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EFFECT OF NANOFERTILIZER AND POT SIZE ON THE VEGETATIVE TRAITS OF BOTTLEBRUSH (*CALLISTEMON VIMINALIS* L.)

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SUMMARY

The seedlings' development in the nursery and preparing them for planting depends on some main primary factors, including the pot size and fertilization. The timely study aimed to determine the effects of pot size and nanofertilizer levels on the growth and development of bottlebrush (*Callistemon viminalis*) seedlings, carried out in 2021 at the University of Mosul, Mosul, Iraq. The study comprised two factors, with the first factor using pots with three different sizes (small, medium, and large), and the second factor was the treatment with NPK nanofertilizer at three concentrations (0, 2, and 4 g L^{-1}). The results showed pot size, NPK nanofertilizers, and their interactions have a significant impact on all studied traits. The large pot size and increased level of NPK nanofertilizer (4 g L^{-1}) individually exhibited the highest increase in seedling height, stem diameter, number of branches, number of leaves, and shoot dry weight. The interaction between the large pot and NPK nanofertilizer (4 g L^{-1}) also showed the best performance for the traits: seedling height (131.73 cm), stem diameter (12.06 mm), number of branches (39.06 branch $seedling^{-1}$), number of leaves (1,181.4 leaves $seedling^{-1}$), and shoot dry weight (68.78 g).

Keywords: Bottlebrush (*Callistemon viminalis*), pot size, NPK nanofertilizer, morphological and growth traits

Key findings: The large pot size and increased level of NPK nanofertilizer (4 g L^{-1}) individually and in combination exhibited the highest increase in seedling height, stem diameter, number of branches and leaves, and shoot dry weight.

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INTRODUCTION

Bottlebrush (*Callistemon viminalis* L.) is a beautiful evergreen shrub or small tree. It belongs to the genus *Callistemon* of the family Myrtaceae, which includes 34 species worldwide, with 10 of them found in India (Shokri *et al.*, 2012). The *C. viminalis* is a woody aromatic tree (about 5–7 m in length) widespread over humid tropical regions worldwide (Oyedeji *et al.,* 2002; Srivastava *et al.,* 2003; Abdelhady *et al.,* 2011). This tree is characteristically a dense evergreen, with pendulous branches and narrow and light-green colored leaves. The flowers are crimson red, bright, cylindrical, and consisting of multiple long stamens resembling bristly hairs, and the fruits are capsules (Shokri *et al.*, 2012). The bottlebrush is a strong plant that resists freezing, air currents, and temperatures falling below minus 10 °C, as well as tolerating soil salinity (Brophy *et al.,* 1997). It is also tolerant of high temperatures in the summer and prefers light, rich, well-drained, and aerated soil.

The bottlebrush tree can be propagated sexually through seeds or vegetatively through cuttings. The preferred method of propagation is semi-hardwood cuttings taken from selected cultivars (Hartman *et al.,* 2002). However, it also requires treatment with growth regulators (Hameed and Asmaa, 2020). Different types of bottlebrush trees widely apply as windbreaks in forests, reclaiming and rehabilitating degraded lands, as well as being used in the forestation of parks, public gardens, and roadsides due to the beauty of their flowers (Salem *et al.,* 2013). The bottle tree has also become an important medicinal plant used to treat infections, stomach and intestinal pain, diarrhea, skin infections, respiratory problems, and for various other medical benefits (Afrah, 2012; Gohar *et al.,* 2014).

In nurseries, the use of pots is one of the main factors in the success of seedling development (Poorter *et al.,* 2012). In arid and semi-arid zones, the successful tree planting requires a high-strength seedling, carrying out the practices in the nursery affecting the strength of seedlings, and thus, successfully cultivating them in the field (Oliet *et al.,* 2009; Del-Campo *et al.,* 2010). Seedlings of four important tree species, namely, *Acacia nilotica, Acacia tortilis, Dobera glabra,* and *Ziziphus spina-christi,* grown in different sizes of plastic containers and soil mixtures, revealed seedlings raised in large pots had a taller height and a significantly broader root diameter than those raised in small containers (Abera *et al.,* 2018).

As a result of the negative effects of the improper use of mineral fertilizers, including soil pollution in addition to the increased salinity of the soil, it is necessary to consider using modern fertilizers as an alternative to traditional fertilizers. Moreover, use them to provide the nutrients necessary for plant growth and development, increased productivity, and preserving the soil environment from pollution (Miransari, 2011). One such product, which is also environmentally friendly and a highly effective fertilizer, are nanofertilizers. These fertilizers' application can be in minimal quantities compared with the traditional mineral fertilizers used, helping maintain environmental safety (Noaema *et al.*, 2020).

A past study conducted on *Albizia lebbeck* seedlings revealed adding NPK nanofertilizers (2 g L^{-1}) led to a significant increase in the growth and yield-related traits (Al-Jibouri *et al.*, 2021). After spraying the NPK nanofertilizer on *Pinus brutia* seedlings, the results showed the seedlings sprayed with the nanofertilizer were superior in performance than the seedlings of the control treatment for studied characteristics. Based on the above discussion, the presented study sought to determine the appropriate size of the pot that gives the best vegetative growth. Similarly, it aimed to know the effect of foliar application of NPK nanofertilizers in stimulating the vegetative system of the bottlebrush (*Callistemon viminalis*) seedlings.

MATERIALS AND METHODS

Study site and the experimental design

The study proceeded in 2021 under the wooden canopy of the nursery at the University of Mosul, Mosul, Iraq. It aimed to know the effects of pot size and the foliar application of NPK nanofertilizer on the vegetative traits of bottlebrush (*C. viminalis*) seedlings. Sample seedlings were two years old with uniform size, height, and lateral branches and intact from pathological and mechanical injuries, and planted in black polyethylene bags. The study employed a randomized complete block design (RCBD) with two factors and three replications. The first factor was the pots with three sizes, i.e., small (18 cm × 18 cm, 3 kg), medium (22 cm × 22 cm, 9 kg), and large size (27 cm × 32 cm, 12 kg). The second factor was the foliar application of the neutral NPK nanofertilizer (20:20:20) with three concentrations (0, 2, and 4 g L^{-1}). The NPK neutral nanofertilizer came from purchases in agricultural supply stores.

Seedlings and their spraying time

Seedlings' transfer to black plastic pots of three sizes (small, medium, and large) contained mixed soil**.** The spraying of seedlings with NPK nanofertilizers transpired on four dates (spring 2 + autumn 2). In the spring, the first foliar application ensued on April 1, 2022, while the second spraying was one month later after the first spraying. The fall, which was the third spray, occurred on September 15, 2022, with the second fall spraying made one month later after the first spray. The control treatment spray used distilled water only. The spraying process progressed early in the morning by using an eight-liter capacity sprinkler. The field operations of hoeing and percolation, in addition to watering, continued in sufficient quantities until the end of the experiment.

Studied traits

The characteristics measured before applying the treatments and after completing the experiment included seedling height, seedling diameter, number of branches, and number of leaves. Five seedlings taken from three replications had the said traits measured. For seedling height (cm), measuring began for the length of the main stem of the seedling from the area of contact of the stem with the root to the end of the apex. For diameter of the main stem (mm), the measurement of diagonal growth included the diameter of the main stem of the seedling at a point 0.5 cm from the point where the stem connects to the root using the vernier digital foot. The number of branches on the main stem incurred counting. For the number of leaves per seedling, calculating the increase in the number of total leaves proceeded by finding the difference in number before and after the treatment. Measuring fresh shoot weight (g), separating the shoots from the root, and then estimating the fresh weight of the shoot for each seedling used a sensitive electric balance. For dry weight of shoots (g), the shoots of the selected seedlings bore drying by placing them in an electric oven at a temperature of 70 °C until the weight was stable, weighing with an electric balance.

Data analysis

All the recorded data underwent assessment according to the analysis of variance (ANOVA) as per randomized complete block design (Gomez and Gomez, 1984). Using the least significant difference (LSD) helped compare and separate the mean differences for all the parameters. The statistics software GenStat12 was the tool for the analysis.

RESULTS AND DISCUSSION

Seedling height

The pot size and NPK nanofertilizer treatments showed significant differences and a considerable effect on seedling height of the bottlebrush (*C. viminalis*) (Table 1). The highest increase in the seedling height was visible with a large pot size (114.85 cm), differing significantly from the medium and small pots. However, the small pots gave the lowest average height of the seedlings (97.11 cm). The NPK nanofertilizer concentration (4 g L^{-1}) emerged with the premiere increase in seedling height (124.4 cm), and it varied substantially from the nanofertilizer concentration (2 g L^{-1}) and control treatment,

Table 1. Effect of pot size, Nano-NPK on the seedling height in bottlebrush (*C. viminalis*).

Pot size (kg^3)	NPK nanofertilizer concentrations ($g\ L^{-1}$)			Means (cm)
	0	2	4	
Small	60.20	112.00	119.13	97.11
Medium	75.8	116.4	122.33	104.84
Large	89.80	123.03	131.73	114.85
Means (cm)	75.26	117.14	124.40	

$LSD_{0.05}$ Pot size: 2.82, Nano-NPK: 2.82, Pot size x Nano-NPK: 5.64

Table 2. Effect of pot size, Nano-NPK on the diameter of the main stem of seedlings.

Pot size (kg^3)	NPK nanofertilizer concentrations ($g\ L^{-1}$)			Means (mm)
	0	2	4	
Small	6.55	8.18	8.78	7.83
Medium	7.37	8.50	9.92	8.60
Large	7.50	9.89	12.06	9.820
Means (mm)	7.14	8.86	10.25	

$LSD_{0.05}$ Pot size: 0.86, Nano-NPK: 0.86, Pot size x Nano-NPK: 1.72

which hardly gained the seedling height of 75.26 cm.

In the interaction between the pot sizes and NPK nanofertilizer concentrations, the rise in seedling height reached its maximum rate in the interaction of the large pot and the nanofertilizer concentration of 4 g L^{-1} (131.73 cm). The said interaction was significantly different from other interactions, while the control treatment showed the lowest seedling height (60.20 cm). These results were consistent with past findings, as reported that the larger plastic bags significantly affected the growth of *Prosopis cineraria* seedlings (Alrubaiee *et al*., 2019; Abugre and Oti-Boateng, 2011; Al-Tamimi *et al*., 2023; Ali *et al*.,2024). Nanotechnology plays a role in better delivering nutrients to plants, raising the efficiency of their absorption and use by the plant. It also increases the ability of the roots to absorb nutrients from the soil effectively and thus can contribute to enhancing the plant's ability to withstand harsh environmental conditions, improving their growth. These results agreed with Soliman *et al.* (2015), who reported foliar application of nanofertilizer considerably improved the growth of *Moringa peregrine*.

Main stem diameter

For main stem diameter in bottlebrush (*C. viminalis*), the pot size and NPK nanofertilizer treatments showed significant differences (Table 2). The largest pot size provided the highest rate of main stem diameter (9.82 mm), which varied meaningfully from the seedlings grown in medium-sized pots. However, the small-sized pot gave the lowest main stem diameter (7.78 mm). In the case of NPK nanofertilizer treatments, the maximum concentration (4 g L^{-1}) revealed the topmost value for the main stem diameter (10.25 mm), which significantly differed from the concentration of 2 g L^{-1}. However, the control treatment showed the lowest main stem diameter (7.14 mm).

In the interaction treatments of pot size and nanofertilizer levels, the interaction between the large pot and the nanofertilizer concentration (4 g L^{-1}) had the highest value of the main stem diameter (12.06 mm), significantly differing from the rest of the interactions. However, the comparison treatment appeared with the lowest rate for the said trait (6.55 mm). Dumroese *et al.* (2011) noted the positive effect of container size on the stem diameter of *Acacia koa* seedlings. Larger pots provide more space for better expansion and growth of the roots, which eventually affected the overall growth and development of spruce (*Picea smithiana*) (Mugloo *et al.*, 2015). Nanofertilization has an influential role in improving the seedling growth by increasing soil resources and the seedling's ability to collect more resources, and consequently, enhancing the rate of photosynthesis and stem diameter and seedling height in the plants (Razaq *et al.,* 2017).

Branches per seedling

The pot size and NPK nanofertilizer treatments showed notable differences for branches per seedling in bottlebrush (*C. viminalis*) (Table 3). Results revealed the large pot size showed an increased number of branches per seedling (28.44) and was significantly diverse from the medium and the small pot sizes. However, the small pot gave a smaller number of branches per seedling (16.35). In the case of NPK nanofertilizer, the concentration of 4 g L^{-1} enunciated the highest rate of the number of branches per seedling (27.57). It remarkably differed from the nanofertilizer with low concentration (2 g L^{-1}) and the comparison treatment, giving the lowest number of vegetative branches per seedling (14.93).

The interaction between the different pot sizes and NPK nanofertilizer concentrations showed a significant effect on increasing the number of branches per seedling. The interaction between the large pot and the nanofertilizer concentration (4 g L^{-1}) provided the most average branches per plant (39.06), and it was very different from the other interactions. The comparison treatment, on the other hand, had the fewest stems per plant (11.73). The research by Abera *et al*. (2018) stated making the planting pot bigger has a big impact on the growth of crop seedlings. Seedlings grown in big pots will get bigger and stronger faster than seedlings grown in small pots. The better performance of seedlings in larger pots is due to more space for growth, and these results were consistent with past findings reported in stone pine (*Pinus pinea*) seedling development (Dominguez-Lerena *et al.,* 2006). NPK nanofertilizer indicated a significant increase in most of the vegetative and root traits of *Pinus brutia* seedlings. This may be due to the ability of nanofertilizer to improve the plant’s absorption of nutrients due to their small size. These fertilizers can quickly and effectively penetrate into plant tissues, enhancing the plant’s ability to use nutrients better and increasing its overall growth, increasing the number of plant branches (Sharif, 2021).

Table 3. Effect of pot size, Nano-NPK on the increase in the number of branches.

Pot size (kg^3)	NPK nanofertilizer concentrations (g L^{-1})			Means (branches $seedling^{-1}$)
	0	2	4	
Small	11.73	17.46	19.86	16.35
Medium	14.66	22.93	23.80	20.46
Large	18.4	27.86	39.06	28.44
Means (branches $seedling^{-1}$)	14.93	22.75	27.57	

$LSD_{0.05}$ Pot size: 2.73, Nano-NPK: 2.73, Pot size x Nano-NPK: 5.46

Table 4. Effect of pot size, Nano-NPK on the number of leaves.

Pot size (kg^3)	NPK nanofertilizer concentrations (g L^{-1})			Means (leaves $seedling^{-1}$)
	0	2	4	
Small	438.46	530.73	886.33	618.51
Medium	517.33	842.40	1050.46	803.40
Large	635.80	963.80	1181.40	927.00
Means (leaves $seedling^{-1}$)	530.53	778.97	1039.40	

$LSD_{0.05}$ Pot size: 60.87, Nano-NPK: 60.87, Pot size x Nano-NPK: 121.74

Leaves per seedling

For leaves per seedling in bottlebrush (*C. viminalis*), the pot size and NPK nanofertilizer levels revealed significant differences (Table 4). The large pot size showed the most number of leaves per seedling (927.00). It differed substantially from the rest. However, the small pot exhibited the least number of leaves per seedling (618.51). The nanofertilizer concentration of 4 g L^{-1} showed the maximum average number of leaves per seedling (1039.40), significantly varying from the lower concentration of 2 g L^{-1}. However, the control treatment provided the lowest average number of leaves per seedling (530.53).

The results further revealed the interaction between the different pot sizes and NPK nanofertilizer concentrations indicated a considerable impact on increasing the number of leaves per seedling. The interaction of a large size pot with NPK nanofertilizer concentration (4 g L^{1}) showed the ultimate number of leaves per seedling (1181.4), and the said interaction considerably contrasting from the rest of the interactions. However, the comparison treatment gave the lowest number of leaves per seedling (438.46). The promising results were consistent with past findings in studying the response of *Citrus reticulata* seedlings to foliar application of NPK nanofertilizer. The effect of nanofertilization on increasing the number of leaves per seedling could be a result of its role in providing the necessary nutrients to the plant. This, then, contributes to raising the efficiency of growth processes by stimulating photosynthesis and metabolism in the plant, enhancing growth and leaf development (Al-Karaawi 2020; Al-Taie, 2020).

Fresh shoot weight

The pot size and foliar application of NPK nanofertilizer treatments exhibited noteworthy variations for fresh shoot weight in bottlebrush (*C. viminalis*) (Table 5) The highest fresh shoot weight was evident in the seedlings grown in medium-sized pots (86.17 g); however, it did not differ significantly from the seedlings developed in the large pots. The small pot manifested with the lowest average fresh shoot weight (75.01 g). The NPK nanofertilizer higher concentration of 4 g L^{-1} showed the optimum fresh shoot weight (107.80 g), and it differed significantly from the lower concentration (2 g L^{-1}). However, the control treatment provided the lowest fresh shoot weight (47.29 g).

The interaction between the studied factors displayed a significant effect on the fresh shoot weight. The interaction between the medium pot size and NPK nanofertilizer concentration of 4 g L^{-1} showed the highest fresh shoot weight (121.18 g), and it also differed significantly from the rest of the interactions. However, the comparison treatment gave the lowest fresh shoot weight (45.68 g). Al-Jibouri *et al.* (2021) treating *Albizia lebbeck* seedlings by adding NPK nanofertilizer with 2 g L^{-1} led to a significant increase in fresh and dry shoot weight. These results were also greatly analogous to past findings by treating the *Pinus brutia* seedlings with nanofertilizer (5 g L^{-1}). It outperformed the rest of the seedlings in all the studied characteristics, including an increase in longitudinal and diagonal growth and fresh and dry shoot weight (Sharif, 2021; Al-Mathidy *et al.*, 2023; Al-Musawi and Al-Tamimi, 2023).

Dry shoot weight

The pot size and NPK nanofertilizer treatments demonstrated major differences for dry shoot weight in bottlebrush (*C. viminalis*) (Table 6). The results revealed the large pot gave the maximum average of dry shoot weight (50.90 g); however, it did not differ significantly from the medium size pot but differed from the small size pot, recording the minimum average dry shoot weight (39.05 g). The NPK nanofertilizer (4 g L^{1}) treatments exhibited the highest rate of dry shoot weight (61.59 g), and it significantly varied from the nanofertilizer low concentrations (2 g L^{-1}). However, the control treatment gave the lowest dry shoot weight (23.41 g).

The interactions between the different sizes of pots and the NPK nanofertilizer concentrations surfaced, with a significant effect on the dry shoot weight. The interaction between the large pot and NPK nanofertilizer

Table 5. Effect of pot size, Nano-NPK on the fresh weight of the shoots.

Pot size (kg^3)	NPK nanofertilizer concentrations ($g\ L^{-1}$)			Means (g)
	0	2	4	
Small	45.68	82.07	97.28	75.012
Medium	46.74	90.59	121.18	86.17
Large	49.47	93.42	104.95	82.61
Means (g)	47.29	88.69	107.80	

$LSD_{0.05}$ Pot size: 4.52, Nano-NPK: 4.52, Pot size x Nano-NPK: 9.04

Table 6. Effect of pot size, Nano-NPK on the dry weight of the shoot.

Pot size (kg^3)	NPK nanofertilizer concentrations ($g\ L^{-1}$)			Means (g)
	0	2	4	
Small	18.92	43.37	54.88	39.05
Medium	24.11	51.48	61.11	45.57
Large	27.21	56.71	68.78	50.90
Means (g)	23.41	50.52	61.59	

$LSD_{0.05}$ Pot size: 5.38, Nano-NPK: 5.38, Pot size x Nano-NPK: 10.66

(4 g L^{-1}) provided the highest average dry from the rest of the interactions. However, the comparison treatment gave the lowest dry shoot weight (18.92 g). Abugre and Oti-Boateng (2011) authenticated the dry shoot weight was contrasting and boosted with the large size container in the *Jatropha curcas.* Mugloo *et al.* (2015) also reported the addition of nanofertilizer indicated a prominent increase in the fresh and dry shoot weight of Albizia tree seedlings.

CONCLUSIONS

The results revealed large pot size has a primary role in the seedling growth traits of bottlebrush (*C. viminalis* L.). Nanofertilization (4 g L^{-1}) has a positive effect in raising the efficiency of growth and development processes by increasing the seedling's ability to utilize the resources available in its surroundings.

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