.2	8.8
16/benomyl	4.6	9.6	-	9.5	8.2	8.8
16/water	4.6	9.7	-	9.3	8.1	8.7
SED (30 df)	0.10	0.18		0.15	0.15	0.18
Significance	NS	NS		***	*	NS

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