

IMPACT ON POT-BOUND CHARACTERISTICS TO COMMERCIALIZE NATIVE ORNAMENTAL (MUSSAENDA FRONDOSA L.) POT PLANT THROUGH PINCHING, PACLOBUTRAZOL AND HEADING BACK

Yogendra Singh Adhikari^{1*}, Priyanka Thakur², Santan Barthwal³, Ajay Thakur⁴, B.S. Diltia⁵, Puja Sharma⁶, Mamta Bohra⁷ and Pooja Karki⁸ and Pranjali Sinha⁹

^{1,2,5&6}Department of Floriculture and Landscape Architecture, College of Horticulture, Dr YSP, University of Horticulture and Forestry Nauni, Solan (HP), India

^{1&7}Department of Floriculture and Landscaping, College of Horticulture, VCSG, Uttarakhand, India
University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India

^{3&4}Department of Genetics and Tree Improvement, Forest Research Institute, Dehradun Uttarakhand, India

⁸Faculty of Agriculture, Maharishi Markandeshwar University (Deemed to be University), Mullana, Haryana, India

⁹Department of Plant Pathology, College of Horticulture and Research Station silphili surajpur, MGUVV Durg, Chhattisgarh, India

*Corresponding author: Yogendra Singh Adhikari, Email ID: yogendra.adhikari04@gmail.com

ABSTRACT

The present study was conducted over two consecutive growing seasons (2021–2023) at the Regional Horticultural Research and Training Station, Dhaulakuan, Himachal Pradesh, to evaluate the influence of pinching, heading back, and paclobutrazol on root architecture and biomass dynamics of *Mussaenda frondosa* L. under pot culture. The experiment followed a factorial randomized complete block design (RCBD) with three replications. During the first season, treatments included three pinching levels (no pinch, single pinch, and double pinch) and four concentrations of paclobutrazol (0, 50, 100, and 150 ppm). In the subsequent season, two heading back levels (no heading back and single heading back) were introduced, while continuing the same paclobutrazol treatments. Root and shoot parameters were assessed post-anthesis through destructive sampling. Double pinching (P3) significantly reduced the primary root length (32.58 cm) and enhanced secondary and tertiary root proliferation (144.50 and 384.42), fresh and dry root weight (49.29 and 32.81 g, respectively), and shoot biomass (178.43 g fresh). Among paclobutrazol concentrations, 150 ppm (PBZ4) consistently yielded the highest root-shoot ratio (0.36), tertiary roots (365.00), and biomass accumulation. The interaction P3 × PBZ4 exhibited synergistic effects, producing the highest tertiary root count (418.00) and root fresh weight (55.17 g). In the second year, single heading back (H2) significantly improved root-shoot attributes, particularly when combined with 150 ppm PBZ (H2 × PBZ4), resulting in maximum shoot biomass (260.13 g fresh) and root weight (78.98 g fresh at 50 ppm). Control plants consistently showed the least growth. These findings underscore the potential of integrating morphological manipulations with growth regulators to optimize pot-bound *M. frondosa* cultivation for ornamental use.

KEYWORDS: Native ornamental shrub, *Mussaenda frondosa*, Paclobutrazol, Pinching, heading back and pot-bound.

1. INTRODUCTION

The integration of native plants into modern gardens offers unique flowering and foliage characteristics that enhance visual appeal while preserving ecological harmony with the surrounding environment (Garland, 2020; Hulme *et al.*, 2018). Among these, *Mussaenda frondosa*—a member of the family Rubiaceae and commonly known as “Wild *Mussaenda*” or “Dhobi tree” (Shimpale *et al.*, 2009, Chaithanya and Karunakar, 2025) holds considerable promise for domestication as a potted ornamental plant. Native to the Indo-Malaysian region, the species occurs widely in India, particularly in Assam, Meghalaya, Sikkim, parts of Uttarakhand, as well as in Sri Lanka and Nepal (Jayasinghe *et al.*, 2002; Jayaweera and Don, 1963). It is a perennial, deciduous shrub attaining 1.5 - 2.0 m height, with pale green ovate leaves and striking orange-yellow tubular flowers that bloom profusely from May to November in the Northern Hemisphere (Pollunin and Stainton, 1984; Rashid and Nahar, 2019). These features render it valuable both as a landscape plant and as a potential pot plant for interior and exterior decoration (Aurigue, 2022 and Oghu *et al.*, 2017). For successful commercialization of potted ornamentals, plant architecture serves as factor influencing their aesthetic appeal and marketability (Wani *et al.*, 2024). For maintaining aesthetic appeal of plants and regulating flowering, cultural practices i.e., pinching and heading back play a significant role. These practices help maintain plant bushiness and symmetry along with profuse flowering. Both the practices are widely employed to suppress apical dominance, stimulate axillary bud development and promote lateral branching (Dorajearao and Mokashi, 2012; Mutlu and Agan, 2015) These practices enhance the shoot system by generating a bushier canopy, improving light interception, and reducing labour in intercultural operations, thereby increasing cost-effectiveness (Lalit *et al.*, 2020). Pinching has been reported to delay flowering but simultaneously increase the number of flowers in several floricultural crops (Mounika *et al.*, 2019). Nowadays, other than cultural manipulations, the application of paclobutrazol provides an efficient means of modifying plant architecture. It is a triazole derivative and extensively used to regulate excessive stem elongation and promote compactness in ornamentals (Banon *et al.*, 2002; Taychasinpitak and Manochai, 2003). It inhibits gibberellin

biosynthesis by blocking kaurene oxidation via the cytochrome P450 pathway, thereby restricting internode elongation and encouraging robust branching (Davis and Andersen, 1989; Fletcher *et al.*, 2010). When judiciously applied, paclobutrazol not only controls shoot height but also enhances root-to-shoot balance, prolongs flowering duration, and improves the overall quality of potted plants (Beattie *et al.*, 1990).

Besides influencing vegetative and floral attributes, these practices also have a significant effect on root growth. The root system is the vital component of the plant, as it absorbs nutrient and water from the growin-/-p; medium, which are the essential for healthy plant growth and development (Lopez-Bucio *et al.*, 2003). A healthy and well-developed root system promotes vigorous vegetative growth, which ultimately contribute to enhance flowering an overall plant performance (Comas *et al.*, 2013). As a native ornamental plant with a magnificent flowers and prolonged flowering duration, *Mussaenda frondosa* holds a considerable potential as a promising option for crop diversification in ornamental pot industry. However, the literature on combined effects of pinching, heading back and paclobutrazol application on root and shoot architecture of *Mussaenda frondosa* is meagre. Therefore, the present study was undertaken to evaluate the influence of pinching, heading back and paclobutrazol on root and shoot growth of *Mussaenda frondosa* under pot culture.

2. MATERIAL AND METHODS

2.1 Study site:

The present investigation was conducted over two successive growing seasons, 2021-2022 and 2022-2023, at the floriculture and landscaping farm, Regional Horticultural Research Station (RHR&TS), Dhaulakuan. This station operates under the auspices of Dr Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (HP), India (30°30'20" latitude N and 77°20'30" longitude E, 468 meters, amsl), characterizing the low-hill agro-climatic zone of the Sirmour district (Paonta Sahib). For procurement of authentic germplasm, indigenous *Mussaenda frondosa* L. plants were sourced from the Forest Research Institute (FRI), Dehradun, located in Uttarakhand (30°20'31.56" of Latitude N and 77°59'50.28" of Longitude E, 460 m, amsl) as shown in (Figure. 2.1a).

The site-specific agro-meteorological conditions during the study period were recorded and analyzed. Meteorological parameters, including temperature, relative humidity and precipitation were monitored throughout the experimental period to account for seasonal variability framework in which the experimental crop was grown (Figure: 2.1b)

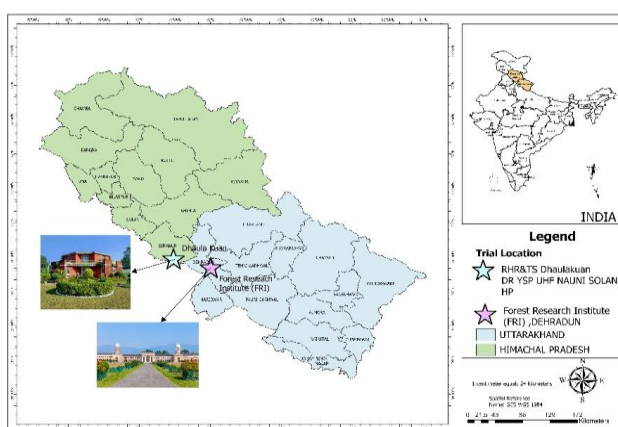


Figure 2.1a: Location map of the experimental site



Figure 2.2: *Mussaenda frondosa* L. identified at Dehradun herbarium

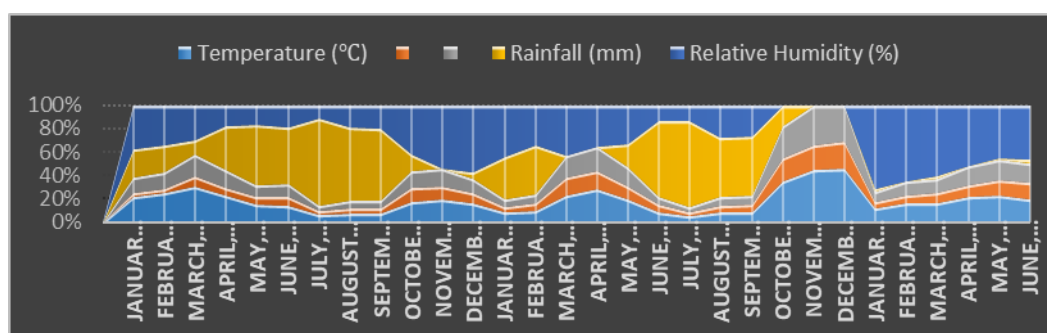


Figure 2.1b: Agro-meteorological data during the experimental period (2021-2023)

2.2 Plant material Identification, procurement and Propagation

The *Mussaenda frondosa* L. specimen was authenticated by herbarium records preserved by the Division of Botany, Dehradun (voucher specimen number: 150746) in order to obtain an appropriate botanical identification (Figure: 2.2). During the active growing stage, semi-hardwood cutting (10-15 cm length; pencil thickness; 3-4 node) was collected

from healthy and pathogen-free mother plants to initiate the propagation phase. Because of their greater rooting capacity, and survival rate, semi-hardwood cuttings are frequently used for ornamental shrub production (Shade and Webb, 2013; Bhardwaj and Kumar, 2020). To minimise fungal infections during roots, the basal ends of the cuttings were submerged in a fungicidal solution containing Dithane M-45 (0.2%) and Bavistin (0.1 %) for 10-15 minutes (Yeboah *et al.*, 2010).

Subsequently, cuttings were treated with indole-3-butyric acid (IBA) solution at 2000 ppm for 2-5 minutes to stimulate early root initiation and uniformity (Kaushik and Shukla, 2020). In a propagation chamber, treated cuttings were planted in a sterilised substrate made of cocopeat and coarse sand (1:1 v/v). Root establishment was confirmed by the appearance of 4-6 leaves approximately 40-45 days after planting. After successful rooting, the saplings were transplanted into 10-inch white plastic pots filled with a well-drained and nutrient-rich potting mixture prepared from garden soil, sand and well-decomposed farmyard manure in a 2:1:1 volumetric ratio. The pots were provided with drainage holes at the bottom to facilitate excess water drained out. Irrigation was done by using rose-can depending upon the moisture content of the potting media. During the experimental period, no extra fertilisers were used; instead, FYM added to the potting media acted as a basal organic nutrient source. The pots were maintained at uniform spacing throughout the experiment to ensure adequate plant growth and minimize inter-plant competition and mutual shading.

2.3 Experimental design and treatment application

The pot experiment was laid out using a factorial randomized complete block design (FRCBD) with three replications. Each treatment unit comprised one plant per pot, with five pots per replication, summing to 15 plants per treatment. In the first season (2021-2022), the experimental design integrated three level of pinching treatments (P1: no-pinch (control), P2: single pinching at 25-30 days after transplanting at 4-5 node stage and P3: double pinching applied 20-25 days after single pinching at 3-4 node stage) and four paclobutrazol concentrations (PBZ1: 0 ppm (control), PBZ2: 50 ppm, PBZ3: 100 ppm and PBZ4: 150 ppm), which was applied through soil drenching 3-4 days after each pinching treatment. Plants grown without pinching were assigned as no-pinching (control). The second experiment was conducted during (2022-2023), based on the performance observed in the first year. The potted plants subjected to double pinching were selected as the base plants material for evaluating the subsequent response to heading back and paclobutrazol, while the no-pinched (untreated) plants were retained as the control. Thus in second year, heading back was evaluated at two levels in combination (No-heading back and Single heading back, performed 15-20 days post-anthesis by heading back at 30 cm above the base of plant) with the same four paclobutrazol concentrations. While, plants assigned to control treatment were left no-heading back. The paclobutrazol with 0 ppm (distilled water) serving as control. One day prior to paclobutrazol application, the pot plants were thoroughly irrigated to ensure adequate and uniform moisture in the growing medium. For each treatment, 50 ml of prepared paclobutrazol solution of different concentrations was applied as a soil drenched to the root-zone around the base of each plant according to the treatment allocation, while 50 ml of distilled water was applied similarly to the control plants. Thus, the first year comprised a 3×4 factorial combinations (12 treatments), while the second year comprised a 2×4 factorial combination (8 treatments).

2.4 Collection of root sample from pot

At the end of the flowering phase, one representative plant per treatment was randomly selected for destructive sampling to assess root architecture and biomass allocation. Since *Mussaenda frondosa* plants are in pots it is very easy to determine the complete root biomass. Cut the top part of the plant (above ground biomass) at soil surface in the pot. The pot-bound plant was gently extracted to preserve the integrity of the root system. To facilitate soil disintegration, the root mass was enclosed in a muslin bag and submerged in a water-filled container for approximately 24 hours. Once the soil is well soaked, break it and wash the excess soil on a 1.4 mm sieve. Extracted soil should be put in a cloth bag after that. Then the pot-bound is cleaned with sprinkler water, and by putting it between the folds of filter paper, excess water is wiped out. Then the roots will be cut with a dryer at the collar and root and shoot weights will be taken as fresh and dry after drying at 65 oC ± (for 3 days) expressed in grams to constant weight in an oven as shown in figure 2.4.

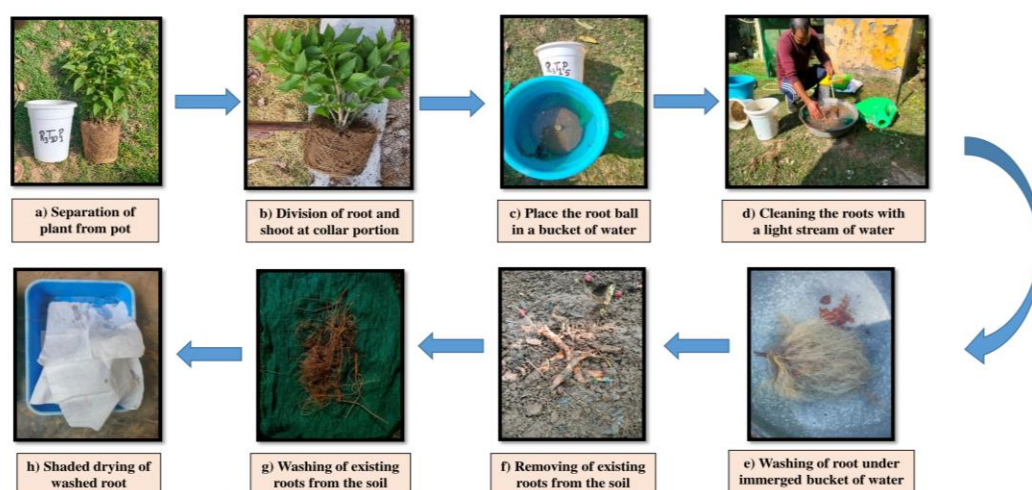


Figure 2.4: Procedures of root sample collection and washing during the pot experiment

2.5 Statistical analysis

The data obtained from each observed character under the study was statistical analysed separately using MS EXCEL, OPSTAT etc. The mean values of data were subjected to one-way analysis of variance (ANOVA) as per “Statistical procedures for Agriculture Research” by Gomez and Gomez (1984) for Factorial randomized completely block design (FRCBD) and the treatments were compared at the 0.05% significance level.

4. RESULTS AND DISCUSSION

Effect of pinching and paclobutrazol on root growth of *Mussaenda frondosa* (2021-22).

During first year, the findings of data presented in table 4.1 indicates that, both pinching and paclobutrazol treated plants markedly improved root growth parameters of *Mussaenda frondosa* under pot conditions. Among pinching treatments, double pinching (P3) significantly reduced in primary root length (32.58 cm) compared to the without pinched plant (P1) act as control. The reduction may attributed to auxin inhibition, which suppress cell division, elongation and differentiation in root meristem (Friml, 2003), resulting in reduction of root length in plant. Noor-El-Deen (2020) in *Ruellia simplex* and Abou-Dahab *et al.* (2015) in *Russelia equisetiformis* stated that double pinching consistently reduced the root length in pot. The findings of this study were comparable to those of Saraswathy *et al.* (2011) in *Withania somnifera*, Sarkar *et al.* (2018) in *Tagetes erecta*, Abou-Dahab and Habib (2005) in *Barleria cristata* and Rezzazadeh and Haekess (2015) in *Odontonema callistachyum*. Furthermore, the same treatment consistently enhanced the highest proliferation of secondary and tertiary root (144.50 and 384.42, respectively), fresh and dry weight of root per plant (49.29 and 32.81 g, respectively), fresh and dry weight of shoot per plant (178.43 and 89.13 g, respectively) and maximum rootshoot ratio (0.37). This may be due to pinching, which promotes lateral shoot development (Lalit *et al.*, 2020 and Sharaf-Eldien., 2017) by reducing apical dominance and enhance cytokinin activity, there by stimulating lateral root and shoot initiation and thickening (Lloret and Casero, 2002; Ferguson and Beveridge, 2009). Abd-El-Aal and Mohamed (2017) in *Pelargonium zonal L.* and Mohamed *et al.* (2022) in *Tecoma capensis* reported that double pinching was most effective to enhance more root growth. Such results are in agreement with those obtained by Abd El-Kader (2009) in *Cestrum elegans* and *Tecoma stans*; Youssef (2004) in *Strelitzia reginae* and Saker (2004) in *Hibiscus rosea sinensis* and *Tabernaemontana coronaria* plant. Additionally, increase in rootshoot ratio might be due to increasing the weight of roots, resulting to increase rootshoot ratio. In *Tagetes erecta*, pinching significantly increased the rootshoot ratio was stated by Sarkar *et al.* (2018). Positive effect of pinching was earlier reported by Ribeiro *et al.* (2011) in *Helianthus annuus*; Youssef and Abd-El-Aal (2013) in *Tabernaemontana coronaria* and Rajput *et al.* (2020) in *Tagetes erecta* plant.

The results also revealed that paclobutrazol application significantly affected root growth parameters on *Mussaenda frondosa* pot plant as depicted in table 4.1. Out of four paclobutrazol concentrations, plants drenched with 150 ppm paclobutrazol (PBZ4) produced highest secondary and tertiary counts (132.11 and 365.00), fresh and dry weight of roots per plant (46.06 and 30.09 g, respectively), fresh and dry weight of shoots per plant (169.29 and 83.23 g, respectively) and root shoot ratio (0.36) as compared to distilled water i.e. 0 ppm paclobutrazol act as control. The enhanced root and shoot growth under higher concentrations might result from paclobutrazol suppressed gibberellin biosynthesis and altered cytokinin activity (Desta and Amare, 2021), favouring assimilate allocation, root proliferation, weight of roots and increase shoot growth (Tekalign and Hammes, 2005; Wang *et al.*, 1987), thereby increasing root and shoot traits (Ewais *et al.* 2013 and Youssef and Abd-El-Aal, 2013). The higher dose of paclobutrazol might have also effective to enhance root counts, root and shoot biomass as well as root shoot ratio was reported by Abou-Dahab *et al.* (2015) in *Russelia equisetiformis* and Abou-Dahab (2013) in *Cestrum nocturnum*. Similar results was also reported by Mishra *et al.* (2005) in *Callistephus chinensis*, Banon *et al.* (2001) in *Phillyrea angustifolia* and Noor-El-Deen (2020) in *Ruellia simplex*. Furthermore, plants drenched with 100 ppm paclobutrazol (PBZ3) had significantly reduced primary root length (34.68 cm) as compared to control. This is because paclobutrazol applied as a soil drench, it gets absorbed by roots and translocate via the xylem to apical meristems (Syngenta, 2003), which inhibits gibberellin biosynthesis (Desta and Amare, 2021), causing cell elongation restriction in root apex, resulting in shorter primary root length. Similar inhibitory effects on root length have been reported by Nazarudin (2012) in *Hibiscus rosa-sinensis L.*, Heikal (2017) in *Sanchezia nobilis* and Noor-El-Deen (2020) in *Ruellia simplex*.

The interaction between pinching and paclobutrazol substantial influenced most of the root parameters (Table 4.1). The combination of double pinching with 150 ppm paclobutrazol (P3 × PBZ4) produced the highest number of tertiary roots per plant (418.00), which was significantly greater than untreated (P1 × PBZ1) control. The enhanced development of tertiary root indicates a favourable response of the root system to the combination of canopy manipulation and paclobutrazol (Ghatas, 2016 and Abou-El-Ghait *et al.*, 2021). The findings of this study were comparable to those of Abd-El-Aal and Mohamed (2017) in *Pelargonium zonal L.*, Abd El-Kader (2009) in *Cestrum elegans* and *Tecoma stans*; Abou-Dahab *et al.* (2015) in *Russelia equisetiformis* plants. Furthermore, the combination of double pinching with 100 ppm paclobutrazol (P3 × PBZ3) resulted in maximum fresh and dry weight of shoot per plant (186.30 and 94.21 g, respectively) in comparison with control (P1 × PBZ1). This may because treatment combination substantially modifying shoot growth and biomass accumulation (Chaney, 2005 and Lalit *et al.*, 2020), resulting in improved fresh and dry weight of shoot per plant. The findings of this study were comparable to those of Youssef (2004) in *Strelitzia reginae*, Abou-Dahab *et al.* (2013) in *Cestrum nocturnum* and Rajput *et al.* (2020) in *Tagetes erecta*. Whereas, primary root length, number of secondary root, fresh and dry weight of root and rootshoot ratio was found to be non-significant.



Results of first year *Mussaenda frondosa* pot-bound

4.2 Effect of heading back and paclobutrazol on root growth of *Mussaenda frondosa* (2022-23).

During second year, perusal of data presented in table 4.2 revealed that single heading back and paclobutrazol considerably enhanced root and shoot growth parameters. Among heading back treatments, single heading back (H2) treated plants produced shortest primary root length (46.11 cm), maximum secondary and tertiary root per plant (227.92 and 388.25, respectively), fresh and dry weight of root per plant (72.74 and 45.19 g, respectively) and fresh and dry weight of shoot per plant (223.39 and 136.64 g, respectively) compared to no-heading back (H1) known as control. A notable reduction in primary root length due to diminished auxin synthesis, which impairs cell elongation at the root apex and enhance of lateral root counts per plant, resulting shortest root length and more lateral roots count in treated plant. Conversely, increased in root and shoot biomass in same treatment might be attributed to increased root system density, shoot proliferation and branching, which increase more number and thickness lateral roots and shoots in plant. This may result in increased root and shoot biomass per plant. This aligns with findings by Cronje *et al.* (2004), where heading back induced compact, bushier growth through enhanced lateral shoot development. However, root:shoot ratio was found to be non-significant.

With respect to paclobutrazol concentrations, root and shoot growth parameters were significantly enhanced in *Mussaenda frondosa* (Table 4.2). 150 ppm paclobutrazol (PBZ4) produced shortest primary root length (47.68 cm), increased secondary and tertiary root numbers (261.67 and 392.50, respectively) and fresh and dry weight of shoot (223.57 and 124.57 g, respectively) compared to the control (PBZ1). This might be due to inhibition of gibberellin restricted cell elongation, which enhanced lateral root branching and promote more shoot growth, resulting in a more compact root and shoot growth (Karmran *et al.* 2018). Similar findings were also reported by Mishra *et al.* (2005) in *Callistephus chinensis* and Banon *et al.* (2001) in *Phillyrea angustifolia*. Additionally, fresh and dry weight of root (64.92 and 39.69 g, respectively) was recorded under 50 ppm paclobutrazol treatment (PBZ2). Lower PBZ may restrict shoot growth, while maintaining root activity, thereby promoting assimilate allocation root biomass accumulation. Similar results was also reported by Abd El-Kader (2009) in *Cestrum elegans* and *Tecoma stans* and Noor-El-Deen (2020) in *Ruellia simplex* plant.



Results of second year *Mussaenda frondosa* pot-bound

Among interactions, single heading back interact with 150 ppm paclobutrazol (H2 × PBZ4) consistently produced shortest primary root length (41.47 cm), maximum fresh and dry weight of shoot per plant (260.13 and 153.13 g, respectively) as compare with control (H1 × PBZ1). This is because the combined use restricts gibberellin and auxin biosynthesis, which suppresses primary root elongation, meristematic activity in the root and promotes more lateral vegetative growth (Karaguzel *et al.*, 2004; Sharma and Singh, 2018 and Choudhary *et al.*, 2019), resulting in shorter root length and shoot biomass in pot plant. Additionally, maximum fresh and dry weight of root per plant (78.98 and 52.05 g, respectively) was noticed under single heading back coupled with 50 ppm paclobutrazol (H2 × PBZ2). These results demonstrate that response of root biomass allocation carried with treatment combination. Whereas, root:shoot ratio was found to be non-significant during experiment.

Table 4.1a: Effect of paclobutrazol and pinching on root growth parameters on native ornamental shrub (*Mussaenda frondosa* L) in 10 inches plastic pots during first year (2021-22)

Treatments	Primary root length (cm)	Number of secondary root per plant	Number of tertiary root per plant	Fresh weight of root per plant (g)	Dry weight of root per plant (g)	Fresh weight of shoot per plant (g)	Dry weight of shoot per plant (g)	Root Shoot ratio
Pinching levels (P)								
P1 (no-pinch) Control	41.32	95.08	285.67	31.91	14.68	147.46	68.63	0.21
P2 (Single pinching)	36.37	125.25	337.58	43.10	25.47	162.13	77.50	0.33
P3 (Double pinching)	32.58	144.50	384.42	49.29	32.81	178.43	89.13	0.37
Significance	S	S	S	S	S	S	S	S
CDat 0.05	1.62	4.58	5.88	2.55	2.20	3.25	1.39	0.03
SE(d)	0.78	2.21	2.83	1.23	1.06	1.56	0.67	0.01
SE(m)	0.55	1.56	2.00	0.87	0.75	1.11	0.47	0.01
Paclobutrazol levels (PBZ)								
PBZ1 (0 ppm) Control	39.76	111.44	296.78	35.22	19.31	152.32	70.65	0.26
PBZ2 (50 ppm)	37.17	118.78	331.33	41.90	21.65	161.81	77.34	0.27
PBZ3 (100 ppm)	34.68	124.11	350.45	42.56	26.24	167.27	82.46	0.31
PBZ4 (150 ppm)	35.43	132.11	365.00	46.06	30.09	169.29	83.23	0.36
Significance	S	S	S	S	S	S	S	S
CDat 0.05	1.88	5.29	6.79	2.94	2.54	3.75	1.60	0.03
SE(d)	0.90	2.55	3.27	1.42	1.22	1.81	0.77	0.02
SE(m)	0.64	1.80	2.31	1.00	0.86	1.28	0.55	0.01
Treatment interaction								
P1 × PBZ1	43.57	87.33	261.00	28.20	11.73	143.38	62.86	0.17
P1 × PBZ2	42.30	92.00	277.67	30.06	12.67	144.04	65.20	0.19
P1 × PBZ3	40.47	98.00	286.33	33.63	15.49	147.14	71.34	0.22
P1 × PBZ4	38.97	103.00	317.67	35.73	18.82	155.27	75.12	0.25
P2 × PBZ1	39.03	114.67	306.33	36.60	21.69	150.35	67.73	0.32
P2 × PBZ2	36.43	120.67	331.00	42.85	20.54	157.60	78.29	0.26
P2 × PBZ3	34.50	127.00	353.67	45.70	27.32	168.36	84.13	0.33
P2 × PBZ4	35.00	138.67	359.33	47.27	32.33	172.22	79.86	0.40
P3 × PBZ1	36.67	132.33	323.00	40.87	24.51	163.23	81.37	0.30
P3 × PBZ2	32.77	143.67	385.33	52.79	31.73	183.79	88.53	0.36
P3 × PBZ3	29.07	147.33	411.33	48.34	35.91	186.30	94.21	0.38
P3 × PBZ4	31.83	154.57	418.00	55.17	39.10	180.39	92.40	0.42
Significance	NS	NS	S	NS	NS	S	S	NS
CDat 0.05	**	**	11.75	**	**	6.49	2.78	**
SE(d)	1.56	4.41	5.66	2.45	2.12	3.13	1.34	0.03
SE(m)	1.11	3.12	4.00	1.73	1.50	2.21	0.95	0.02

Note: Significance at 5 % level, S= Significant and NS= Non-significant.

Table 4.2: Effect of paclobutrazol and heading back on root growth parameters on native ornamental shrub (*Mussaenda frondosa* L) in 10 inches plastic pots during second year (2022-23)

Treatments	Primary root length (cm)	Number of secondary root per plant	Number of tertiary root per plant	Fresh weight of root per plant (g)	Dry weight of root per plant (g)	Fresh weight of shoot per plant (g)	Dry weight of shoot per plant (g)	Root/Shoot ratio
Heading back (H)								
H1 (no-head back) Control	61.13	216.08	340.00	56.22	29.44	165.96	85.64	0.35
H2 (Single heading back)	46.11	227.92	388.25	72.74	45.19	223.39	136.64	0.33
Significance	S	S	S	S	S	S	S	NS
CDat 0.05	1.52	8.84	13.83	2.13	3.49	8.86	2.65	**
SE(d)	0.71	4.13	6.47	1.00	1.63	4.15	1.24	0.01
SE(m)	0.50	2.92	4.58	0.71	1.15	2.93	0.88	0.01
Paclobutrazol levels (PBZ)								
PBZ1 (0 ppm) Control	59.03	228.00	336.33	56.08	26.31	157.15	94.30	0.27
PBZ2 (50 ppm)	53.18	246.17	358.50	72.67	47.66	187.74	108.99	0.46
PBZ3 (100 ppm)	54.58	252.16	369.17	64.26	35.60	210.25	116.70	0.30
PBZ4 (150 ppm)	47.68	261.67	392.50	64.92	39.69	223.57	124.57	0.32
Significance	S	S	S	S	S	S	S	S
CDat 0.05	2.15	12.50	19.56	3.02	4.93	12.53	3.74	0.03
SE(d)	1.01	5.85	9.15	1.41	2.31	5.86	1.75	0.02
SE(m)	0.71	4.13	6.47	1.00	1.63	4.15	1.24	0.01
Treatment interaction								
H1 × PBZ1	67.47	202.33	318.00	48.81	19.61	146.97	78.97	0.25
H1 × PBZ2	57.20	213.67	328.33	66.35	43.27	153.27	81.26	0.53
H1 × PBZ3	65.97	219.00	337.33	52.82	24.30	176.59	86.31	0.28
H1 × PBZ4	53.90	229.33	376.33	56.91	30.57	187.00	96.02	0.32
H2 × PBZ1	50.60	253.67	354.67	63.36	33.01	167.34	109.62	0.30
H2 × PBZ2	49.17	278.67	388.67	78.98	52.05	222.20	136.73	0.38
H2 × PBZ3	43.20	285.33	401.00	75.71	46.89	243.91	147.08	0.31
H2 × PBZ4	41.47	294.00	408.67	72.93	48.80	260.13	153.13	0.32
Significance	S	NS	NS	S	S	S	S	S
CDat 0.05	3.04	**	**	4.27	6.97	17.73	5.29	0.04
SE(d)	1.42	8.27	12.94	2.00	3.26	8.29	2.47	0.02
SE(m)	1.01	5.85	9.15	1.41	2.31	5.86	1.75	0.02

Note: Significance at 5 % level, S= Significant and NS= Non-significant.

6. CONCLUSION:

The present investigation elucidated the significant role of growth manipulation practices specially, pinching, heading back and paclobutrazol application on the modulation of pot-bound characteristics in *Mussaenda frondosa* L. grown under controlled pot culture. The results distinctly demonstrated that double pinching and single heading back in combination with 150 ppm paclobutrazol application, substantially enhanced root proliferation, root biomass and shoot development, contributing to a compact and commercially desirable potted plant architecture.

7. Future recommendation:

Future studies should focus on hormonal profiling and gene expression studies to better understand the underlying physiological mechanisms. Long term assessments of pod-bound root architecture and post-treatment recovery are also needed. Multi-location trials and cost-benefits analyses will help evaluate commercial viability. Additionally, exploring organic alternatives to paclobutrazol can enhance the sustainability of this production system, aligning with eco-friendly horticulture practices.

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