Plant Growth Regulator Impacts on Vegetative Cutting Production of Moroccan Pincushion (*Pterocephalus depressus*) Plants[1]

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Abstract

Moroccan pincushion (*Pterocephalus depressus*) is a drought-tolerant perennial that is being used in landscapes throughout arid areas of the western United States. This paper describes two experiments researching vegetative cutting production from stock plants. Moroccan pincushion stock plants received foliar applications of gibberellic acid (GA_3), benzyladenine, ethephon, or auxin [indole-3-butyric acid (IBA)] plant growth regulators (PGR). Plant growth regulators were applied singularly and in combination with GA_3 to determine efficacy on stock plant growth. A propagation study was conducted simultaneously to determine effects of these different PGR treatments applied to stock plants on the rooting of moroccan pincushion cuttings. The stock plant study showed GA_3 + benzyladenine application increased cutting production over other PGR treatments. Fresh weight of moroccan pincushion cuttings did not differ among treatments. While cuttings did not differ in dry weight in experiment 1, statistical differences were observed in experiment 2. However, these differences in dry weight did not affect the quality of the cuttings. Cuttings from stock plants treated with GA_3 + IBA treatment had the highest numerical growth index [(height + width + width)/3]. Cuttings from stock plants treated with GA_3 alone or in combination with another PGR were all greater in average growth index and statistically differed from those without GA_3 being applied. PGR treatments did not affect rooting percentages of the cuttings with nontreated stock plant cuttings successfully rooting at an average rate of 95%. However, GA_3 + IBA was the only treatment where cuttings had 100% rooting for both experiments, indicating potential rooting benefits.

Index words: Plant growth regulator, propagation, *Pterocephalus depressus*, vegetative cuttings.

Species used in this study: Moroccan pincushion [*Pterocephalus depressus* Archibald].

Chemicals used in this study: gibberellic acid (GA_3), benzyladenine, ethephon, indole-3-butyric acid (IBA).

Significance to the Horticulture Industry

Moroccan pincushion (*Pterocephalus depressus*) is one of several perennials being evaluated as part of the Plant Select® landscape plants program at Colorado State University. As a drought-tolerant perennial ground cover, moroccan pincushion can provide a new option for drought affected areas in the western United States. The compact growth is ideal for use in smaller residential landscapes. The primary obstacle to further adoption of moroccan pincushion by producers thus far has been the lack of propagation success. Colorado State University researchers are developing production protocols for Plant Select® varieties, but these need to be proven successful before deployment to producers. Vegetative propagation is the most widely used method of propagation of moroccan pincushion. However, success with vegetative propagation has been variable. Stock plant quality has a large impact on the success of cuttings taken from moroccan pincushion. The use of gibberellic acid (GA_3), benzyladenine, ethephon, or indole-3-butyric acid (IBA) may improve stock plant production and cutting fresh weight as an indicator of cutting quality. We found that 0.025 $g \cdot L^{-1}$ (25 ppm) gibberellic acid (GA_3) in combination with 0.25 $g \cdot L^{-1}$ (250 ppm) benzyladenine was the best combination for increasing stock plant growth which produced a greater number of vegetative cuttings. Also, 0.25 $g \cdot L^{-1}$ (250 ppm) indole-3-butyric acid (IBA) can have a positive effect on rooting success.

Introduction

Production of cuttings from herbaceous perennial stock plants can be challenging for producers. Stock plants in a juvenile state are desired for their high-quality propagation material. Reproductive tissue which occurs on cuttings will inhibit root and vegetative development during propagation (Gibson and Cerveny 2005). Producers often prune stock plants manually or use a PGR to encourage vegetative plant growth and eliminate reproductive tissue (Preece and Read 1993). However, manually pruning perennials to encourage vegetative growth can be labor intensive (Banko and Stefani 1996) and thus increase production costs (Holland et al. 2007). Applying a PGR is generally less labor intensive than manual pruning, although there is a chance it can cause phytotoxicity in certain crops (Meijón et al. 2009). Research is required to determine PGR efficacy on new perennial species.

This research focused on utilizing gibberellic acid (GA), which increased cutting production in previous research on several herbaceous perennial stock plants (Markovic and Klett 2020). Gibberellic acid is isolated from a species of the fungus, *Gibberella fujikuroi* (Salisbury and Ross 1969), and has become a useful PGR in the ornamental

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horticulture industry. Gibberellic acid promotes growth primarily with uniform cell elongation throughout plant tissue (Moore 1984). Therefore, application of GA on herbaceous perennials could result in more propagation material.

Cytokinins, specifically benzyladenine, are involved in nearly all aspects of plant growth and development (Leopold and Kriedemann 1975). Benzyladenine is known for cell enlargement, not cell elongation as with auxins and gibberellic acid, and it promotes cell growth in all directions (Preece and Read 1993). This results in decreased apical dominance if cytokinin levels in the plant are elevated (Hartmann et al. 2002). In tomato (*Solanum lycopersicum* L.), GA inhibits cytokinin signaling in its response pathway, while cytokinin is also thought to affect the downstream branch(es) of the GA signaling pathway (Fleishon et al. 2011). The ratio of GA to cytokinin is an important factor during interactions, not the overall concentrations. Positive interactions from applications of GA_{4+7} + benzyladenine on stock plants of coral bells (*Heuchera sanguinea* L.), mojave sage (*Salvia pachyphylla* Munz), and cape daisy (*Osteospermum species* L.) suggest a proper ratio of the PGR is important (Markovic and Klett 2020). Therefore, application of benzyladenine, which causes more lateral growth, could produce more propagation material from stock plants.

Ethephon is an ethylene inducer which enters the plant and breaks down into three molecules: phosphate, chloride, and ethylene. These molecules are released into plant systems, effecting plant growth and reproductive development (Preece and Read 1993). These molecules promote auxiliary shoot development without damage to the apical meristem (Hayashi et al. 2001). The relationship between ethylene and GA has shown signaling between the two hormones during times of stress, such as flooding in rice (Oryza sativa. L.) or stress-induced floral initiation (Kuroha et al. 2018, Achard et al. 2007). When applied, ethylene signals the plant to increase GA concentrations. Increasing the GA concentration increases internode elongation; therefore, a beneficial effect of this hormone interaction was observed (Kuroha et al. 2018). An increase in branching and decrease in flower development could lead to more vegetative growth on herbaceous perennials.

Auxins generate many different responses from the plant such as: apical dominance, shoot elongation, organ differentiation, induction of cambial cell division, and root initiation (Buchanan et al. 2000). Auxin and GA have been shown to promote many of the same plant responses such as internode elongation and apical dominance. The auxin and GA interaction has been studied and there is evidence that auxin promotes GA biosynthesis in pea (*Pisum sativum* L.) (Ross et al. 2000). Auxins, like GA, are mainly synthesized in the apical meristem. Auxin from the apical meristem can transport down into the stem where it directly or indirectly maintains enzymes involved in GA biosynthesis (Ross et al. 2000). Auxin was included in this study mainly for its positive effect on root initiation. This advantageous interaction with GA could have an unforeseen benefit for stock plant cutting production.

Fig. 1. Visual guide for moroccan pincushion (*Pterocephalus* depressus) cutting protocol provided by Gulley Greenhouse, Fort Collins, CO. Cuttings show the ideal size and preparation for harvest. Measurements in inches (1 inch = 2.54 cm).

Herbaceous perennial responses to PGRs can vary across cultural and environmental conditions (Cochran and Fulcher 2013). Coral bells and 'Orange Carpet' hummingbird trumpet (*Epilobium canum* ssp. *garrettii* 'PWWG01S' L.) were found to have greater numbers of cuttings produced by stock plants when treated with GA_{4+7}, but the quality of the cuttings had a disparity with coals bells having high quality and hummingbird trumpet having low quality (Markovic and Klett 2020). Low quality cuttings had low fresh weights and low rooting percentages when propagated. The wide range of possible plant responses indicates the importance of continued research on herbaceous perennials and their response to PGRs.

The herbaceous perennial utilized in these experiments was moroccan pincushion. During meetings with greenhouse and nursery growers propagating this perennial, growers identified two production problems with this plant: 1) lack of quantity of vegetative propagation material from stock plants and 2) too long of a time period between cutting collection. Based on prior research, it was concluded that using a PGR could possibly resolve these problems.

The research objective was to evaluate moroccan pincushion stock plants response to GA_3 applied singularly or in combination with benzyladenine, ethephon, or auxin. The hypothesis of this study was that applications of GA_3 would increase vegetative cuttings numbers and quality from moroccan pincushion stock plants. A second hypothesis was that successful rooting of moroccan pincushion cuttings would not be affected by PGR applications to stock plants.

Materials and Methods

Stock plant study. Moroccan pincushion stock plants were treated with ten different plant growth regulator treatments to determine if they would produce more cuttings (Fig. 1). The stock plant experiment was repeated for moroccan pincushion; the first experiment was conducted during Summer and Fall 2019 and repeated in Fall and Winter 2019-20.

All experiments were conducted at the Colorado State University Horticulture Center greenhouse, Fort Collins, CO (lat. 40.577953° N, long. 105.080925° W; U.S. Department of Agriculture hardiness zone 5b). Plants of uniform size (98-plug tray) were purchased from a local greenhouse (Gulley Greenhouse, Fort Collins, CO). Over 135 rooted cuttings were potted into black, square 10 cm (4 inch) containers on 11 February 2019 and 9 June 2019. The substrate used was composed of blonde peat moss, wood fiber, dolomitic limestone, and a wetting agent (Pindstrup, Ryomgaard, Denmark). Four replicates of three (12 total plants) were then placed in a complete randomized design and placed in rows of 3 plants (same treatment) with an empty row between in 15-count carrier flats placed on a single greenhouse bench.

During establishment, plants were watered by hand with 14N-1.7P-11.6K water-soluble fertilizer (GreenCare; Blackmore Company, Belleville, MI) at a rate of 200 ppm. Fertilizer was applied during each watering using a handheld hose with breaker (400 PL, Dramm, Manitowoc, WI). Daytime temperatures were maintained with an aspirator (Model M4821, Wadsworth Control Systems, Arvada, CO) sensor between 18 and 23 C (65 and 73 F), while night-time temperatures were held between 16 and 22 C (61 and 73 F).

The four PGRs applied and their application concentration were: auxin (indole-3-butyric acid): 250 ppm (Hortus USA Corp., New York, NY); ethephon: 400 ppm (Nufarm Americas, Inc., Alsip, IL); benzyladenine: 250 ppm (Fine Agrochemicals Limited, Worcester, U.K.); and GA_3: 25 ppm (gibberellic acid 3) (Valent USA Corp., Fresno, CS). Treatments in both experiments were applied two weeks before each data collection over a 6-month period. In the first experiment, treatments were repeatedly applied on 12 June 2019, 8 August 2019, 26 September 2019, and 6 November 2019. In the second experiment, treatments were repeatedly applied on 8 August 2019, 26 September 2019, 6 November 2019, and 3 February 2020. Treatments were applied to foliar run-off, including those in the control group, which were sprayed with plain water. All treatments were applied using a 3.78 L (1 gal) hand pump sprayer.

Initial measurements for height and width of each stock plant were taken after five weeks of growth after planting. Subsequently, stock plant height, stock plant width, number of cuttings, total cutting fresh weight (FW), and total cutting dry weight (DW) were measured during each collection event. Stock plants were measured from the highest leaf to the substrate, across the plant, and then across at a 90-degree angle. These three values were added together and divided by three to determine the GI for each plant. Fresh weight was measured immediately after harvesting the cuttings from stock plants and this measurement was used to determine quality of the harvested cutting.

When cuttings were harvested, two-thirds of the total vegetative growth of the stock plant was left intact to ensure continual plant growth. This was suggested by commercial growers during discussions about production processes. Cuttings were harvested approximately two weeks after each PGR treatment application. Ideal cutting size and diameter are shown in Fig. 1. The ideal moroccan pincushion cutting has up to a 5 cm (2 inch) height and a stem with 0.3 cm (0.12 inch) diameter. Cuttings from each stock plant were counted, weighed to determine FW in grams, then placed in a drying oven at 70 C (158 F) for 48 h to determine DW in grams. One month after the fourth collection of cuttings, stock plants had all the shoot growth above the soil line removed, dried, and weighed. This provided average top growth of the stock plants for each treatment.

Propagation study. After each stock plant experiment, a propagation experiment was performed. Two stock plants for each treatment randomly selected from experiments 1 and 2 were grown under the same conditions. The only variable was the different PGR applied during the stock plant treatments. Three repetitions of the propagation experiments 1 and 2 were conducted with 10 cuttings being rooted in a completely randomized design in two 72-count propagation flats. Cuttings from moroccan pincushion were harvested every 4 weeks: 8 August 2019, 26 September 2019, and 6 November 2019 for the first experiment and 26 September 2019, 6 November 2019, and 3 February 2020 for the second experiment. Cuttings were taken in the morning before 11:00 AM and dipped for 30 s in 500 ppm indole-3-butyric acid/1-naphthylacetic acid (IBA/NAA) (Dip ‘N Gro, Clackamas, OR) and propagated in trays of peat moss and binding agent (Preforma; Jiffy, Lorain, OH).

A mist timer (NOVA, 1626ET, Phytotronics, Earth City, MO) was used to control the amount of moisture administered on the cuttings which were under mist nozzles (03034211-b pcs 25 coolpro c 4x7 head +ad20, Netafim, Fresno, CA). Bottom heat was provided by heating mats (Redi Heat model RHD 2110, Phytotronics) at a temperature of 24 C (75 F). During the experiment, cuttings were misted for 10 s throughout the 24 h day at varying time intervals each week. Time intervals included: week 1, every 15 min; week 2, every 30 min; and weeks 3 and 4 every 60 min. Rooting data was collected weekly to 4 weeks after sticking. Plants were pulled out of the propagation tray cell to determine rooting percentage and visible roots were counted along the sides of the cell and returned to the tray. The data collected included rooting success percentage during weeks 2 to 4 on the mist bench. Also, the number of visible roots were determined by counting up to 30 individual roots in each of the cells.

Experimental analysis. Data analysis was performed using R version 3.3.1, statistical computing software (R Foundation for Statistical Computing, Vienna, Austria) with car, LSMeans, and ggplot packages. A one-way analysis of variance (ANOVA) was run separately for the response variables. Response variables included average number of cuttings per stock plant, average GI per stock plant, average FW per cutting, average DW per cutting, final average DW of total shoot growth per stock plant, average cutting rooting percentage per treatment, and average number of visible roots per treatment. The data were analyzed and averaged over the 4 collections and

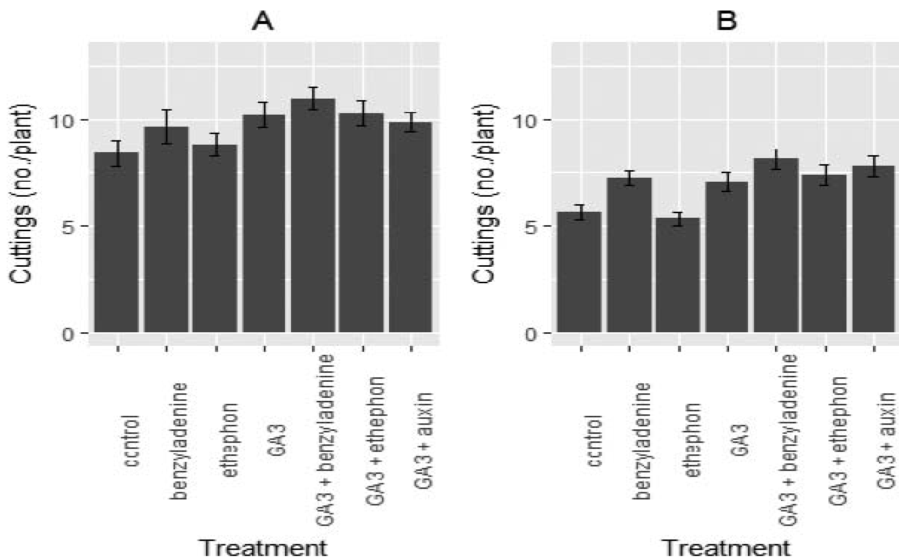

Fig. 2. Mean number of cuttings harvested per plant from moroccan pincushion stock plants averaged over four harvest dates for Expt. 1 (A) and Expt. 2 (B) as influenced by seven plant growth regulator treatments: benzyladenine, ethephon, gibberellic acid 3 (GA_3), GA_3 + benzyladenine, GA_3 + ethephon, GA_3 + IBA, and a nontreated control. Plant growth regulators were foliarly applied until run-off occurred on leaves, with clear water applied to nontreated control plants.

analyzed specific to each experiment (1 and 2). Included in the statistical models were predictor variables that matched the PGR treatments applied to the stock plants. Pairwise comparisons and least squares means were calculated using the LSmeans package for each response variable. Tukey adjusted pairwise comparisons were considered and significant differences were noted using α=0.05.

The propagation study had response variables with a combined sample size of 30 from three repetitions for each experiment. Data analyzed included successful rooting percentage and average number of visible roots per replicant. Data were analyzed using an initial arcsine transformation for the rooting percentages. Then, one-way ANOVAs were run for rooting percentage and average number of visible roots for each experiment. Included in the statistical models were predictor variables matching PGR treatments. Pairwise comparisons and least squares means were calculated using the LSmeans package for each response variable. Tukey adjusted pairwise comparisons were considered and significant differences were noted using α=0.05.

Results and Discussion

Number of cuttings harvested. The data from these experiments were averaged across all 4 harvest dates. There were no differences among the 4 harvest dates (data not shown). Foliar sprays containing GA_3 + benzyladenine (25 and 250 ppm) resulted in a greater number of cuttings harvested compared to all other treatments in experiment 1 and 2 (Fig. 2). The results were not statistically different when comparing all treatments together. However, statistical differences were observed in comparison to only the nontreated control, as plants treated with GA_3 + benzyladenine (25 and 250 ppm) produced 2.59 (23.5%) more cuttings in experiment 1, while plants treated with GA_3 + benzyladenine (25 and 250 ppm) produced 2.49 (30.6%) more cuttings in experiment 2 compared to the nontreated control (Fig. 2).

More vegetative cuttings were harvested from stock plants treated with GA_3 + benzyladenine compared to all other treatments (Fig. 2). The additional lateral shoot growth of the stock plants combined with increased internodal elongation produced more available cuttings. Results for coral bells were comparable when treated with GA_{4+7} + benzyladenine (50 ppm) applications (Markovic and Klett 2020). Similarly, ‘Bressingham Bronze’ coral bells treated with benzyladenine (1,000 ppm) had more lateral shoots (Martin and Singletary 1999).

Benzyladenine (250 ppm) application resulted in a small increase in the number of cuttings harvested compared to the nontreated control due to increased lateral branching (Fig. 2). Ethephon (400 ppm) application resulted in similar growth to the nontreated control with no effect on the number of cuttings collected and results were not statistically different (Fig. 2). No flowering was observed throughout the experiments on any treated plants. Therefore, ethephon application did not affect reproductive tissue compared to other PGR treatments.

The application combination of GA_3 and IBA, ethephon, or benzyladenine increased the average number of cuttings collected. During the first experiment, stock plants treated with GA_3 + benzyladenine had a greater number of cuttings compared to the other treatments, while GA_3, GA_3 + IBA, and GA_3 + ethephon-treated plants were all similar to each other. In the second experiment, GA_3 + IBA and GA_3 + benzyladenine-treated stock plants produced greater numbers of cuttings and were statistically different than GA_3 + ethephon-treated plants, which in turn differed from GA_3 alone treated plants (Fig. 2). The addition of another PGR to GA_3 showed positive interactions which increased the number of cuttings produced by stock plants, which follows the patterns in previous research performed on

Table 1. Individual cutting fresh weight, individual cutting dry weight, and growth index of moroccan pincushion stock plants averaged over 4 harvest dates (Expt. 1 and Expt. 2) as influenced by seven plant growth regulator treatments: benzyladenine, ethephon, gibberellic acid 3 (GA_3), GA_3 + auxin (IBA), GA_3 + benzyladenine, GA_3 + ethephon, and a nontreated control.

Treatment[z]	Rate (ppm)[y]	Fresh wt (g)[x]	Dry wt (g)	Growth index (cm)[w]
Experiment 1				
Control	0	0.44	0.057	8.9
Benzyladenine	250	0.43	0.056	8.8
Ethephon	400	0.45	0.05	8.8
GA3	25	0.41	0.093	9.3
GA3 + IBA	25 + 250	0.42	0.044	9.5
GA3 + Benzyladenine	25 + 250	0.42	0.049	9.5
GA3 + Ethephon	25 + 400	0.41	0.05	9.3
P value		0.894	0.694	0.095
Experiment 2				
Control	0	0.35	0.04ab	7.3ab[v]
Benzyladenine	250	0.33	0.04ab	7.6abc
Ethephon	400	0.38	0.05b	7a
GA3	25	0.36	0.04ab	8.1cd
GA3 + IBA	25 + 250	0.34	0.04ab	8.6d
GA3 + Benzyladenine	25 + 250	0.31	0.03a	8.3cd
GA3 + Ethephon	25 + 400	0.31	0.03ab	7.88bcd

[z]Treatments were applied foliarly, nontreated control received water only.

[y]1 ppm = 1 $mg \cdot L^{-1}$.

[x]Fresh and dry weights were taken as a total for each plant harvested and the average individual cutting weight was determined using total weight and dividing by the number of cuttings harvested from the single plant. 1g = 0.0353 oz.

[w]Growth index (GI) determined from one height and two width measurements at the largest diameter cross-sections, equation GI = (Height + Width 1 + Width 2)/3; 1 cm = 0.3937 inch.

[v]Mean separation in columns with Tukey adjusted least squares means at $P \leq 0.05$ (lowercase letters).

pea (Ross et al. 2000), rice (Kuroha et al. 2018), and coral bells (Markovic and Klett 2020).

Fresh and dry weight per cutting. Fresh weight has been a better indication of cutting quality than DW (Markovic and Klett 2020, Brown and Klett 2020). Fresh weight of moroccan pincushion in experiment 1 and 2 did not differ among treatments (Table 1). Dry weights showed no differences as with FW in the first experiment, but in experiment 2 differences were observed. The differences did not appear to have a significant effect on cutting quality.

Ethephon-treated cuttings had the greatest DW and statistically differed from all other treatments (Table 1). Cuttings from stock plants treated with the combination GA_3 + benzyladenine in experiment 2 had the least DW and statistically differed from all other treatments (Table 1). This did not affect the rooting percentage when compared to other PGR treatments. Low cutting DW was observed in previous PGR research involving mojave sage, coral bells, and hummingbird trumpet when GA_{4+7} + benzyladenine were applied (Markovic and Klett 2020).

Growth index. There were no statistical differences in GI between treatments in the first experiment, but in experiment 2 statistical differences were observed (Table 1). The GA_3 + IBA treatment caused the greatest overall growth increase, which differed from all other treatments. These results are comparable to those of Ackerman and Hamernik (1994) on coral bells. Treatments that included GA_3 all resulted in greater average GI and statistically differed from treatments without GA_3 applied. This could be expected due to GA_3 being involved with cell elongation (Moore, 1984). Plants treated with GA_3 + ethephon had the lowest average GI of all GA_3 treatments but was not statistically different (Table 1). This interaction was interesting because ethephon-treated stock plants had the least amount of growth during experiment 2. However, they had some of the greatest fresh weights, which was similar to mojave sage findings (Markovic and Klett 2020). Ethephon applications caused added growth through stem thickness of the plants, but not in height and width. These results contradict research performed on a broad range of annual floriculture crops, where biomass accumulation was reduced with ethephon applications (Miller et al. 2012).

Propagation experiments. Successful rooting rates ranged from 63% with cuttings from ethephon-treated plants in experiment 1 to 100% with cuttings from GA_3 + IBA treatments in both experiments (Table 2). Although results indicated the rooting percentages did not significantly differ among treatments, 100% is what producers strive for in herbaceous perennials when propagating. The addition of IBA to stock plants suggests potential benefits for rooting success compared to other PGR treatments. Difficulty in propagating moroccan pincushion by growers was not observed during these experiments with nontreated stock plants producing cuttings with an overall 95% rate of successful rooting. The quality of the propagation facility may be the underlying factor for successful propagation of moroccan pincushion.

The number of visible roots of cuttings did not statistically differ between treatments. While cuttings from GA_3 + benzyladenine-treated stock plants had the greatest average number of visible roots from experiment 1 (Table 2), cuttings from gibberellic acid 3-treated plants alone had the greatest average number of visible roots from experiment 2. Results were not consistent for these two

Table 2. **Influence on moroccan pincushion stock plants by seven plant growth regulator treatments: benzyladenine, ethephon, gibberellic acid 3 (GA_3), GA_3 + IBA, GA_3 + benzyladenine, GA_3 + ethephon, and a nontreated control on cutting rooting percentage and number of visible roots. Data were collected after four weeks under mist and averaged over harvest date within Expt. 1 (August to November 2019) and Expt. 2 (September 2019 to February 2020).**

Treatment[z]	Rate (ppm)[y]	Average rooting percentage	Average number of visible roots
Experiment 1			
Control	0	93	15.7
Benzyladenine	250	83	16.8
Ethephon	400	63	16.9
GA3	25	90	14.4
GA3 + IBA	25 + 250	100	14.6
GA3 + Benzyladenine	25 + 250	83	18.6
GA3 + Ethephon	25 + 400	90	15.2
P value		0.653	0.829
Experiment 2			
Control	0	97	11.7
Benzyladenine	250	100	10.3
Ethephon	400	83	11.2
GA3	25	97	13.4
GA3 + IBA	25 + 250	100	13.3
GA3 + Benzyladenine	25 + 250	93	12.9
GA3 + Ethephon	25 + 400	100	13.2
P value		0.874	0.889

[z]Treatments were applied foliarly, control received water only.

[y]1 ppm = 1 $mg \cdot L^{-1}$.

treatments across the two experiments. Therefore, no conclusions can be made on which treatment to stock plants may increase the number of roots fort moroccan pincushion cuttings.

This study was conducted to determine whether GA_3, benzyladenine, ethephon, or a combination of GA_3 and benzyladenine, ethephon, or IBA applications can improve the number of cuttings and successful rooting of cuttings taken from moroccan pincushion stock plants. Gibberellic acid 3 + benzyladenine application appears to have the greatest potential for improving propagation of moroccan pincushion. This can be attributed to the increase in plant growth between cutting collections by GA_3, plus increased lateral growth from the addition of benzyladenine. The use of GA_3 + benzyladenine application increased number of cuttings harvested, but produced minimal effect on the ability to improve rooting percentage or number of roots on cuttings. The application of IBA could be utilized to increase the rooting percentage of cuttings, however further research into applications of GA_3, benzyladenine, and IBA need to be studied to confirm potential benefits.

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