

Paclobutrazol Soaked Seeds: An Alternative for Transplant Height Control

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Abstract

Bedding plants and many vegetable crop transplants are often started by seed in plug trays. Some crops, like marigold (*Tagetes* spp. L.), tend to stretch very early after germination, especially if grown in low light environments. By the time growers apply plant growth regulators (PGRs), the stretching of the hypocotyl has already occurred and seedling sprays are ineffective. It was hypothesized that seedling height could be controlled by applying the plant growth regulator directly to the seed. To test this hypothesis, seeds of marigold (*Tagetes patula* L.) 'Bonanza Gold', geranium (*Pelargonium × hortorum* L. H. Bailey) 'Cherry Orbit' and tomato (*Lycopersicon esculentum* Mill.) 'Sun 6108', ornamental kale 'Nagoya Red' (*Brassica oleracea* L.), cabbage 'Benefit' (*Brassica oleracea* L.), and Jalapeño pepper 'Mitla' (*Capsicum annuum* L.) were soaked in water or paclobutrazol solutions at different soaking times. After imbibition, seeds were dried for 24 h prior to sowing in plug trays. Increasing concentrations of paclobutrazol and time of imbibition produced shorter seedlings of all the crops tested but also reduced seedling emergence of geranium, ornamental kale and pepper. In the cases of ornamental kale and peppers, further studies with lower concentrations of paclobutrazol should be conducted. These results indicate that application of PGRs to seeds for height control may be possible in some species. It was speculated that after sowing, the active ingredient does not move into the seed. It is possible that the PGR remains on the seed coats and likely diffuses from the coat into the moist growing medium and it is then absorbed by the seedling root after germination and emergence. Chemical name used: (+)-(R*,R*)-β-[(4-chlorophenyl)methyl]-α-(1,1-dimehtyl)-1H-1,2,4-triazole-1-ethanol (paclobutrazol).

Introduction

A common challenge for transplant producers is height control. Many plant growth regulators (PGRs) are applied as foliar sprays or substrate drenches (Barrett and Nell, 1989; Dasoju et al., 1998; Whipker and Hammer, 1997). Soil drenches with growth retardants are often preferred over foliar sprays due to minimal drift of active ingredient, but growing media components by paclobutrazol interactions are significant (Million et al., 1998). Application of PGRs directly to seeds may circumvent some of these limitations for bedding plant production. The systemic properties of paclobutrazol and other triazoles

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(Davis et al., 1988) have been shown to allow the application of growth retardants to seeds with no effect on seed germination (Pasian and Bennett, 2001).

Some vegetable crops have the same tendency to early stretching as some bedding plant species do. Stretching and legginess in processing pepper and cabbage transplants becomes a problem when field planting in the spring is delayed due to weather conditions. Difficulties in mechanical transplanting and field survival are challenges that processing pepper and cabbage growers face with increased transplant heights.

In the US, plant growth regulators cannot be used on vegetable crop transplants. Growers have a difficult time keeping vegetable transplant (plug) height under control. We have decided to test the effectiveness of paclobutrazol on vegetable plug height control because we have hypothesized that the amount of growth regulator carried by the seed is very small and will be diluted in the plant with its growth. At the time of fruit harvest, the active ingredient may be practically undetectable.

The objective of these studies was 1) to compare seedling survival and seedling height for three bedding plant species (marigold, geranium, and ornamental kale), and one vegetable species (tomato) after soaking seeds in water alone or varying paclobutrazol solutions at three different soaking times; 2) to study the effect of paclobutrazol-soaked seeds on ornamental kale plugs and its long term effect; and 3) to compare several paclobutrazol concentrations to control plug height of cabbage and pepper by soaking their seeds and to determine any subsequent effects in the field on flowering, time to harvest, yield, and fruit characteristics.

Materials and Methods

Seed soaking.

Marigold 'Bonanza Gold', geranium 'Cherry Orbit' and tomato 'Sun 6108' seeds were soaked in water or paclobutrazol solutions at 500 or 1000 mg L⁻¹ for 6, 16, or 24 h. Ornamental kale (*Brassica oleracea*) 'Nagoya Red' seeds were soaked in water or paclobutrazol solutions at 50, 200, 500 or 1000 mg L⁻¹ for 5, 45 and 180 minutes. Cabbage 'Benefit', and jalapeño pepper 'Mitla' seeds were soaked in paclobutrazol solutions at 0, 500, and 1000 mg L⁻¹ for 5 and 45 minutes.

Nonsoaked seeds were used as a control. All other seeds were soaked in a 50 mL glass beaker containing the appropriate paclobutrazol solution. Beakers were agitated constantly during the soaking period. After soaking, seeds were dried for at least 16 h at 25°C on an open bench.

Seed sowing and experimental protocols.

In order to obtain plug seedlings, treated and untreated seeds were sown one seed per cell in 288 plug trays (cell depth: 3.1 cm) filled with Sunshine LP5 (Sun Gro Horticulture, Bellevue, WA) plug mix. After sowing, seeds were covered with a small portion of the plug medium and placed under an intermittent light mist at 25°C for two to five days. Plants were then moved to a greenhouse bench (temperature setting 22 °C) and irrigated as needed with tap water. Plugs were fertilized with a 20N-8.7P-16.7K liquid fertilizer (Peters Professional® water-soluble fertilizer, Scotts-Sierra Horticultural Products Company, Marysville, OH) at a rate of 200 mg L⁻¹ N every third watering.

The experiments were conducted in a completely randomized design using 200 seeds per treatment with

four replications of 50 seeds each. Percent of usable plugs, and seedling height (the distance from the plug tray and the top of the seedling, cm), were measured 16, 26, and 36 days after sowing for marigold, geranium and tomato, and 13 and 20 days after sowing for ornamental kale. Percent of usable plugs was measured 7, 14, and 21 days after sowing for cabbage and 14, 21, and 35 days after sowing for peppers. Plugs with no deformities, healthy and with symptoms of active growth were considered usable.

Four ornamental kale seedlings per replication per treatment were transplanted 28 d after sowing in 15.3 cm diameter (1800 ml) plastic containers using a commercial soilless growing medium (Metro-Mix⁷ 360, Scotts-Sierra Horticultural Products Company, Marysville, Ohio) containing horticultural vermiculite, Canadian sphagnum peat moss, processed bark ash, and washed sand. Forty-two days after sowing, height and diameter of the kale plants were recorded. Kale plants were measured for final height, and diameter 116 d after sowing. After harvesting, kale plants were placed in a drying oven at 72 C for 3 d for dry weight determination.

Seven-week-old cabbage plants were transplanted to the field on May 30 in a randomized complete block design in 3 replications of each seed soak concentration. Plant height, leaf number stem length and dry weights were recorded at field transplanting. Plant heights and head diameter measurements were recorded one month after transplant. Standard production practices for the Midwest U.S. (disease/insect management, fertilizer rates, weed control, etc.) were followed throughout the growing season. Pepper plant height, internode length and stem diameter were recorded at the time of field establishment. One month after transplanting to the field plant height, internode length and stem diameter measurements were recorded. Pepper fruits were harvested on August 13, September 7 and October 4. Marketable green and red T/A were recorded along with cull T/A.

Rate responses to the plant growth regulator effect on plant height and seedling survival were determined by regression analysis using the GLM procedure of SAS (SAS Institute, Cary, NC). Single degree of freedom contrasts were used to evaluate treatment effects. The effect of water soaking (water only soaked seeds vs. non-soaked seeds or true control) on the same characteristics, was evaluated by testing for LSD.

Results and Discussion

Marigold, geranium and tomato.

The paclobutrazol soaking solutions used in this work had no effect on percent usable transplants (plugs) of geranium when seeds were soaked for 6 or 16 h (Table 1). However, when seeds were soaked for 24 h, the trend of reduced percent of usable transplants was significant with increasing concentration of paclobutrazol. A similar effect was noticed with marigolds (Table 1). Percent of usable tomato seedlings was not affected by higher concentrations and longer soaking times (Table 1). Water imbibition (water only treatment) of seeds had no effect on marigold, geranium and tomato percent usable transplants. No significant differences were found between the control (no soaking) and the water only soaking treatment (results not shown).

All seedlings from paclobutrazol treated seeds appeared to have greener foliage. Significant trends in plug height reduction were observed with increasing concentrations of paclobutrazol (Table 2) for all

three dates of measurement. Water imbibition of tomato and marigold seeds (water only) had no effect on seedling height. No interactions between imbibition time and paclobutrazol concentration on seedling height were found with the exception of geraniums measured 36 d after sowing (Table 3). Imbibition time had a significant effect on geranium seedling height. Based on data presented in this work, it cannot be explained why imbibition affects seedling height. However, it can be speculated that the longer the imbibition time, the larger the amount of paclobutrazol which moves into the seed thereby inhibiting germination.

Ornamental kale.

Paclobutrazol seed soaking solutions had a significant effect on percentage usable kale plugs (Table 4). As long as growth regulator concentrations were not larger than 200 mg L^{-1} and times of soaking were not longer than 45 minutes, usable transplant percentages were not significantly reduced. Significant trends in plug height reduction were measured with increasing concentrations of paclobutrazol (Table 5) for all three dates. Forty-two days after sowing, a significant trend of reduced plant height with increasing paclobutrazol concentrations was noticeable (Table 6). This significant trend was not noticeable on mature plants 116 days after planting. From a practical point of view, this is important because this methodology would allow growers to have shorter seedlings and customers to enjoy large garden plants. No significant trends were noticed for plant diameter or dry weight (Table 6 and Table 7 respectively). It was also noted that plants from seeds soaked with paclobutrazol at concentration 500 mg L^{-1} or higher had thicker, straighter stems than plants from non-treated seeds or seeds treated at lower concentrations of PGR. At concentrations lower than 500 mg L^{-1} , this effect was less noticeable and plants with crooked stems were more noticeable. More work will have to be done to quantify this difference.

Cabbage.

Seedling survival was lower (10-15%) for the 1000 mg L^{-1} soaked seeds (Table 8). There were significant differences in plant heights in transplants at 7, 14, and 21 days after sowing between the paclobutrazol soaked and unsoaked seeds. Differences in plant height due to paclobutrazol treatment were also present at the time of field establishment. One month after transplanting, no significant differences were present in head diameter and plant height measurements which indicates that plants showed no long term adverse effects from the growth regulator seed soak. Results show a significant increase in yield with the paclobutrazol soaked seeds versus the dry control and water soak only treatments (Table 9). Other head characteristics (average weight, core length, etc.) were not affected by seed treatment. Brief soaks (5 min.) of cabbage seed in 500 mg L^{-1} paclobutrazol gave 13% reductions in seedling height at transplanting. Longer soaks (45 min.) in 500 mg L^{-1} paclobutrazol, or either of the 1000 mg L^{-1} paclobutrazol treatments produced seedling height reductions of approximately 35% (Table 8).

Peppers.

Percent germination was significantly lower for the paclobutrazol soaked seeds compared to dry control and water soak only (Table 10). Rate effects (1000 mg L^{-1} vs. 500 mg L^{-1}) appear to be more damaging to germination than the soak times. At field establishment, seedling heights were reduced by 10-25% for plants from paclobutrazol-treated seeds. Total yield after 3 fruit harvests shows no significant differences in marketable green, total marketable (green + red) or cull fruit (Table 11). Additional work will be needed to investigate reduced paclobutrazol concentrations to maximize pepper seed

germination, while achieving desired reductions in transplant height.

These results indicate that seedling height of some species with long hypocotyls may be controlled by soaking seeds in paclobutrazol. The primary mode of action of paclobutrazol is by inhibition of the biosynthesis of gibberellins (Davis et al., 1988). Based on these results, it is hypothesized that for species that show a reduction in seedling height without a reduction in seedling survival, paclobutrazol may adhere to the seed coats rather than diffuse into the seed. It has been shown that tomato, pepper, leek, and onion seeds have a semi-permeable layer in the seed coats (Beresniewicz et al., 1995a; 1995b). This layer, located at the innermost layer of the seed coats, has been found to be permeable to water while inhibiting amino acid leakage or uptake of tetrazolium or lanthanum salts. In the case of seeds treated with paclobutrazol, it is speculated that after sowing, the active ingredient likely diffuses from the seed coats into the growing medium and is then absorbed by the seedling root after germination and emergence. In the case of treatments where seeds remain in the paclobutrazol solution for longer periods, it is possible that a greater amount of PGR moves inside the seed with detrimental effects on germination.

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Table 1. Seedling survival (%) from tomato ('Sun 6108'), geranium ('Cherry Orbit'), and marigold ('Bonanza Gold') seeds soaked in water or two paclobutrazol (Bonzi™) solutions (500 or 1000 mg L⁻¹) prior to sowing in 288 plug trays.

| Treatment | Seedling survival (%) | | | | | | | | | |
|-------------------------|-----------------------|------|------|-----------------|------|------|-----------------|------|------|--|
| | 6 h imbibition | | | 16 h imbibition | | | 24 h imbibition | | | |
| | 16 d | 26 d | 36 d | 16 d | 26 d | 36 d | 16 d | 26 d | 36 d | |
| Tomato | | | | | | | | | | |
| Water only | 97 | 97 | 97 | 96 | 97 | 97 | 99 | 99 | 99 | |
| 500 mg L ⁻¹ | 99 | 97 | 97 | 95 | 95 | 95 | 94 | 95 | 95 | |
| 1000 mg L ⁻¹ | 99 | 95 | 95 | 93 | 95 | 95 | 98 | 98 | 98 | |
| Significanc | | | | | | | | | | |
| Linear | n.s. | n.s. | n.s. | * | n.s. | n.s. | n.s. | n.s. | n.s. | |
| Quadr. | * | n.s. | n.s. | n.s. | n.s. | n.s. | * | n.s. | n.s. | |
| Geranium | | | | | | | | | | |
| Water only | 96 | 97 | 97 | 97 | 99 | 99 | 97 | 99 | 99 | |
| 500 mg L | 97 | 97 | 97 | 95 | 97 | 97 | 94 | 98 | 98 | |
| 1000 mg L | 97 | 97 | 97 | 94 | 98 | 98 | 56 | 71 | 80 | |
| Significanc | | | | | | | | | | |
| Linear | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | ** | ** | ** | |
| Quadr. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | ** | ** | n.s. | |
| Marigold | | | | | | | | | | |
| Water only | 97 | 97 | 97 | 97 | 97 | 97 | 98 | 97 | 97 | |
| 500 mg L | 95 | 97 | 97 | 99 | 99 | 99 | 96 | 97 | 97 | |
| 1000 mg L | 96 | 95 | 95 | 94 | 96 | 96 | 87 | 94 | 94 | |
| Significanc | | | | | | | | | | |
| Linear | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | ** | * | * | |
| Quadr. | n.s. | n.s. | n.s. | n.s. | n.s. | * | n.s. | n.s. | n.s. | |

n.s., *, and ** : nonsignificant, significant and highly significant, respectively. Significant differences between Treatment effects were analyzed by regression analysis.

Table 2. Seedling height (cm) of tomato ('Sun 6108'), geranium ('Cherry Orbit'), and marigold ('Bonanza gold') from seeds soaked in water or two paclobutrazol (Bonzi™) solutions (500 or 1000 mg L⁻¹) prior to sowing in 288 plug trays.

| Treatment | Seedling height (cm) | | | | | | | | |
|-------------------------|----------------------|------|------|-----------------|------|------|-----------------|------|------|
| | 6 h imbibition | | | 16 h imbibition | | | 24 h imbibition | | |
| | 16 d | 26 d | 36 d | 16 d | 26 d | 36 d | 16 d | 26 d | 36 d |
| Tomato | | | | | | | | | |
| Water only | 3.8 | 8.2 | 12.4 | 3.9 | 8.5 | 13.1 | 3.7 | 8.1 | 12.4 |
| 500 mg L ⁻¹ | 2.7 | 5.2 | 8.8 | 2.6 | 4.9 | 8.1 | 2.8 | 5.0 | 8.9 |
| 1000 mg L ⁻¹ | 2.6 | 4.7 | 8.5 | 2.6 | 5.3 | 9.0 | 2.7 | 5.1 | 7.9 |
| Significance | | | | | | | | | |
| Linear model | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| Quadratic model | ** | * | ** | ** | ** | ** | ** | ** | ** |
| Geranium | | | | | | | | | |
| Water only | 2.3 | 5.1 | 9.0 | 2.3 | 4.7 | 8.2 | 2.1 | 4.9 | 8.3 |
| 500 mg L ⁻¹ | 1.2 | 2.8 | 5.4 | 1.4 | 3.0 | 5.9 | 1.3 | 2.1 | 3.8 |
| 1000 mg L ⁻¹ | 0.9 | 1.9 | 3.5 | 1.1 | 2.6 | 5.2 | 0.6 | 1.2 | 2.0 |
| Significance | | | | | | | | | |
| Linear model | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| Quadratic model | n.s. | * | ** | ** | ** | ** | n.s. | ** | ** |
| Marigold | | | | | | | | | |
| Water only | 3.2 | 6.7 | 8.5 | 3.3 | 6.3 | 8.6 | 3.4 | 6.3 | 8.6 |
| 500 mg L ⁻¹ | 2.4 | 5.3 | 6.5 | 2.1 | 4.9 | 6.1 | 2.1 | 5.0 | 6.2 |
| 1000 mg L ⁻¹ | 1.9 | 4.5 | 5.9 | 2.0 | 4.2 | 5.3 | 1.9 | 3.8 | 5.1 |
| Significance | | | | | | | | | |
| Linear model | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| Quadratic model | n.s. | * | ** | ** | ** | ** | ** | n.s. | ** |

n.s., *, and ** : non-significant, significant and highly significant, respectively. Significant differences between treatment effects were by regression analysis.

Table 3. Significance of main effects and interactions on tomato, geranium, and marigold seedling height from seeds soaked in water or two paclobutrazol (BonziTM) solutions (500 or 1000 mg L⁻¹) prior to sowing in 288 plug trays.

| Source | Days after sowing | | |
|-----------------------|-------------------|------|------|
| | 16 d | 26 d | 36 d |
| Tomato | | | |
| Growth regulator (GR) | ** | ** | ** |
| Imbibition time (IT) | n.s. | n.s. | n.s. |
| GR x IT | n.s. | n.s. | n.s. |
| Geranium | | | |
| Growth regulator (GR) | ** | ** | ** |
| Imbibition time (IT) | * | * | ** |
| GR x IT | n.s. | n.s. | * |
| Marigold | | | |
| Growth regulator (GR) | ** | ** | ** |
| Imbibition time (IT) | n.s. | n.s. | n.s. |
| GR x IT | n.s. | n.s. | n.s. |

n.s., *, and ** : non significant, significant and highly significant, respectively. Significant differences between treatment effects were analyzed by regression analysis.

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Table 4. Percent ornamental kale "Nagoya Red" usable plugs 13 and 20 days after sowing from seeds soaked for 5, 45, or 180 minutes in four paclobutrazol (Bonzi™) solutions.

| Treatment (mg L ⁻¹) | Usable plugs (%) | | | | | |
|------------------------------------|------------------|--------|--------|--------|---------|--------|
| | 5 min | | 45 min | | 180 min | |
| | 13 d | 20 d | 13 d | 20 d | 13 d | 20 d |
| 0 | 87.5 | 85.0 | 93.8 | 93.8 | 91.3 | 91.3 |
| 50 | 91.3 | 90.0 | 85.0 | 86.3 | 90.0 | 91.3 |
| 200 | 91.3 | 95.0 | 92.5 | 95.0 | 77.5 | 77.5 |
| 500 | 60.0 | 65.0 | 72.5 | 73.8 | 58.5 | 58.5 |
| 1000 | 55.0 | 60.0 | 70.0 | 71.3 | 60.0 | 58.8 |
| Pr > F | | | | | | |
| Linear | 0.0037 | 0.0171 | 0.0006 | 0.0010 | 0.0084 | 0.0050 |
| Quadratic | 0.1499 | 0.1122 | 0.3469 | 0.2268 | 0.9723 | 0.8844 |

Table 5. Ornamental kale "Nagoya Red" seedling height 13, 20, and 27 days after sowing from seeds soaked for 5, 45, or 180 minutes in four paclobutrazol (Bonzi™) solutions.

| Treatment (mg L ⁻¹) | Seedling height (cm) | | | | | | | | |
|------------------------------------|----------------------|--------|--------|--------|--------|--------|---------|--------|--------|
| | 5 min | | | 45 min | | | 180 min | | |
| | 13 d | 20 d | 27 d | 13 d | 20 d | 27 d | 13 d | 20 d | 27 d |
| 0 | 2.98 | 3.60 | 5.40 | 3.25 | 3.74 | 5.70 | 3.03 | 3.54 | 5.41 |
| 50 | 2.26 | 2.91 | 4.69 | 2.00 | 2.61 | 4.04 | 1.78 | 2.32 | 3.45 |
| 200 | 2.08 | 2.71 | 4.17 | 2.12 | 2.63 | 4.19 | 1.96 | 2.51 | 3.45 |
| 500 | 1.87 | 2.36 | 3.59 | 1.39 | 1.88 | 2.89 | 1.34 | 1.73 | 2.67 |
| 1000 | 1.57 | 1.95 | 2.82 | 1.32 | 1.81 | 2.70 | 1.25 | 1.54 | 2.21 |
| Pr > F | | | | | | | | | |
| Linear | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 | <.0001 |
| Quadratic | 0.0743 | 0.4679 | 0.8094 | 0.0069 | 0.0319 | 0.0205 | 0.0216 | 0.1938 | 0.0201 |

Table 6. Height and diameter of ornamental kale "Nagoya Red" plants 42 and 116 days after sowing from seeds soaked for 5, 45, or 180 minutes in four paclobutrazol (Bonzi™) solutions.

| Treatment (mg L ⁻¹) | Time of soaking | | | | | |
|------------------------------------|---------------------|--------|---------|--------|----------|--------|
| | 5 min. | | 45 min. | | 180 min. | |
| | 42 d | 116 d | 42 d | 116 d | 42 d | 116 d |
| | Plant height (cm) | | | | | |
| 0 | 8.0 | 23.3 | 8.5 | 23.3 | 8.9 | 23.3 |
| 50 | 9.1 | 22.8 | 7.5 | 23.0 | 8.0 | 23.3 |
| 200 | 8.5 | 23.8 | 8.5 | 24.3 | 6.9 | 22.3 |
| 500 | 6.0 | 22.5 | 5.6 | 23.3 | 5.63 | 21.8 |
| 1000 | 5.3 | 22.0 | 4.6 | 21.0 | 4.2 | 21.5 |
| Pr > F | | | | | | |
| Linear | <.0001 | 0.3471 | <.0001 | 0.0911 | <.0001 | 0.1443 |
| Quadratic | 0.0079 | 0.5114 | 0.0038 | 0.0415 | 0.5744 | 1.000 |
| | Plant diameter (cm) | | | | | |
| 0 | 15.8 | 30.5 | 15.6 | 30.5 | 16.3 | 32.3 |
| 50 | 16.5 | 29.5 | 15.5 | 30.4 | 16.1 | 30.5 |
| 200 | 16.0 | 30.1 | 15.0 | 30.6 | 16.5 | 30.0 |
| 500 | 16.3 | 30.5 | 14.6 | 30.1 | 14.1 | 31.3 |
| 1000 | 14.5 | 31.8 | 14.3 | 31.6 | 13.0 | 29.9 |
| Pr > F | | | | | | |
| Linear | 0.2175 | 0.0404 | 0.2420 | 0.1806 | 0.0016 | 0.1147 |
| Quadratic | 0.1458 | 0.0937 | 0.9282 | 0.1590 | 0.0786 | 0.3866 |

Table 7. Dry weight at harvest of ornamental kale "Nagoya Red" plants 116 days after sowing from seeds soaked for 5, 45, or 180 minutes in four paclobutrazol (Bonzi™) solutions.

| Treatment (mg L ⁻¹) | Time of soaking | | |
|------------------------------------|-----------------|---------|----------|
| | 5 min. | 45 min. | 180 min. |
| | Dry weight (g) | | |
| 0 | 22.6 | 24.9 | 25.2 |
| 50 | 23.1 | 25.6 | 23.4 |
| 200 | 25.8 | 21.3 | 25.9 |
| 500 | 25.3 | 26.2 | 24.0 |
| 1000 | 24.1 | 23.7 | 21.6 |
| Pr > F | | | |
| Linear | 0.2756 | 0.6283 | 0.1547 |
| Quadratic | 0.2430 | 0.4974 | 0.2978 |

Table 8. Paclobutrazol seed soak for cabbage transplant height control 7, 14, 21 days after sowing (DAS), at time of field transplanting, and one month after field transplanting.

| Cultivar: 'Benefit' | 7 DAS | | 14 DAS | | 21 DAS | | At transplanting | | | | 1 mth. after transplant | |
|---------------------|--------|---------------|--------|---------------|--------|---------------|------------------|----------|-------------|-----------------|-------------------------|----------------|
| | % germ | Plant ht (cm) | % germ | Plant ht (cm) | % germ | Plant ht (cm) | Plant ht (cm) | Leaf no. | Dry wt. (g) | Stem diam. (mm) | Head diam. (cm) | Plant ht. (cm) |
| Dry Control | 77 | 2.32 | 79 | 5.57 | 79 | 8.79 | 15.75 | 4.08 | 1.47 | 3.98 | 31.77 | 17.20 |
| H2O - 5 min | 78 | 2.86 | 75 | 6.31 | 75 | 9.63 | 15.08 | 5.08 | 1.70 | 4.04 | 33.43 | 17.03 |
| H2O - 45 min | 78 | 2.28 | 79 | 6.47 | 79 | 9.96 | 16.08 | 5.75 | 2.13 | 3.58 | 32.33 | 17.57 |
| 500 ppm - 5 min | 73 | 0.96 | 73 | 4.01 | 73 | 7.39 | 13.58 | 4.33 | 1.00 | 2.33 | 31.67 | 16.23 |
| 500 ppm - 45 min | 73 | 1.12 | 75 | 3.33 | 75 | 7.27 | 10.25 | 5.58 | 1.07 | 1.58 | 31.77 | 15.47 |
| 1000 ppm - 5 min | 63 | 0.48 | 65 | 1.93 | 65 | 5.38 | 9.79 | 6.50 | 1.00 | 0.91 | 31.33 | 18.20 |
| 1000 ppm - 45 min | 61 | 0.67 | 67 | 2.28 | 66 | 5.19 | 9.50 | 4.50 | 0.80 | 0.75 | 32.10 | 18.00 |
| LSD (0.05) | 9.52 | 0.37 | 8.51 | 0.49 | 8.37 | 0.66 | 1.03 | 0.63 | 0.18 | 0.39 | NS | NS |
| P value | | | | | | | | | | | 0.951 | 0.404 |
| CV | 11.1 | 59.6 | 9.3 | 42 | 9.4 | 24.1 | 22 | 17.2 | 35.2 | 55.6 | 6.5 | 9.5 |

Table 9. Paclobutrazol seed soak for cabbage transplant crop production traits.

| Cultivar: 'Benefit' | Yield | | | | | |
|---------------------|------------|-----------|------|----------|------------|-------------|
| | Marketable | Avg. head | Cull | Polar | Equatorial | Core length |
| Treatment | T/A | wt. (lbs) | T/A | (inches) | (inches) | (inches) |
| Dry Control | 9.90 | 3.07 | 2.88 | 5.53 | 6.17 | 1.64 |
| H2O - 5 min | 13.90 | 2.96 | 2.76 | 5.47 | 5.72 | 1.92 |
| H2O - 45 min | 17.90 | 2.91 | 2.18 | 5.42 | 5.86 | 2.01 |
| 500 ppm - 5 min | 21.90 | 3.32 | 4.29 | 5.61 | 6.03 | 1.72 |
| 500 ppm - 45 min | 25.90 | 2.87 | 0.70 | 5.72 | 5.94 | 1.89 |
| 1000 ppm - 5 min | 29.90 | 3.24 | 2.78 | 5.69 | 5.89 | 1.89 |
| 1000 ppm - 45 min | 33.90 | 3.13 | 1.06 | 5.53 | 5.83 | 1.70 |
| LSD (0.05) | 1.75 | NS | NS | NS | NS | NS |
| p value | | 0.687 | 0.19 | 0.971 | 0.772 | 0.901 |
| CV | 37.6 | 11.1 | 74.3 | 6.8 | 5.4 | 19.6 |

Paclobutrazol Soaked Seeds: An Alternative for Transplant Height Control

Table 10. Paclobutrazol seed soak for jalapeño pepper transplant height control 2, 3, 5 weeks after sowing (WAS), at field transplanting, and one month post-transplanting.

| Cultivar: 'Mitla' | 2 WAS | | 3 WAS | | 5 WAS | | At transplanting | | | One month post-transplanting | | |
|-------------------|---------|---------|---------|---------|---------|---------|------------------|-------------|-----------|------------------------------|-------------|-----------|
| | Plant | | Plant | | Plant | | Plant | Internode | Stem | Plant | Internode | Stem |
| Seed Soak | % germ. | ht (cm) | % germ. | ht (cm) | % germ. | ht (cm) | ht (cm) | length (cm) | diam (mm) | ht (cm) | length (cm) | diam (mm) |
| Dry control | 90 | 5.18 | 90 | 15.93 | 90 | 19.65 | 24.50 | 7.10 | 2.98 | 33.35 | 3.38 | 6.68 |
| H2O - 5 min | 91 | 5.75 | 91 | 17.35 | 91 | 22.33 | 23.78 | 6.95 | 3.20 | 33.93 | 3.70 | 6.50 |
| H2O - 45 min | 94 | 4.80 | 94 | 15.58 | 94 | 20.35 | 23.43 | 7.00 | 3.18 | 32.15 | 2.93 | 6.43 |
| 500 ppm - 5 min | 66 | 2.28 | 67 | 11.10 | 67 | 17.33 | 18.43 | 5.28 | 2.40 | 30.25 | 2.35 | 6.63 |
| 500 ppm - 45 min | 68 | 1.85 | 69 | 10.35 | 69 | 18.50 | 22.00 | 6.73 | 3.05 | 29.33 | 2.25 | 7.40 |
| 1000 ppm - 5 min | 48 | 1.55 | 52 | 8.88 | 52 | 15.90 | 20.25 | 4.73 | 2.93 | 28.15 | 2.88 | 6.43 |
| 1000 ppm - 45 min | 44 | 1.25 | 48 | 8.68 | 48 | 13.80 | 18.00 | 5.10 | 2.99 | 28.75 | 2.63 | 7.08 |
| LSD (0.05) | 11.51 | 0.29 | 9.93 | 0.64 | 9.93 | 1.34 | 1.28 | 0.59 | 0.26 | 2.99 | 0.92 | NS |
| p value | | | | | | | | | | | | 0.176 |
| CV | 29 | 56.3 | 26 | 27.4 | 26 | 15.4 | 12.1 | 17 | 10 | 9.1 | 25.8 | 9.1 |

Table 11. Paclobutrazol seed soak for jalapeño pepper transplant crop yield.

| Cultivar: 'Mitla' | YIELD | | | |
|----------------------|-------------------------|-----------------------|--------------------------------|----------|
| | Marketable green T/A | Marketable red T/A | Total mktable. yield T/A | Cull T/A |
| Dry control | 18.30 | 0.50 | 18.80 | 0.05 |
| H2O - 5 min | 18.00 | 1.20 | 19.20 | 0.08 |
| H2O - 45 min | 17.50 | 0.70 | 18.20 | 0.07 |
| 500 ppm - 5 min | 16.90 | 0.90 | 17.80 | 0.03 |
| 500 ppm - 45 min | 17.20 | 0.70 | 17.90 | 0.06 |
| 1000 ppm - 5 min | 17.20 | 0.90 | 18.10 | 0.06 |
| 1000 ppm - 45 min | 17.70 | 1.60 | 19.30 | 0.06 |
| LSD (0.05) | NS | 0.64 | NS | NS |
| p value | 0.778 | | 0.589 | 0.891 |
| CV | 7.1 | 56.2 | 7.5 | 87.3 |