



Comparative Study of Airpot and Conventional Containers-root Phenotyping with RhizoVision Explorer Software

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ABSTRACT

Background: Container design plays a vital role in nursery production as it influences overall plant quality and field establishment. Conventional containers often induce root circling and deformation, while air root pruning containers increase the number of descending roots. Therefore, the present study aimed to compare root pruning container and traditional container production systems on the growth and root architecture of *Tabernaemontana divaricata* (Dwarf).

Methods: The experiment was conducted in a completely randomized design with six treatments and three replications. Six 10-inch height containers were tested in this experiment: Brown plastic pot, black plastic pot, airpot, growbag, black polybag and white polybag. Two-month-old plants were grown in a medium of red soil, vermicompost and cocopeat enriched with biofertilizers. Growth, biomass and root parameters were recorded at 120 days after planting and root architecture was analyzed using RhizoVision Explorer software.

Result: Airpot (T₃) recorded superior shoot growth with maximum plant height (28.95 cm), stem diameter (10.54 mm), inflorescence per plant (6.66), number of branches/plant (58.00), number of leaves/branch (16.30), leaf area (2.49 cm²), chlorophyll content (52.13), shoot fresh weight (49.43 g), shoot dry weight (11.15 g) and shoot dry matter content (22.55%). Root phenotyping revealed greater root spread, total root length, root tips and branching points in growbag, while the black plastic pot recorded higher root volume and root biomass. Airpot containers minimized root circling and produced better quality nursery plants of *Tabernaemontana divaricata*.

Key words: Air pruning, Container type, Nursery production, Root architecture, *Tabernaemontana divaricata*.

INTRODUCTION

In contemporary horticulture, size, shape and material of the container have a major impact on the growth and development of plants in containerized plant production systems. Plant biomass output, physiological function and nutrient uptake efficiency are ultimately influenced by these parameters, which also have an impact on root development and the root-zone environment. Although they are frequently used in plant production, traditional nursery containers like plastic pots and polybags frequently produce unfavorable circumstances for root development resulting in root distortion, circling and poor plant establishment following transplanting (Pokhrel and Albrecht, 2024).

Modified container technologies, such air-pruning containers, have been created to improve root architecture in order to overcome these problems. The root tips of these containers are exposed to air through holes or perforations in their walls, which naturally prunes the root apex. A dense and fibrous root system is the outcome of this process, which disrupts apical dominance and encourages the growth of many lateral roots (Elsysy and Einhorn, 2022). Additionally, air-pruning containers promote even root distribution and avoid root-bound problems that are frequently seen in traditional containers (Singh *et al.*, 2024). A demonstrable growth advantage after transplanting perennial plants produced in air-pruning containers was purportedly due to a combination of greater absorptive

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capacity and limited transplant disturbance of their root systems compared to plants produced by alternative production methods.

Tabernaemontana divaricata (L.) R. Br. ex. Roem. and Schult., also known as Crape Jasmine or pin wheel

jasmine or milk flower, is a perennial evergreen shrub native to India and is extensively cultivated throughout South-East Asia and warm regions of continental Asia. Because of its eye-catching blossoms and bushy look, the dwarf variety is often favored for hedges and displays.

The ornamental plants' aesthetic value is enhanced by the containers, which are essential to plant and root growth. With a focus on the effectiveness of air-pruning containers in comparison to traditional nursery containers, the current study was carried out to compare the influence of conventional containers and the air pruning containers on the growth and root characteristics of *Tabernaemontana divaricata* Dwarf.

MATERIALS AND METHODS

An experiment to study the effect of different plant growing containers on shoot growth and root architecture was conducted during the year 2025-26 at SRM College of Agricultural Sciences, Chengalpattu. The location is situated between the latitudes of 12°23'19.7"N and the longitudes of 79°44'37.4"E, with an average altitude of 50 m and a relative humidity of 50 to 70 per cent. The average temperature in the area ranged from 23°C to 38°C during the study period. The experiment was laid out in a completely randomized design (CRD) with six treatments and three replications. The treatment comprises of different containers of 10-inch size: T₁- Brown pot, T₂- Black pot, T₃- Airpot, T₄- Growbag, T₅- Black polybag, T₆- White polybag. Uniform, healthy, disease-free, 2-month-old *Tabernaemontana divaricata* Dwarf plants were planted in different containers filled with red soil: Vermicompost: Cocopeat (2:1:1). The growing media in each container were enriched with 20 grams each of *Trichoderma viride*, *Pseudomonas fluorescens* and *Azospirillum*. The shoot and root characteristics were recorded on the 120th day of planting. Root morphological parameters were also analyzed using RhizoVision Explorer (version 2.0.3) software (Seethepalli *et al.*, 2021) after 120 days of planting. The data collected were subjected to ANOVA as per the design using statistical software (OPSTAT/R). Significant differences among treatments were assessed using the F-test and means were compared using CD at 5% level.

RESULTS AND DISCUSSION

Effect of containers on shoot characteristics of *Tabernaemontana divaricata* Dwarf

In the present study, shoot parameters of *Tabernaemontana divaricata* Dwarf recorded on 120 days of planting were significantly influenced by the type of containers used for cultivation (Table 1).

The highest plant height (28.95 cm) was recorded in T₃ (Airpot), which was statistically on par with T₄ (Growbag) (28.83 cm). The lowest plant height (24.33 cm) was observed in T₅ (Black polybag). Stem diameter at 120 DAP ranged from 8.83 mm to 10.54 mm across the treatments, which was statistically non significant. The maximum stem

Table 1: Effect of containers on shoot characteristics of *Tabernaemontana divaricata* Dwarf (120 DAS).

Treatments	Plant height (cm)	Stem diameter (mm)	No. of branches/plant (Nos.)	No. of leaf/branch (Nos.)	Leaf area (cm ²)	Chlorophyll content	Inflorescence per plant (Nos.)	Shoot fresh weight (g)	Shoot dry weight (g)	Shoot dry matter content %
T ₁	25.03	10.33	33.66	15.33	1.76	30.63	5.00	25.34	9.40	37.09
T ₂	25.30	10.21	41.66	13.33	1.92	48.16	5.22	43.22	10.57	24.45
T ₃	28.95	10.54	58.00	16.30	2.49	52.13	6.66	49.43	11.15	22.55
T ₄	28.83	10.38	47.33	15.00	2.23	48.53	4.55	33.11	8.03	24.25
T ₅	24.33	8.83	33.00	14.33	1.85	38.93	3.33	17.49	4.08	23.32
T ₆	26.30	9.57	38.33	12.33	1.49	27.83	3.11	24.21	6.39	26.39
SE (d)	1.20	0.78	0.96	0.33	0.04	4.43	0.73	0.38	0.14	0.63
CD at 5%	2.61	NS	2.09	0.75	0.10	9.65	1.60	0.83	0.30	1.37

diameter was observed in T₃ (Air pot) (10.54 mm), followed by T₄ (Growbag) (10.38 mm) and T₁ (Brown plastic pot) (10.33 mm). Among all treatments, plants grown in the T₃ (Airpot) consistently performed better, producing the highest number of branches (58.00), along with more number of leaves per branch (16.30) and greater leaf area (2.49 cm²). On the other hand, comparatively lesser branches (33.00) were recorded in treatments such as T₅ (Black polybag), while no. of leaf/branch (12.33) and leaf area (1.49 cm²) were lesser in T₆ (White polybag). A significant variation was observed in the number of inflorescence produced per plant. The highest number of inflorescence was recorded in T₃ (Airpot) (6.66), which was significantly higher than other treatments and statistically superior to T₅ (Black polybag) (3.33) and T₆ (White polybag) (3.11). The highest chlorophyll content was recorded in T₃ (Airpot) with 52.13 SPAD units, followed by T₄ (Growbag) (48.53) and T₂ (Black plastic pot) (48.16). In contrast, the lowest chlorophyll content was observed in T₆ (White polybag) (27.83), followed by T₁ (Brown plastic pot) (30.63). The treatment T₃ (Airpot) recorded maximum shoot fresh weight (49.43 g) and dry weight (11.15 g), while T₅ (Black polybag) recorded minimum shoot fresh (17.49 g) and dry weight (4.08 g). The shoot dry matter content ranged from 22.55% to 37.09%, with the highest and lowest value recorded in T₁ (Brown plastic pot) and T₃ (Airpot) respectively.

Effect of containers on root characteristics of *Tabernaemontana divaricata* dwarf

The root growth characteristics of *Tabernaemontana* plants were significantly influenced by the type of container used for cultivation (Table 2). The highest root volume was recorded in T₂ (Black plastic pot) (120.00 cm³), followed by T₁ (Brown plastic pot) (87.00 cm³) and the lowest (19.00 cm³) recorded in T₆ (Whitepoly bag). The treatment T₂ (Black plastic pot) recorded maximum root fresh weight (81.22 g) and dry weight (30.22 g), while T₆ (White polybag) recorded minimum root fresh (13.90 g) and dry weight (2.90 g). The root dry matter content ranged from 16.50% to 37.20%, with the highest value recorded in T₂ (Black plastic pot). The highest root:shoot ratio was observed in

T₂ (Black plastic pot) (2.85), while the lowest root:shoot ratio was observed in T₆ (White polybag) (0.45).

Root phenotyping using the rhizoVision explorer software

Among the root parameters analyzed using software (Table 3), the maximum values for root spread (26.8 cm), total root length (19763.20 cm), number of root tips (10069), number of branch points (12063.00) and root perimeter (10552.30 cm²) were recorded in T₄ (Growbag) while, the maximum values for root length (65.40 cm) and branching frequency (0.13 mm⁻¹) was recorded in T₂ (Black plastic pot). The lowest values for root length (28.00 cm), root spread (15.30 cm), root diameter (0.90 mm), total root length (4578.34 cm), branching frequency (0.053 mm⁻¹), number of root tips (3062.00), number of branch points (2257.00) and root perimeter (3275.04 cm²), total root length ≤0.4 mm (4061.75 mm) were recorded in T₆ (White polybag). The treatment T₃ (Airpot) recorded a root length (43.60 cm), root spread (21.40 cm), root diameter (1.73 mm), total root length (14566.01 cm), branching frequency (0.099 mm⁻¹), number of root tips (6345.00), number of branch points (6362.00) and root perimeter (6147.60 cm²), total root length ≤0.4 mm (10568.65 mm).

The success of plant growth in the nursery and cultivation is greatly influenced by the design of the container. The purpose of this study is to investigate different containers, their distinctive qualities and how they affect *Tabernaemontana divaricata* Dwarf root properties and plant growth and development. Additionally, this study highlights the significance of container type and design in influencing root development and plant performance as it is the first report on root architectural attributes influenced by various container types. Containers affect root system development and architecture (Heiskanen and Rikala, 1998; Chirino *et al.*, 2008) growth and biomass allocation (Tsakalidimi *et al.*, 2005; Gilman *et al.*, 2010; Dumroese *et al.*, 2011).

Impact of containers on shoot characteristics

The airpot container (T₃) outperformed the other treatments in the following shoot parameters: Plant height (28.95 cm), stem diameter (10.54 mm), inflorescence per plant (6.66),

Table 2: Effect of containers on root characteristics of *Tabernaemontana divaricata* Dwarf (120 DAS).

Treatments	Root volume (cm ³)	Root fresh weight (g)	Root dry weight (g)	Root dry matter content %	Root: Shoot ratio
T ₁	87.00	44.27	9.55	21.57	1.01
T ₂	120.00	81.22	30.22	37.20	2.85
T ₃	48.00	33.51	6.21	18.53	0.55
T ₄	69.00	49.94	8.71	17.44	1.08
T ₅	22.00	23.51	3.88	16.50	0.95
T ₆	19.00	13.90	2.90	20.86	0.45
SE (d)	1.30	0.40	0.13	0.53	0.03
CD at 5%	2.83	0.88	0.29	1.17	0.06

root: Shoot ratio (0.55), number of branches/plant (58.00), number of leaves/branch (16.30), leaf area (2.49 cm²), chlorophyll content (52.13), shoot fresh weight (49.43 g), shoot dry weight (11.15 g) and shoot dry mater content (22.55%). This is in line with the findings of Pinto *et al.* (2011) and Bühler *et al.* (2012), that container parameters affect sapling growth and development and consequently, the quality of saplings produced. The increased ability of tiny roots to absorb available water and nutrients may be the cause of the overall improvement in the shoot properties of plants cultivated in air pots. This result is consistent with Elsysy and Einhorn (2022) and Bouma *et al.* (2001).

The improved shoot features in this study were concordant with those reported by Mariotti *et al.* (2015), who reported that container configuration significantly affected the growth and development of seedlings of *Quercus robur* and *Juglans regia*. According to several research (Annapurna *et al.*, 2004; Poorter *et al.*, 2012), the size and form of the container affect plant biomass and its distribution; hence, the saplings generated in this manner have an effect on the field establishment upon transplanting (Chirino *et al.*, 2008). According to Wilson and Jacobs (2006), this study emphasizes some characteristics of saplings that should be taken into account because they are likely to impact the performance when planting out.

The superior growth performance of *Tabernaemontana divaricata* (dwarf) grown in air-pot containers in the current study demonstrated that greater nutrient uptake and root-zone aeration in air-pot containers may be responsible for improved shoot growth. Airpots' perforated structure improves root respiration and nutrient absorption by preventing water logging in the growing medium and facilitating improved oxygen diffusion. Singh *et al.* (2024) found similar results, showing that *Buxus sempervirens*, *Lawsonia inermis*, *Murraya paniculata*, *Schefflera arboricola* and *Tecoma stans* plants grown in airpots had far greater shoot biomass, collar diameter and plant height than those planted in polybags.

The results of this study are in line with those of Simshaw *et al.* (2015), who found that the dry weights of *Amelanchier* × *grandiflora* 'Cole's Select' and *Rhus aromatica* 'Gro Low', shoots in the airpots (T₃) were around 66% higher than those in the smart pot (298 g). The findings of Tsakalimi *et al.* (2005), Gilman *et al.* (2010) and Dumroese *et al.* (2011) that containers affect plant development and biomass allocation comply with the greater biomass found in this study. Given its correlation with field performance in semi-arid settings (Leiva and Fernandez-Ales, 1998; Villar-Salvador *et al.*, 2004), the shoot/root ratio is a crucial characteristic for hardwood seedling quality evaluation (Wilson and Jacobs, 2006). Because of its greatest root length and fresh weight, the T₂ (Black plastic pot) in the current study had the highest shoot-root ratio. Similar report was given by Kalsi *et al.* (2025).

Table 3: Root phenotyping of *Tabernaemontana divaricata* dwarf using the RhizoVision Explorer software (120 DAP).

Treatments	Root length (cm)	Root spread (cm)	Root diameter (mm)	Total root length (cm)	Branching frequency (mm ⁻¹)	No. of root tips (Nos.)	No. of branch points	Root perimeter (cm ²)	Total root length ≤0.4 mm
T ₁	43.00	26.50	1.11	9862.11	0.114	6090.00	4679.00	4744.30	6447.54
T ₂	65.40	25.20	1.32	16320.45	0.134	6081.00	11169.00	8296.70	7408.81
T ₃	43.60	21.40	1.73	14566.01	0.099	6345.00	6362.00	6147.60	10568.65
T ₄	42.80	26.80	1.50	19763.20	0.115	10069.00	12063.00	10552.30	8356.33
T ₅	30.60	15.50	0.98	8769.09	0.105	7101.00	7779.00	7891.50	4271.17
T ₆	28.00	15.30	0.90	4578.34	0.053	3062.00	2257.00	3275.04	4061.75
SE (d)	0.96	0.59	0.02	206.95	0.002	144.91	65.03	137.91	207.79
CD at 5%	2.11	1.28	0.04	452.74	0.005	315.75	141.69	300.49	452.74

Impact of containers on root characteristics

The total root volume for air-pruning containers was significantly greater among the manually measured root parameters in this investigation, which is corresponding to the results of Elsysy and Einhorn (2022) in apple cultivars Gala and Honey crisp at the end of the season. In the same way, the treatment T₂ (Black plastic pot) had larger root fresh weight and dry weight, whereas the air pot had lower root mass in this investigation. In the current study, the root dry matter content percentage and shoot-root ratio are highest in conventional pots and medium in plants produced in air pots (Fig 1). Amoroso *et al.* (2010) found similar results across trees cultivated in traditional smooth-walled containers and small leaf linden trees grown in air-pruning containers for a single season. In a

similar vein, Elsysy and Einhorn (2022) found that various apple cultivars cultivated in air-pruning containers had more shoot biomass and smaller roots than field-grown plants. When plants are eventually transplanted into landscape settings, the decrease in root biomass could be advantageous if it is followed by a decrease in frequent root abnormalities such kinked, circular, or girdling roots. The current study's findings align with those of Fitzpatrick *et al.* (1994) study on mahogany, which found that plants cultivated in normal black plastic containers had larger root masses than those produced in air root pruning containers. Larger carbohydrate reserves are associated with higher total biomass (Close *et al.*, 2010), which implies that air-pruned seedlings would grow more than non-pruned seedlings (Tsakalidimi *et al.*, 2013; Yang *et al.*, 2011).



Fig 1: Root characteristics of *Tabernaemontana divaricata* (dwarf) in black plastic pot and airpot.

RhizoVision Explorer (version 2.0.3) software was used to record the root parameters of *Tabernaemontana divaricata* (dwarf), which revealed a substantial difference between the treatments. The black plastic pot (T_2) had the highest parameters for root length (cm), root spread (cm) and branching frequency (mm^{-1}), whereas T_4 (Growbag) had the highest parameters for total root length (cm), number of root tips (Nos.), number of branch points and root perimeter (cm^2) (Fig 2). Higher root diameter and finer root values were reported in the air pot which is in line with the findings Elsysy *et al.* (2022) of The root circle was extensive, with roots concentrated on the outside wall, even if the root features were on the higher side for the standard pots such plastic pots and growbags in the current study. In contrast, the plants grown in air pots had medium root length and root spread, which prevented the roots from coiling (Fig 3). According to Gilman (2009), Grossnickle and El-Kassaby (2015) and South and Mitchell (2006), these conventional containers may promote root circling and the development of pot-bound roots, which can

negatively impact tree establishment and growth after long-term field transplantation. The importance of having a well-defined root system is frequently emphasized (Ruehle and Kormanik, 1986; Davis and Jacobs, 2005; Wilson and Jacobs, 2006). Elsysy and Einhorn (2022) found that several apple cultivars grown in air-pruning containers had smaller roots and higher shoot biomass than field-grown liners.

The results revealed reasonable values for root parameters when compared to growbags and plastic pots, despite the fact that airpots (T_3) are intended to encourage air pruning and avoid root circling. Instead of prolonged root elongation, more root tip pruning may result in the production of many lateral roots, which could affect measures of total root length. In comparison to containers with a higher rooting volume, air pruning containers may decrease total root extension while stimulating fibrous root systems (Dumroese *et al.*, 2011).

According to earlier research, air root pruning containers reduce root circling (Marshall and Gilman, 1998)

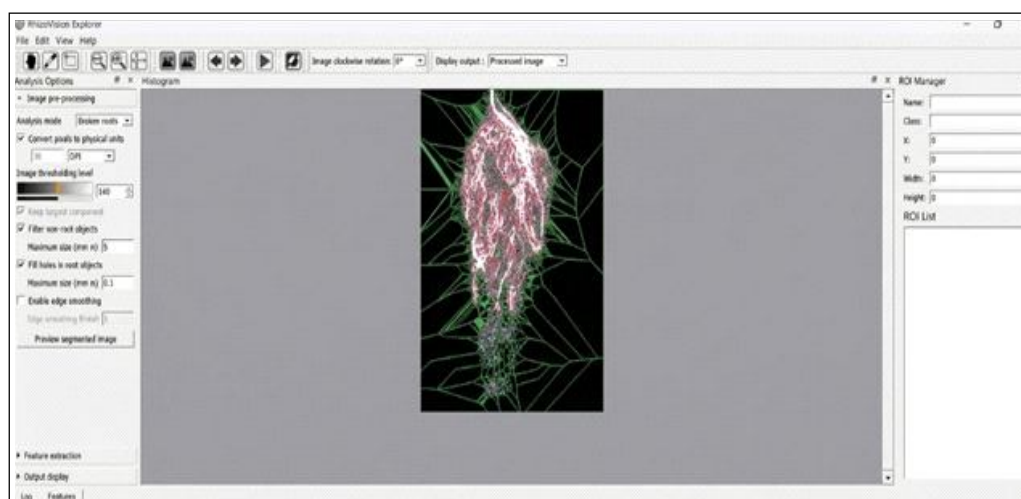


Fig 2: Root phenotyping of black plastic pot grown *Tabernaemontana divaricata* (dwarf) in RhizoVision Explorer software.

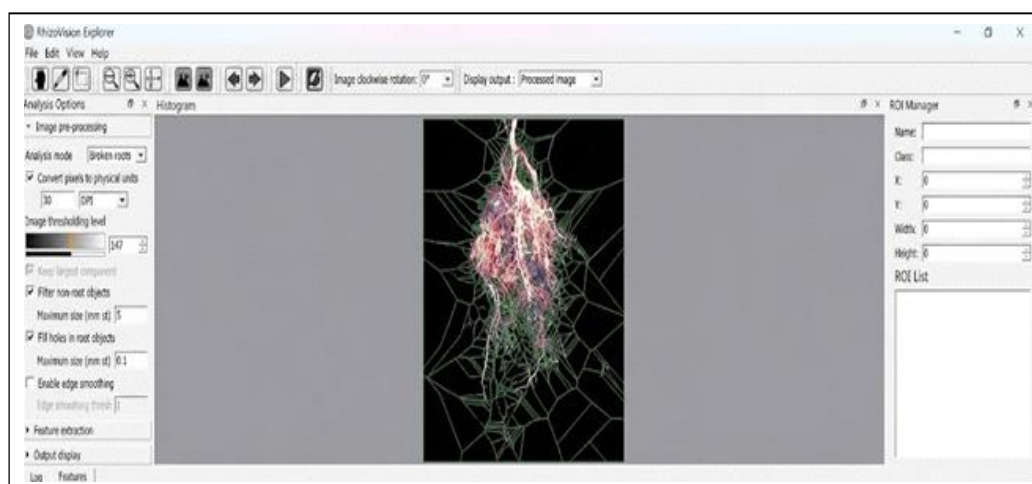


Fig 3: Root phenotyping of airpot grown *Tabernaemontana divaricata* (dwarf) in RhizoVision Explorer software.

and have fewer packed, spiraling and L-shaped roots (Ortega *et al.*, 2006) this is in accordance with the minimal value for the root characteristics in airpot grown plants in the current study.

In contrast to the findings of Pokhrel and Albrecht (2024), who reported that air pruning produced more thicker roots than the other containers, the root diameter in the current study was higher in brown and black plastic pots and smaller in air pots. According to Desrochers *et al.* (2002); Makita *et al.* (2009) and Pregitzer *et al.* (2002), the total length of the root was maximum in traditional containers, whereas the total length of the root ≤ 0.4 mm (finer roots) was maximum in air pots, which typically have a faster respiration rate than coarser roots. More fine-rooted plants are probably better able to adjust to shifting soil conditions, which increases the chances of successful establishment upon transplant. Additionally, some researchers have discovered that fine roots are linked to root adaptations for survival in shifting settings and are involved in the manufacturing of specific growth hormones (Di Iorio *et al.*, 2016; Makita *et al.*, 2016; Mosca *et al.*, 2017). A wider root spread in these containers may be associated with better lateral root expansion due to a larger internal space and reduced root confinement. An essential measure of root exploration ability and nutrient uptake efficiency is root spread (Gregory, 2006).

Using customized containers with walls made to direct roots toward an air hole is known as air pruning. Root tips will become dehydrated when coming into touch with air, which will lead to pruning. Air pruning encourages the development of a dense fibrous root system within the substrate by stimulating lateral root growth and root branching (Elsysy and Einhorn, 2022; Feng *et al.*, 2018).

All of the study's findings suggest that using air-root pruning containers in the nursery may benefit roots, perhaps through improved physiological and ecological processes such as better nutrient and water uptake. The better root architecture of air pot container produced better shoot parameters in *Tabernaemontana divaricata* (dwarf) compared to conventional containers. This air pot also excluded the root coiling and regular root pruning in the container grown nursery plants.

CONCLUSION

In conclusion, the study revealed that container type significantly influenced the growth and root architecture of *Tabernaemontana divaricata* (Dwarf). Among the treatments, plants grown in airpot (T_3) showed superior shoot growth and overall plant performance. Conventional containers such as black plastic pot (T_2) and growbag (T_4) produced higher root mass but also showed root circling. In contrast, airpot containers promoted better root pruning and balanced plant growth. Therefore, airpot containers can be recommended for producing quality nursery plants of *Tabernaemontana divaricata*.

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Compliance with ethical standards

Ethical issues

None.

Conflict of interest

The authors have disclosed no conflicts of interest.

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