EFFECTS OF DIFFERENT POT SIZES AND WATER DEFICIENCIES ON THE GROWTH PERFORMANCE OF SHOOT AND ROOT ALLOTMENT OF *Azadiratcha indica* A. JUSS seedlings

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Abstract: Study examined the effect of pot sizes and water deficiencies in the growth performances and root allotment of *A. indica* seedlings were studied while four sizes of pots were selected for use. The smallest pot size was the polythene bag used for potting mixture (16cm length x 10cm top diameter x 10 cm bottom diameter) approximately 2L in volume. The second pot used was cement bag with (23cm length x 25cm top diameter x 15cm bottom diameter) approximately 4L in volume. Other two pot sizes were made from polyvinyl chloride (PVC) pipe of 4 inches and 6 inches cut to 50 cm length which produced pots with approximate volumes of 4L and 9L. The pots were filled to 2.5 cm below the brim of the pots with a topsoil and poultry manure at ratio 2:1 which were taken from the departmental nursery. Randomised Complete Design of eight treatment combinations with seven replications were applied. Results showed that there is significant difference in total shoot length between the pot size ($F_{7, 48}$=8.45, P=0.0001, stem diameter ($F_{3, 54}$=34.80, $P < 0.001$), mean root length ($F_{1, 54}$ = 1.136, P=0.249), the mean number of lateral roots ($F_{7, 48}$=26.42, $P<0.001$), mean root / shoot ratio ($F_{7, 48}$= 23.55, $p<0.001$). Pot size in this study was associated with an increased allocation of root/shoot ratios revealed apparent differences in growth response to water deficit. Therefore, pot size of (23cm length x 25cm top diameter x 15cm bottom diameter) approximately 4L in volume is adequate for producing large *A. indica* seedlings

Keywords: *Azadiratcha indica*, pot sizes, root allotment, variations and water deficit

Introduction

Tree growing in arid areas evolved many physiological, morphological and anatomical adaptation mechanisms to adapt with water deficit and drought in the arid conditions with strong water restrictions, a poorly developed seedling root system will lead to high mortality in plantations (Arndt *et al*.. 2001, Mundree *et al*.. 2002). Consequence from this, it is necessary to produce seedlings with a suitable biomass distribution, an optimum root/shoot ratio and a root system capable of reaching more quickly the deeper horizons where some soil moisture could be available during the dry season.

The use of seedlings produced in containers or plastic pots is the most common technique for introducing native species in dry and semi-arid ecosystems (Cortina *et al.,* 2004). Plant species which are native to arid environment typically have high root: shoot ratios and show plasticity in response to changes in soil water status (Jibo and Barker, 2019). For instant, a significant increase in root:shoot ratio has been shown in young seedlings of *A. senegal* seedlings as the level of water stress increased (Jibo and Barker, 2019, Jibo and Barker 2020). The establishment of tree root depends to a large extent on site conditions as roots adapt to the temporal and spatial fluctuations of their growth medium (Puhe, 2001). Site conditions affect availability of water, aeration, organic matter content and other minerals within the soil required for the physiological and morphological growth of plants. In a water-limited environment, in addition to site conditions, the availability of these resources also depends on the sizes and natures of the root systems, and on root competition (Stefan 2018; Jibo and Barker, 2019; Jibo and Barker, 2020). Root development is fundamentally involved in the response to many plant stresses, including drought (Jibo and Barker, 2019; Jibo and Barker, 2020). A deeper root system has been shown to allow crops to extract more water from the soil, resulting in higher yield potential under drought (Jibo and Barker 2020; Louise *et al*., 2013). The contribution of root depth to drought avoidance is considered highly site specific (Bernier *et al.,* 2007). Therefore, efficient regulation of root/shoot growth could be an important characteristic of drought tolerance in plants. The root-shoot ratio is usually given as the ratio of the weight of the roots to the weight of the top of a plant. Considering the number of pot, studies done on plant in response to soil water deficits, it is surprising that no information exists on the likelihood that pot size might influence the sensitivity of plants to soil drying. Sometimes there is no distinction made between pot for herbaceous plants, shrubs or trees. This is especially true because of the fact that root growth and the mechanisms of water uptake might be influenced by the soil volume. This study aimed to examine the sensitivity of root allotment to soil drying in pots of different rate by volume.

Materials and Methods

Description of the area

A. indica seedlings under evaluation are sampled in the nursery of the Forestry and Wildlife Management in the Faculty of Agriculture of the Federal University Dutse. The Forestry and Wildlife Nursery in Federal University of Dutse. Study area has coordinate of latitude 11^{0}42 '04"N, 9^{0}20'31"E and longitude 11^{0}.70 '11^{0}N, 9.3^{0}41'94" E (Jibo *et al.,* 2022). There is little rainfall throughout the year with precipitation of 743mm falls and also average temperature of 26.5^{0}C annually (Salami *et al.,* 2022; Lawal *et al.,* 2020). Location is known with population estimated of 153,000 (National Population Commission, 2006). Dutse and its environment are well known for Date trees (Dabino) of different varieties. The area is characterized with undulating topography and hilly walls. The Jigawa (from Jigayi) is attributed to such topology. Dutse is predominately farmers; other occupations typical to rural areas were also available among the populace. The topography is characterized by high land area which is almost 750m. Soil are well known to be fertile ranging from sandy – loamy, pH ranges from 6.07-6.72, nitrogen content ranges from 0.63 to 1.64g/kg, phosphorus 6.25 to 12.04mg/kg and potassium ranges from 0.18 to 0.63 cmol/kg respectively. Sunshine hours showed that the town enjoys 10-11 hours of sunshine depending on the season (Salami *et al.,* 2019; Jibo *et al.,* 2021).

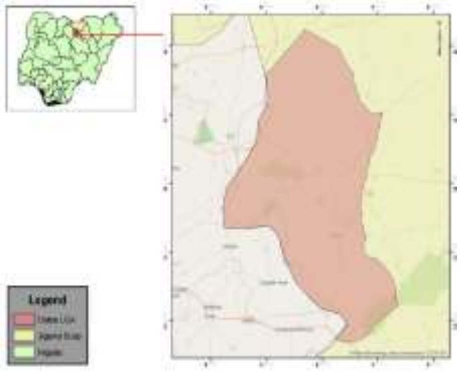

Fig. 1. Map of the study area

Adapted from: Garba *et al.,* (2021)

Data Collection

Seedlings of *A. indica* grown from seeds were obtained from the Department of Forestry and Wildlife Management seed bank. The top soil and river sand used were taken from the departmental nursery. The pots of different sizes were filled with a potting mixture of Top soil (2 portion), river sand (2 portion) and poultry manure (1 portion) (2:2:1)

Experimental Design

The experiment was conducted in a Randomized Complete Block Design with two factors (pot size and watering regime). There were two treatments using: a fully watered (control) and severe drought (10% Gravimetric Water Content (GWC).

Table 1: Experimental layout

Treatments	P1	P2	P3	P4
A	P1A	P2A	P3 A	P4 A
B	P1B	P2B	P3B	P4B

Note: A = Fully Watered, B=Drought

Four sizes of different pots were selected for use in the study. The smallest size of polythene bag used for potting mixture in the nursery with (16cm height ×10 cm top diameter ×10 cm bottom diameter) 2 L. The second pot used was cement bag (23cm height × 25 cm top diameter ×15 cm bottom diameter) 4

L. The other two pot sizes were made from polyvinyl chloride (PVC) pipe of 4 and 6 inches. One end of the pipes was sealed with PVC caps with small holes drilled in the bottom for drainage. The pots were filled with a mixture of Top soil (2 portion), river sand (2 portion) and poultry manure (1 portions) (2:2:1).

Pre-sowing

To ensure a fast and quick germination rate, the outer coat of *A. indica* seedlings were scarified before sowing and this process helped the seedlings to absorb water quickly which in turns fasten and quicken the germination rate of the seedlings Before the water deficit was initiated, pots were fully watered for four weeks. All pots were weighed and this weight was defined as the initial pot weight. The study is designed with pot size as the treatment, and within each pot size there were two watering regimes; a well-watered control (seven pots for each pot size) and a water deficit regime (seven pots per pot size). To maintain well-watered conditions but prevent anaerobic conditions in the control a pot, water was added, when necessary, to maintain a pot weight below the initial saturated pot weight for the pots, respectively.

Seedling growth assessment

The parameters assessed were: shoot height, root length, stem diameter, lateral root and root shoot ratio. Shoot height of seedlings was measured from collar to the tip of the terminal bud and this was1 done with the aid of a metric ruler. The collar diameter of each seedling was measured with the aid of a vernier calliper.

Plate 1A and B: *Showing pots of different sizes and seedlings of A. Indica growing in experiment.*

Data analysis

One-way analysis of variance (ANOVA) was carried out to test any differences among treatments. Significance levels were taken at 5% level. Analysis of variance and Turkey's honestly significant difference was used to evaluate the effect of pot size on root dry weight. All analyses were performed using the statistical software MINITAB® Release 16.12.0. & Sigma Plot® Release 12.0). A normality test was performed on all the data, which log-transformed in cases where residuals were not normally distributed.

Results and discussion

Results

Shoot height (cm)

Total shoot height (SH) of all seedlings in each treatment are presented in (Figure 1), during the 35 days of the experiment. Mean SH of *A. indica* shows a significant difference ($F_{1, 54}$= 52.28, P<0.001) in the drought treatment. There was also a significant difference in total shoot lengths between the among Pot size ($F_{7, 48}$=8.45, P=0001).

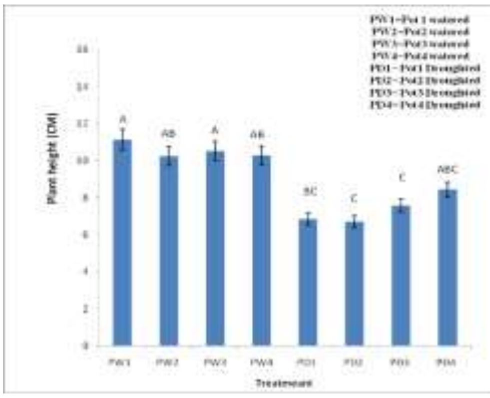

Figure 1 Mean (±SE) Shoot height between pot sizes and water deficit of *A. indica* n= 7. Mean with different letter are significantly different within treatment after a Tukey test (P< 0.05).

Stem Diameter (cm)

The mean stem diameter in each treatment Pot size is presented in (Figure 2). The mean shoot diameter of *A. indica*, shows a significant difference ($F_{3, 54}$= 34.80, P<0.001). There was also a statistical difference in mean shoot diameter in drought treatment ($F_{1, 54}$= 146.20, P<0.001).

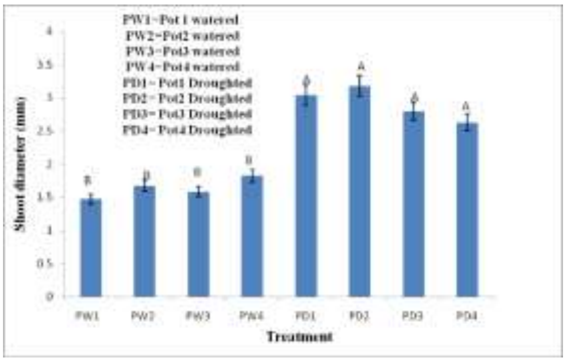

Figure 2 Mean (±SE) Shoot diameter between pot sizes and water deficit of *A. indica* n= 7. Mean with different letter are significantly different within treatment after a Tukey test (P< 0.05).

Root length (cm)

At the end of the experiment mean root length was not significant in the drought treatment ($F_{1,54}$= 1.36, P= 0.249), however root length between the pot size (Figure 3) were significantly different ($F_{7,48}$ =20.48 P< 0.001). Similarly, the mean number of lateral roots was significantly different between the treatments (Figure 4.4) $F_{7, 48}$= 26.42, P<0.001 (Water deficit) however there were no significant differences among the number of mean lateral roots among the two treatments (Pot size).

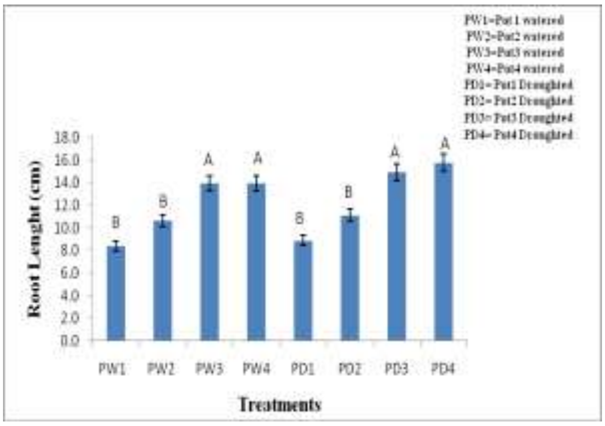

Figure 3 Mean (±SE) root lengths between pot sizes and water deficit of *A. indica* n= 7. Mean with different letter are significantly different within treatment after a Tukey test (P< 0.05).

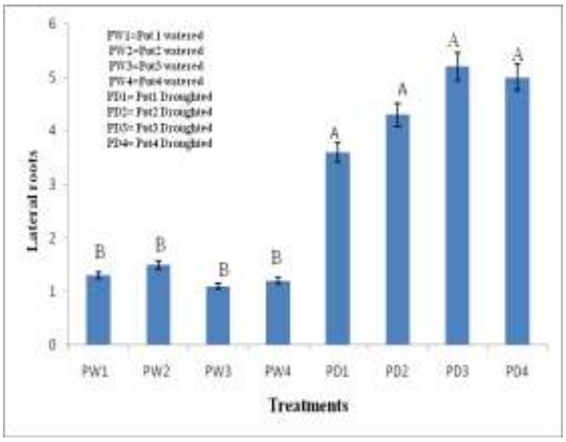

Figure 4 Mean (±SE) lateral roots between pot sizes and water deficit of *A. indica* n= 7. Mean with different letter are significantly different within treatment after a Tukey test (P< 0.05).

Root: shoot ratio

The mean root: shoot ratio of *A. indica* for the Pot size (Figure 5), showed a significant difference ($F_{7, 48}$=23.55, P<0.001) between the treatment, there was also a statistical difference in mean root: shoot ratio between the (Water deficit) treatment ($F_{1, 54}$= 1.04, P= 0.312)

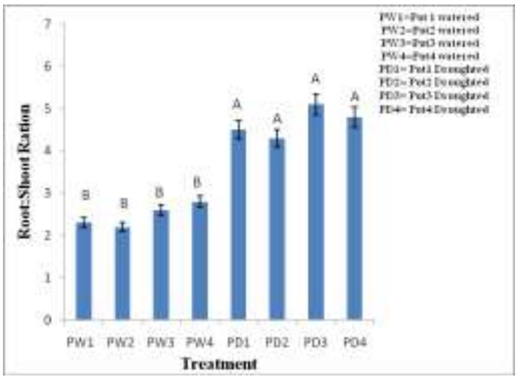

Figure 5 Mean (±SE) root: shoot ratio between pot sizes and water deficit of *A. indica* n= 7. Mean with different letter are significantly different within treatment after a Tukey test (P< 0.05).

Discussion

The responses of *A. indica to* pot sizes and water deficit demonstrated that there were significant differences in the pattern of growth for this species. From the findings in figure 1, result showed that (PW1 well-watered pot) the smallest pot size with a tapered cylindrical pot (16 cm height ×16 cm top diameter ×11 cm bottom diameter commonly used in greenhouse experiments, this pot is approximately 2.3 L in volume) had the highest stem diameter (11.13 cm) while the least was (PD2 pot water deficit) cement bag (23cm height × 25 cm top diameter×15 cm bottom diameter) approximately 4 L in volume (6.71cm) after 12 weeks of planting. The result of this experiment was consistent with previous reports (Jibo and Barker, 2020).

Figure 2 showed that there was a decrement in stem diameter in the (PW well-watered pot of all sizes) with a mean of 1.47 mm, when compared to its counterpart in (PD pot water deficit) with a mean of 2.8mm. This may be indicated a response to lower soil water availability, a reduction in diameter growth may be due to water deficit has been observed in many studies (Salami and Akinyele, 2015; Jibo and Barker 2020).

Result from Figure 4 also showed that (PD4 pot water deficit) polyvinyl chloride (PVC) pipe of 15.2 cm diameters cut to 50 cm lengths approximate volumes of 9 L, had the highest mean root length (14.9 cm) followed by (PD3 pot water deficit) polyvinyl chloride (PVC) pipe of 10.2 cm diameters cut to 50 cm lengths approximate volumes of 4 L with the mean root of 14.9cm while the least mean root length was generated from (PW1 well-watered pot) 8.4cm. At the end of the experiment, there were not significantly differences in root length. the results from these soil drying experiments demonstrated that despite the large effect of pot size on plant growth, there was no significant effect of pot size on the overall relationship this were consistent with reports of (NeSmith and Duva, l998; South *et al*., 2005). Root growth depends on favorable soil or media conditions including water and the physical rooting environment (Leskovar, 1990). Furthermore, the result showed an increase in the number of lateral roots (PD pot water deficit) with a mean number of 5.2 when compared to its counterpart in (PW well-watered pot of all sizes) with a mean number of 1.1, with are similar to the finding of (Hanson, 1987), when Lateral root number depended on container diameter and volume, but not on length root.

Pot size (Figure 5) was associated with an increased allocation of root/shoot ratios revealed apparent differences in growth response to water deficit. There was a decrement in root/shoot ratios in the (PW well-watered pot of all sizes) with a mean of 1.2, when compared to its counterpart in (PD pot water deficit) with a mean of 5.08. The results of these experiments were consistent with previous reports (Townend and Dickinson, 1995) in that large differences existed among pot sizes in root/shoot ratios of well-watered plants at the end of the experiment. Higher shoot height value is important for better survival rate and higher growth performance with better adaptation capacity of the seedlings at field conditions. Shoot height in plants is as a result of apical bud (Salami and Akinyele, 2015).

Conclusion

Plant development can be influenced by container size. In water limiting conditions the allocation of biomass tends to be modified in favour of root growth, leading to an increase in root dry weight and consequently the root to shoot ratios. The effect of pot size is very important for seedling production and post plant performance. Pot size has a huge effect on plant growth and it may affect root and shoot growth, biomass accumulation Growth rates of shoots and roots are interdependent the delicate balance between roots and shoots can be upset when the root system is restricted in a small rooting volume. While the use of smaller containers may improve the efficiency of transplant production, it is unclear how plants grown in smaller root volumes will perform under post plant field conditions. A major effect of decreased container size is that it increases root restricting conditions experienced by transplants. Reduced plant biomass under root restricting conditions could possibly be due to a lower photosynthetic rate.

Recommendations

This study indicates that pot size of (23cm height×25 cm top diameter×15 cm bottom diameter) approximately 4 L with volume, is adequate for producing large *A. indica* seedlings. Pot size and shape influence plant growth, particularly allocation of root/shoot ratio. Moreover, results suggest that the pot size typically used for seedling production seedlings may be too small for optimum growth of *A. indica*

References

Arndt, S., Clifford, S., Wanek, W., Jones, H. and Popp, M (2001). Physiological and morphological adaptations of the fruit tree *Ziziphus rotundifolia* in response to progressive drought stress. *Tree physiology*, 21(11):705-715.

Cortina, J., Bellot, J., Vilagrosa, A., Caturla, R.N., Maestre, F.T., Rubio, E., Ortiz De Urbina, J.M., Bonet, A., 2004. Restauracio´n en semia´ rido. In: Vallejo, V.R., y Alloza, J.A. (Eds.), Avances en el estudio de la gestio´n del monte mediterra´neo. Fundacio´n CEAM, ISBN: 84-921259-3-4 pp. 345–406.

Garba, A., Salami K. D. and Akanbi WB (2021) Assessment of Endangered economic tree species and conservation Techniques in Jigawa state *FUDMA Journal of Agriculture and Agricultural Technology* V 7(2)116-123

Hanson, P. J., Dixon, R. K. and Dickson, R. E. (1987). Effect of container size and shape on the growth of northern red oak seedlings. *Hort Science*, *22*(6):1293-1295.

Jibo, A. U., Mohammad, K. Y., Salami, K. D., Ilu, K. J. and Lana, H. M. (2022) Effect of Scarification Methods On Germination and Early Seedlings Growth Performance of *Delonix regia* (Bojer) *Nigerian Journal of Agriculture and Forestry* 8(1):64-76

Jibo, A. U., Salami, K. D., Kareem Akeem, A., Muhammad, Y. K. and Musa, F. Y: (2021) Impact of Provenances on Seed Germination, Early Growth Performance and Survival Rate of *Tamarindus indica* (L) in North Western Nigeria/ *Nigerian Journal of Horticultural Science (NJHS) Volume 26 Issue 1 and 2 pp 87-104*

Jibo, AU and Barker, M. G. (2019) Effects of Water Deficit on Growth, Biomass Allocation and Photosynthesis of *A. senegal* Seedlings from Nguru and Gujba Provinces of Yobe State, North Eastern Nigeria *J. Appl. Sci. Environ. Manage*. Vol. 23 (12): 2221-2229.

Jibo, AU and Barker, MG (2020) Morphological plasticity of *Acacia senegal* (L) Willd. Seedlings within a drought gradient in north eastern *Nigeria Journal of Agriculture and Environment* Vol. 16 (1):97- 110.

Lawal, A. A., Jibo A.U., Salami K.D., Ilu, K.J., Muhammad, Y.K., Amina, G.H., and Saidu M. (2020) Assessment of Indigenous Fodder Tree Species from Different Land-Use Types In Dutse, Jigawa, Nigeria V12(3):32-38

Louise, H. Comas, Steven R. Becker, Von Mark V. Cruz, Patrick F. Byrne, and David A. Dierig (2013) Root traits contributing to plant productivity under drought *Front Plant Sci*. 2013; 4: 442.

Mundree, SG; Baker, B; Mowla, Peters, S; Marais, S; Willigen, CV; Govender, K; Maredza, A; Muyanga, S; Farrant, JM (2002) Physiological and molecular insights into drought tolerance, *Afr. J. Biotechnol.*. 1. 2, pp. 28-38.

National Population Commission (2006). Projected data on national population. Retrieved on 05/10/2023. Available at https//census.jigawa.dutse.ndb

NeSmith, D. S., and Duval, J. R. (1998). The effect of container size. *Hort Technology*, *8*(4), 495-498

Puhe, J.; Ulrich, B. (2001) Global climate change and human impacts on forest ecosystems: Post-glacial development, present situation and future trends in central Europe. In *Ecological Studies—Analysis and Synthesis*; Springer: Berlin/Heidelberg, Germany, 2001; Volume 143. [Google Scholar]

Salami, K. D and Lawal, A. A (2018). Tree species Diversity and Composition in the Orchard of Federal University Dutse, Jigawa State. *Journal of Forestry Research and Management*. ISSN 0189-8418, www.jfrm.org.ng ,Vol 15(2):112-122

Salami, K. D. and Akinyele, A. O. (2015). Provenance variation in seed and seedlings attributes of *Jatropha curcas* Linn. in South Western Nigeria. *Direct Research Journal of Agriculture and Food Science* (DRJAFS) Vol.3 (7), Pp.143-147, July 2015 Available online at http://directresearchpublisher.org/drjafs-June-2015/ISSN2354-4147©2015 *Direct Research Journals Publisher.*

Salami, K. D., Odewale, M. A., Gidado, A. H and Adam, Z. A (2019): Pre-germination Treatments on Seeds of *Balanites aegyptiaca* (L) Delile and Influence of Potting Mixtures on the Early Growth. *Journal of Forestry Research and Management.* V16(1).107-117; 2019, ISSN 0189-8418. www.Jfrm.org.ng IBADAN

Salami, K.D., Aminu, M., Ilu K. J. Lawal A. A. and Folohunsho, W.O (2022) Evaluation of stem volume, litter fall, Soil fertility of *Azardirachta indica A. JUSS and Eucalyptus camadulensis* Dehnh at Shelterbelt in Kiyawa, Jigawa state, Nigeria. *International Journal of Agricultural Research, Sustainability and food Sufficient*. V9(01): 560 -569

South, D. B., Harris, S. W., Barnett, J. P., Hainds, M. J., & Gjerstad, D. H. (2005). Effect of container type and seedling size on survival and early height growth of Pinus palustris seedlings in Alabama, USA. *Forest Ecology and Management*, *204*(2-3), 385-398.

Townend, J., and Dickinson, A. L. (1995). A comparison of rooting environments in containers of different sizes. *Plant and Soil*, *175*(1), 139–146. http://www.jstor.org/stable/4294757