Therefore there was a tendency for the plants to overcome the restriction of root system with time. By the final sampling date snapdragons had overcome the effect of root restriction caused by clay and Alumipots during the early stages, but three months of field growing was necessary to overcome the restrictive effects.

Students handling the plants in the various containers stated that plant bands and Alumipots were the most difficult to handle. It was difficult to prevent the soil from falling through the bottom of the bands and, to prevent this, considerable care and time was necessary. It was very difficult to knock plants from the Alumipots without seriously disrupting and knocking the soil from around the root system. At the end of three-week period in the greenhouse the organic pots were slightly spongy and broke along the top edges if not handled carefully, however, all students reported that they were still the easiest to work with and took less time in handling than other containers.

Summary

Three 3x4 factorial experiments were established to test the effects of clay, organic and aluminum pots and plant bands and three watering frequencies (daily, every 2 days and 4 days) on the growth of snapdragons, *Antirrhinum majus*, var. 'Navajo', and calendulas, *Calendula officinalis* var. 'Lemon Queen' and *Petunia hybrida*, var. 'White Velvet', from seedling stage to maturity. These plants were placed in randomize block design and replicated four times with 10 plants to the experimental unit. Three and one-half weeks after treatments began seedlings were removed from greenhouse, knocked out of Alumipots and clay pots and planted with the containers.

Generally frequencies of watering had no effect on the longitudinal growth of seedlings nor on the fresh or dry weight of the plants after they were removed to the field.

There was normally little variation between the plants grown in organic pots and asphalt plant bands as far as any of the growth measurements were concerned. However, plants in these two containers were generally taller in the seedling stage and had higher fresh and dry weights in later stages of growth than did plants growing in clay or Alumipots. In most instances plants in Alumipots were shorter and produced less fresh and dry weights than those growing in any of the other containers tested.

The organic pots and plant bands cost less than the other two containers and the organic pots could generally be handled more efficiently than the other containers.

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CONTROL OF GEOTROPIC BENDING IN SNAPDRAGON AND GLADIOLUS INFLORESCENCES

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Snapdragon and gladiolus flowers are some of the more difficult crops to ship because of their great sensitivity to gravity. These crops, if they are not shipped upright, usually have the upper portion of the spike bent and are thus unsaleable. Laboratory treatments confirm commercial experience in shipping problems by showing that after a few hours geotropic bends become fixed through hardening of the stem tissue.

Snapdragons are generally grown in greenhouses near metropolitan areas since they cannot be shipped great distances in a horizontal position and the crop is not of high enough value to afford special upright shipment. Yet this crop could be readily grown in the field in Florida during the winter months and sent to Northern markets if shipping were feasible. Thus the possibility of snapdragons becoming an important cut flower crop in Florida depends largely on development of an inexpensive method of shipping spikes so that they do not bend in transit.

Gladiolus, a relatively high value crop, are shipped in special containers in which the blooms are held upright. If geotropic bending during horizontal shipment could be eliminated gladiolus could be shipped with other commodities rather than in special trucks as is done at present. Gladiolus are already an important cut flower crop. Any saving in shipping costs would increase the income to Florida growers.

Although our primary objective has been the control of geotropic bending during shipment of snapdragon and gladiolus inflorescences, any permanently successful treatment would accrue benefits to the ultimate consumer as well, since the latter would enjoy greater freedom in flower arrangements if geotropic bending were eliminated.

Previous work by Teas and Sheehan (1) showed that geotropic bending of snapdragons could be completely controlled in the laboratory by allowing the cut flower stems to take up water containing N-l-naphthylphthalamate (NP). However, practical methods of shipping blooms horizontal were not developed. Commercial shipments from Chicago to Florida that had been NP treated were only about 40% marketable because of bent stems. However, only 1% of the untreated controls in the same shipments were marketable. Thus, further studies were required to determine the cause of the disparity between laboratory experiments and commercial shipments.

Experiments

Snapdragons

Varietal response – Any treatment for inhibiting geotropic bending of snapdragon flowers should be applicable to many or all commercial varieties. Time-bending response curves and NP response tests were carried out for the following representative single-flowered varieties: Pink Ice, Lavender Lady, Jackpot, Patricia, Navajo, Golden Spike, Citation and Barbara. In these laboratory tests no significant differences were found between varieties. In all eight varieties NP effectively controlled bending. Single-flowered snapdragons are by far the most commonly grown; however, there are some double-flowered varieties grown.

Double- vs. Single-flowered Types—Growers have reported that double-flowered varieties seem to respond to gravity more slowly than single-flowered varieties. The bend angles of eight spikes each of double and single-flowered varieties were measured at half hour intervals for 9 hours and again at 18 hours. The results of this experiment are shown in Figure 1. This Figure demonstrates that there is almost no difference in response between the two types. We suggest that the reputed lesser geotropic sensitivity of doubles compared with singles may derive from an effective camouflage of stem bending in doubles by the greater mass of florets. Also illustrated in Figure 1 is the delay of about 30 minutes after "presentation" before measurable bending occurs. This finding confirms published data (1). Also evident in Figure 1 is the phenomenon of "over-bending", i.e. bending past 90 degrees, and the subsequent slow return toward 90 degrees.

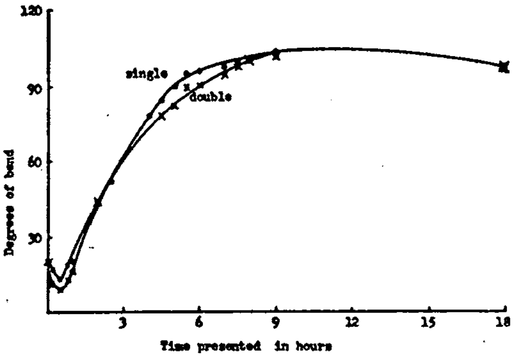

Figure 1 Comparison of the geotropic response of single and double flowered snapdragon inflorescence stems.

Floret opening – A treatment for inhibiting geotropic bending would be of reduced value if it damaged the blooms or inhibited the further opening of florets. A test was carried out to determine whether the florets of NP treated spikes would continue to open normally. Nine spikes were used per treatment and each treatment was replicated three times. The results are summarized in Table 1.

Table 1 Number of Buds that Opened Within 72 hrs. after Treatment

Variety	NP treated*	Control	Gain or loss over control
Pink Ice	4.44	3.52	+.92
Lavender Lady	5.04	4.81	+.23
Golden Spike	7.74	6.81	+.93
Cherokee Scarlet	4.59	3.89	+.70
Navajo	7.37	6.41	+.96
Citation	3.77	4.88	-1.11
Barbara	4.11	3.77	+.34

* NP was used at 1×10^{-4}M

There was less than one floret difference in six of the seven varieties shown in Table 1, actually in favor of the NP treatment. Citation had only 1.1 fewer florets opened on the NP treated spikes than on the controls. It is doubtful whether these small differences in the number of florets would be noticed either by the florists or the ultimate consumers.

Effect of pH on geotropic response – The standard pH 4.6 potassium phosphate at 0.05M was found to be more favorable for rapid geotropic response than distilled water (1). The possibility that pH of the experimental solutions might have an important influence on geotropic response was systematically tested. Spikes of double-flowered snapdragons were dipped into solutions of buffers ranging from pH 2 to pH 9 in increments of 0.5 pH units and their subsequent response to gravity measured. In another experiment, stems of single-flowered snapdragons were dipped into solutions of pH 4, 5 and 6. The results of these experiments indicated that there was no appreciable difference in response to gravity as a result of the pH of the solutions.

The role of flower wilting in geotropic bending control – It was considered possible that wilting of the spikes before NP treatment and subsequent chemical-induced fixation of the resulting bend might account for the reported incomplete control of bending in commercial shipments of flowers (1). Inflorescences of double flowered snapdragons were treated to induce wilting, as follows:

(1) Dried vertical for 5 hours then stems into 1 x $10^{-4}M$ NP for 2 hours (wilted NP).

(2) Dried vertical for 5 hours then stems into buffer for 2 hours (wilted control).

(3) Stems placed immediately into buffer (vertical) for 5 hours, then stem dipped into 1 x 10^{-4}M NP for 2 hours (non-wilted NP control).

(4) Stems placed immediately into buffer (vertical) for 7 hours (non-wilted control).

Eight stems were included in each group. After the above treatments the stems were presented horizontally and bending response measured on shadowgrams. The results of these treatments are shown in Table 2.

This experiment shows that NP inhibited the geotropic response even in spikes which had been previously wilted, but did not fix wilt-induced bends. Thus, the incomplete control of bending reported for NP-treated commercial shipments must have been caused by some factor other than wilting.

Table 2 Response of turgid and wilted snapdragon inflorescence spikes to NP

Treatment	Bending in degrees		
	at 5 hrs.	at 7 hrs.	at 18 hrs.
1	34	15	15
2	25	-5	101
3	4	-6	20
4	10	5	92

The role of NP-fixed geotropic bends in commercial shipments – The finding that wilting was not the cause of shipping failures led to testing the possibility that NP was fixing bends that had been initiated or developed by prior horizontal presentation of the spikes. For this test two levels of NP were used with four spikes per unit and each treatment replicated twice. Spikes of Maryland Pink and Chevaus Pink were presented for four hours and the stems then dipped into NP or control solutions. Controls were held vertical and left dry for four hours so as to be comparable to the horizontal spikes. The stems were then dipped into NP or control solutions and held vertical. After 18 hours the horizontal controls had straightened, whereas the NP treated horizontal spikes were bent. The spikes that remained vertical for 4 hours before NP treatment showed no sign of bend whether they were treated or not, which excludes the possibility that some aspect of NP action itself causes the bending. Another experiment using ½ hour periods of horizontal presentation gave qualitatively similar results. These tests indicate that once there is a bend due to presentation NP can fix this bend and make the spike unresponsive to further (vertical) presentation. Furthermore, experiments have shown that snapdragon spikes, although they do not bend visibly for 20-30 min. after presentation, respond to presentation times as short as 5 min. and, once bending has started, continue to bend for about one hour although in the vertical position.

Commercial handling practices can now be related to the partial failure (60%) of commercial shipments previously reported (1). It is standard practice in cutting snapdragon inflorescences to lay the spikes horizontally until they are picked up. Furthermore they are horizontal on tables during grading. Thus there is likely to be sufficient geotropic presentation of blooms to cause bending, even though the bend may not be evidenced for an

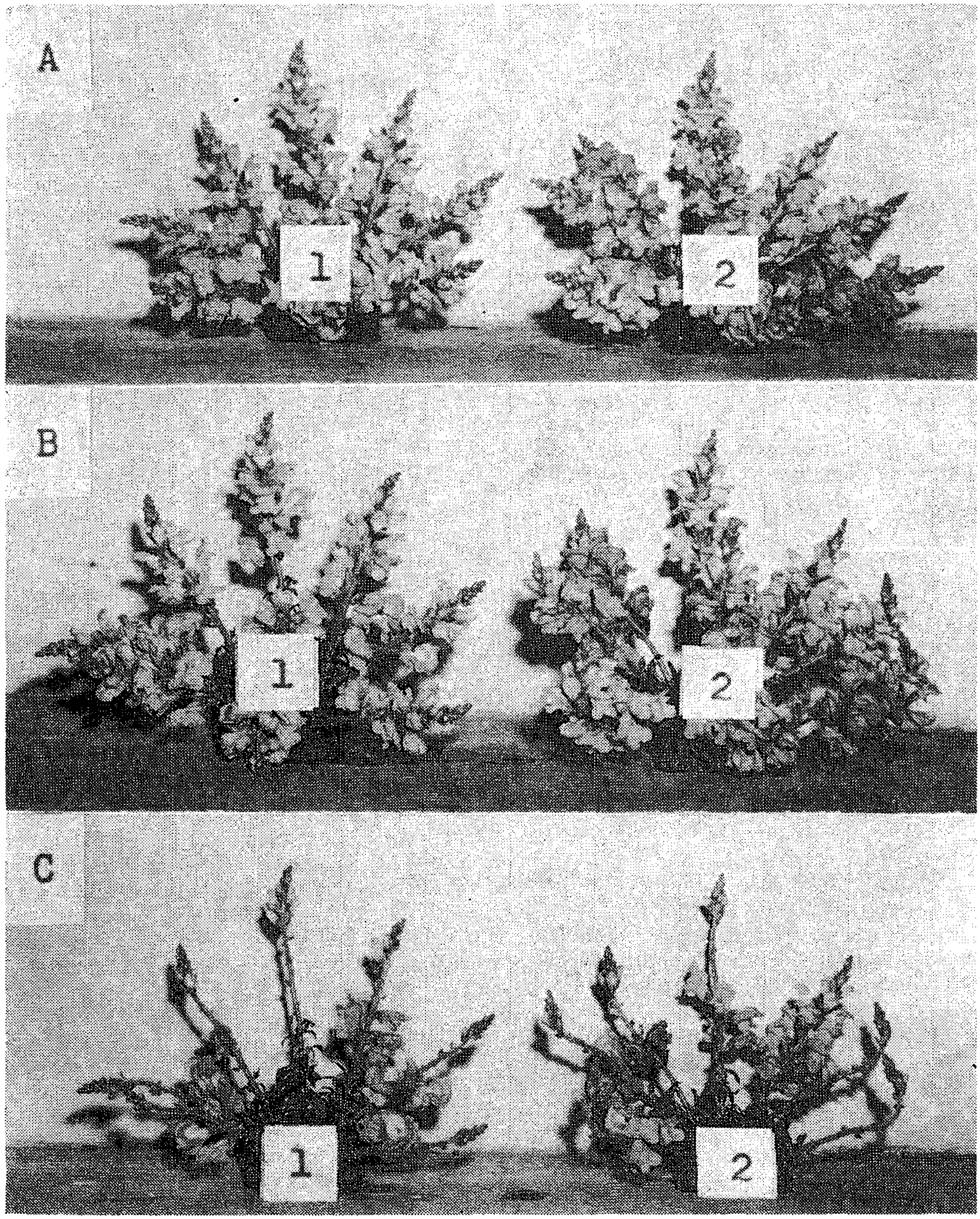

Figure 2. Snapdragon arrangements. (1) Stems dipped into 1×10^{-5}M NP, (2) buffer control. A. Time zero, B. after 24 hours, and C. after 24 hours, with florets removed to show stem bending.

hour or more. If such blooms are placed vertically they recover because of re-presentation and re-response to gravity. However, if the stems are dipped into NP after a few minutes of horizontal presentation (possibly before any geotropic bend has occurred) the chemical effectively desensitizes the spikes to gravity, so that the previously induced bends become fixed.

Thus it seems reasonable that commercial shipment of snapdragons can be developed. Success will depend primarily on a modification of present handling techniques to insure that geotropic presentation associated with cutting and grading operations does not occur or that blooms are stored vertical a sufficient amount of time after grading before NP treatment to assure that the stems are straight.

The effect of NP on snapdragon stems is illustrated by the flower arrangements shown in Figure 2.

Effect of Ionizing Radiation of Geotropic Bending – Snapdragon inflorescences were treated with cobalt-60 gamma radiation at doses of 0; 1,500; 3,000 and 7,500 roentgens (2). After treatment the stems were presented horizontally. Bending as a function of radiation dose is shown in Table 3.

Table 3. Geotropic response of gamma-irradiated snapdragon flower spikes

Dosage Kr	Angle of bend at 24 hours degrees
0	95
1.5	99
3.0	90
7.5	39

In another experiment the dose range was extended to more than 20 Kr. From these preliminary experiments it is apparent that the geotropic response can be inhibited by gamma radiation and that almost complete inhibition can be attained at doses of ca. 20 Kr. This finding suggests that ionizing radiation may be a useful tool in studying the physiology of geotropism, and possibly merit commercial consideration for control of geotropism. Extensive tests of the effect of gamma radiation on growth and geotropism in corn and pea seedlings have been carried out (3).

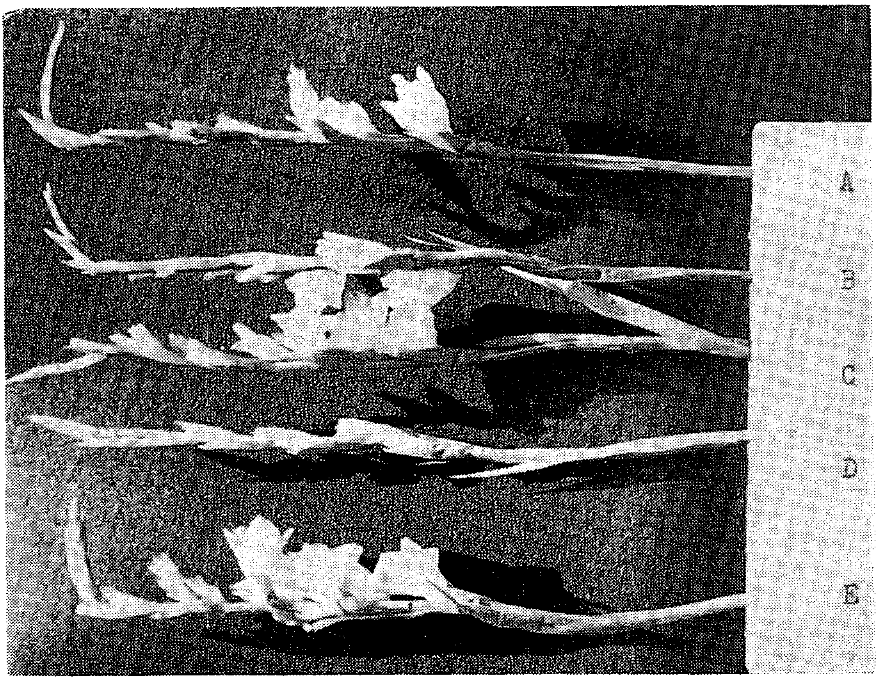

Figure 3. Spikes of gladiolus variety Valaria forty-eight hours after treatment and horizontal presentation. A. 5 x 10^{-5}M NP; B. 1 x 10^{-4}M NP; C. 5 x 10^{-4}M NP; D. 1 x 10^{-3}; and E. buffer control.

Gladiolus

Effects of Chemicals on geotropic response Experiments on the control of geotropic bending in gladiolus were carried out as follows: spikes were recut, dipped into chemical solutions and were maintained vertical for 24 hrs. They were then presented horizontally by inserting the spikes into moistened blocks of plastic foam (Oasis). Bending, floret opening, and floret color were recorded at 24 and 48 hours after presentation. Most gladiolus were shipped to Gainesville by rail. Varieties tested included Spic and Span, Hopman's Glory, June Bell and Valaria. The following chemicals, dissolved in a pH 4.6, .05M phosphate buffer, were tested in the concentrations indicated:

1. NP 1×10^{-3} to 1×10^{-5}M
2. 2,4-dichlorophenoxyacetic acid 1×10^{-4} to 1×10^{-6}M
3. Maleic hydrazide (amine formulation) 500 and 5,000 ppm
4. N-1-naphthylmonochlorophthalamic acid 1×10^{-4} and 5×10^{-4}M
5. N-1-naphthylphthalimide " "
6. o-chlorophenylphthalamic acid " "
7. 2,5-dichlorophenylphthalamic acid " "
8. 2,3,5-triiodobenzoic acid " "
9. 2,3-dichlorophenylphthalamic acid " "

Four flower spikes were used per treatment. The number of replications varied with varieties because the number of straight spikes differed from shipment to shipment. Partial control of geotropic response was achieved by compounds 1, 4, 7 and 8. However, in no case was the result effective enough for commercial use. Highest levels of some chemicals inhibited floret opening, caused stem discoloration or bleached the color from florets. An example of a more favorable gladiolus experiment is shown in Figure 3. Reduction in floret opening occurred at NP levels which effectively controlled geotropic response. There is hope that other chemicals or synergists will improve control. Also ionizing radiation might be useful.

Summary

1. The control of geotropic bending in snapdragon inflorescences was achieved using N-1-naphthylphthalamate (NP) (1), and the geotropic and NP inhibition were found to be equal in the eight varieties tested.

2. It was found that there was no appreciable difference in the geotropic response of single and double-flowered varieties.

3. NP treatments had no significant effect on floral opening and after 72 hours in most cases NP treated spikes had opened one more flower than the control treatment.

4. The pH of the solution had no effect on the geotropic response of snapdragons.

5. Incomplete control of geotropic bending in commercial shipments was traced to NP fixation of geotropic bends induced during handling prior to NP treatment.

6. Gamma radiation between 7.5 Kr and 20 Kr also inhibited geotropic bending of snapdragons.

7. Chemical treatments of gladiolus spikes, using NP and eight other chemicals were less successful than that found for snapdragons.

Acknowledgments

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