From Forest Nursery Notes, Summer 2011

163. Water application rate and frequency affect seedling survival and growth of *Vangueria infausta* and *Persea americana*. Mng'omba, S. A., Akinnifesi, F. K., Sileshi, G., and Ajayi, O. C. African Journal of Biotechnology 10(9):1593-1599. 2011.

African Journal of Biotechnology Vol. 10(9), pp. 1593-1599, 28 February, 2011
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Water application rate and frequency affect seedling survival and growth *of Vangueria infausta* and *Persea americana*

Simon A. Mng'omba[1]*, Festus K. Akinnifesi[1], Gudeta Sileshi[1], Oluyede C. Ajayi[1], Betserai I. Nyoka[1] and Ramni Jamnadass[2]

[1]World Agroforestry Centre (ICRAF), Agroforestry Programme, c/o Chitedze Agricultural Research Station, P.O. Box 30798, Lilongwe 3, Malawi.
[2]World Agroforestry Centre, P.O. Box 30677-00100, Nairobi, Kenya.

Accepted 30 December, 2010

Adequate amount of water is critical to successful tree nursery operation among resource-constrained smallholder farmers in Africa. Two experiments were undertaken with the objectives of evaluating effects of water application rate and frequency on seedling growth and survival of *Persea americana* and *Vangueria infausta*. In experiment 1, water was applied to seedlings at 500 ml per 1 L polyethylene bag daily and at two, four and six day intervals. In experiment 2, water was applied to seedlings every two days at the rate of 25, 50, 100 and 150 ml per polyethylene bag. The results indicated that *V. infausta* was more responsive to the rate than frequency of water application. Water application of 100 ml every two days was effective in promoting seedlings growth and survival for both species. Application of 500 ml of water every two days promoted growth of *P. americana*, while watering frequency had no significant effect on *V. infausta*. It is concluded that *V. infausta* seedlings require less frequent watering. Both species could be successfully raised with 100 ml of water applied every two days.

Key words: Nursery irrigation, nutrient reserves, root collar diameter, seedling mortality.

INTRODUCTION

Water is an important natural resource that supports life and growth of plants, but there is a growing concern on water availability (Goyne and McIntyre, 2003). With the effects of climate change, water will become increasingly scarce in most geographical zones of the world (Morrison et al., 2009). Availability of permanent water supply has been one of the major challenges in fruit tree nursery establishment and management, especially in the drier regions of the tropics and sub-tropics.

Initial growth of seedlings largely depends on stored food reserves contained in the cotyledons and also availability of soil moisture. However, after depletion of food reserves, seedlings rely on photosynthesis for their continued growth and survival (Bargali and Tewari, 2004). Soil moisture plays a key role in this process and also for nutrient uptake from the growing media to support plant growth (Shao et al., 2008). For tree nurseries, regular watering is necessary to produce good quality seedlings at economic rate. This is because any stagnation in seedling growth or subsequent mortality translates into economic loss to a nursery operator. The losses can be huge because seedlings take long to reach an appropriate size for grafting (Mhango et al., 2008) and transplanting or for sale.

Water use requirements depend on tree species, growth stage and time of the year and hence, it is necessary to establish this for each tree species as there are differences in growth rates. According to Bargali and Tewari (2004), the small size, shallow roots and little food storage make seedlings less tolerant to harsh environments.

Most tree seedlings take more than a year to reach a

*Corresponding author. E-mail: smngomba@cgiarmw.org. Tel: +265 1 707 319. Fax: +265 1 707 319.

suitable rootstock size for grafting or sale as seedlings (Mhango et al., 2008). Establishing optimal water requirements for fruit tree seedlings in the nurseries, promotes sustainable water use. In case of commercial nurseries, reduced production costs associated with it is important. Our knowledge on optimal water requirements of most indigenous fruit tree seedlings that thrive in semi arid environments is limited. This gap in knowledge, constrains ability of nursery operators to make informed management decision about their operation.

Commercial nursery operators in the tropics invest in water supply (irrigation facilities), while poor resource-endowed nursery operators in the rural areas continue to face challenges in water supply for their fruit tree seedlings. This challenge is huge during the dry seasons when water becomes scarce as rivers, streams, shallow wells and boreholes dry up. Experience has shown that inadequate source of water is a major constrain to supply good quality fruit tree rootstocks and grafted plants. There have been limited research studies accomplished to establish the optimal water requirements for many indigenous fruit tree seedlings to sustain their growth and survival.

Vangueria infausta Comm. Ex. Juss. (Rubiaceae) is one of the most important wild fruit trees selected for domestication in southern Africa (Akinnifesi et al., 2004). Generally, *V. infausta* fruit yield has been observed to be prolific and superior to some equally important wild fruit trees. Some wild trees are adapted to a harsh (stressed) environment (Villagra and Cavagnaro, 2006), but this character has not been exploited when raising them in the nursery. This piece of information could benefit many nursery operators. Therefore, the objectives of this study is to evaluate the effects of water application rate and frequency on seedling growth and survival of *V. infausta* and *P. americana* Mill (Lauraceae).

MATERIALS AND METHODS

Description of the study site

The experiment was carried out at ICRAF-Makoka nursery (altitude: 1029 m above sea level, latitude: 15°30' S, longitude: 35°15' E). It has annual rainfall variations ranging from 560 to 1600 mm and temperature varies between 16 and 32 °C (Akinnifesi et al., 2004).

Plant material

V. infausta and avocado (*P. americana*) (cv Maypan) seeds were collected and planted in 1L polyethylene bags containing soil mixture of sand and loam soils (3:1). Healthy *P. americana* seedlings were left to grow for two months, while *V. infausta* for five months before commencement of the experiment. It was assumed that, this could allow at least depletion of stored food reserves in the cotyledons so that the seedlings depended on photosynthesis for their survival. Furthermore, *P. americana* seedlings were rapidly growing in the polythene bags and they could be saplings if left to grow for more than five months.

Experimental design and management

Two experiments were carried out for both species in the greenhouse (26 ± 2°C) from June to November 2009. Experiment 1 (application frequency treatments) involved application of 500 ml of water to *V. infausta* and *P. americana* seedlings at either (1) daily, (2) two-day (3) four-day or (4) six-day intervals per 1L polyethylene bag.

Experiment 2 involved water application rate (treatments) either (1) 25 ml, (2) 50 ml, (3) 100 ml or (4) 150 ml per 1L polyethylene bag and was applied every two days. In both experiments, a graduated cylinder was used to measure quantities of water applied. Water application was done during the morning hours only.

The treatments (4) for each experiment were arranged in randomized block design with four replications. For each species, there were 30 seedlings per treatment, but measurements were repeatedly recorded from 20 seedlings per treatment. For each experiment, a total of 320 seedlings (4 × 4 × 20) were used per species.

Data collection and statistical analyses

Monthly data on *V. infausta* and *P. americana* seedling survival, height, root collar diameter (RCD), number of leaves and branches were recorded for both experiments (water application rate and frequency). Seedling height was measured from root collar to the tip of the seedling shoot. Root collar diameter was measured using the calliper (Grossnickle et al., 1991).

For both water application rate and frequency experiments, data on seedling survival were subjected to analysis of variance using mixed models (PROC MIXED of SAS), while monthly data on *V. infausta* and *P. americana* growth such as plant height, number of leaves and branches and root collar diameter (RCD), were analyzed using repeated measures. This is because such data were continuously recorded from the same seedlings for five months. Least squares means were obtained and the final RCD obtained in each experiment was regressed on seedling height to establish their relationship. The data for the two species were analyzed separately because the objective was not to com-pare the two species due to growth differences (genetic) and the difference in the onset of treatments.

RESULTS

Effect on seedling survival

Water application of 25 ml per pot at two-day interval resulted in significantly ($P < 0.0001$) low seedling survival for *V. infausta* and *P. americana* seedlings (Figure 1a, b) as there was 16 and 32% survival for *P. americana* and *V. infausta,* respectively. Water application of 50 ml at two day interval gave more than 80% seedling survival for both species. The optimal application rate was 100 ml, which resulted in almost 100% survival for both species, but 150 ml tended to be superfluous as its effect was not significantly different from that of 100 ml at two day interval. Water application frequency had no significant effect on seedling survival for both species (data not shown).

Effect on seedling growth in height

At the end of five months, water application frequency

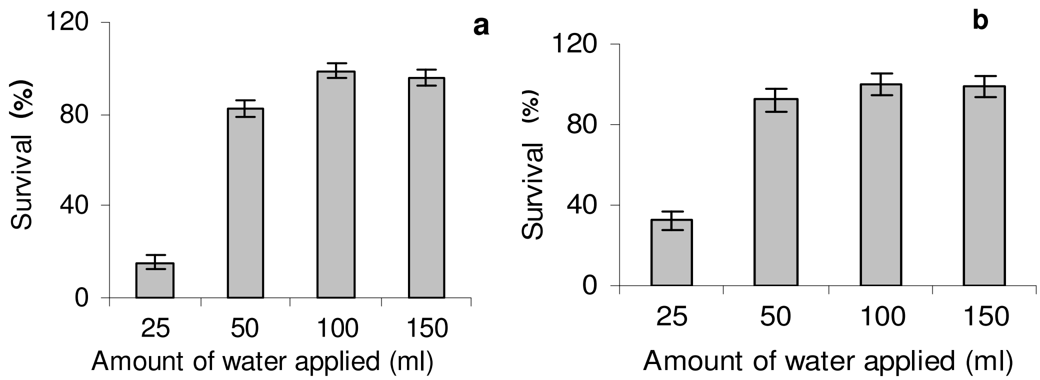

Figure 1. Effect of the amount of water application on survival of :(a) *Persia americana*; (b) *Vangueria infausta* seedlings.

significantly increase ($P < 0.0001$) the height of *P. americana* (Figure 2a). A daily water application increased seedling height by 4 cm when compared with a six-day interval. The water application rate also significantly ($P < 0.0001$) increased seedling height of *P. americana* (Figure 2b) and *V. infausta* (Figure 2d). No significant differences were obtained with respect to water application frequency (Figure 2c). Water application rate of 100 ml increased *V. infausta* seedling height by 3 cm more than at 25 ml water application (Figure 2d).

Effect on root collar diameter

Water application rate and frequency significantly ($P < 0.0001$) increased growth of *P. americana* root collar diameter (RCD) (Figure 3a,b). At 100 ml of water, RCD increased by 0.19 cm more than at 25 ml water application (Figure 3b). For *V. infausta*, there were no significant difference in RCD with respect to water application frequency (Figure 3c). A significant increase ($P < 0.0201$) of 0.7 cm was obtained with 100 ml of water application compared to 25 ml water application rate (Figure 3d).

There were significant and positive, but weak correlations between RCD and height ($P < 0.0001$; $r^2 = 0.17$; n = 239) and ($P < 0.0001$; $r^2 = 0.14$; n = 187) for *V. infausta* seedlings on water application frequency and rate, respectively. For avocado seedlings, there were also positive correlations between RCD and height ($P < 0.0001$; $r^2 = 0.24$; n = 238) and ($P < 0.0001$; $r^2 = 0.33$; n = 178) with respect to water application frequency and water application quantities, respectively.

Effect on number of branches

There were no stem branches on both *P. americana* and *V. infausta* seedlings at the onset of the experiment. A significant number of branches were produced five months after the onset of experiment for *P. americana* (P = 0.0007) and *V. infausta* (P = 0.0019) (Figure 4). For *P. americana*, more branches were produced with daily water application frequency when compared with six day interval, but the reverse is true for *V. infausta*. No significant differences were obtained with respect to water application rate for both *P. americana* and *V. infausta* seedlings (data not shown).

Effect on number of leaves

The highest significant (P = 0.0001) number of *P. americana* leaves (24) was obtained from either daily or 2 day interval of water application (Figure 5a) and the highest number of leaves (23) were produced with 100 ml of water application (Figure 5b). No significant differences were obtained in number of *V. infausta* leaves with respect to water application frequency (Figure 5c). A significant (P = 0.0001) increase in number of leaves (16) were obtained from either 100 ml or 150 ml water application rate, but the latter is superfluous (Figure 5d).

DISCUSSION

According to Domínguez-Caraveo et al. (2010), experiments carried out under greenhouse are vital since one is able to make early conclusions before field assessment and also manipulate environmental conditions. In this study, the use of a greenhouse enabled control of external source of water such as rainfall. Data on root growth was not measured as seedlings were in polyethylene bags. According to Domínguez-Caraveo et al. (2010), plants grown in bags or pots have uniform root growth unlike those grown in the field. If such is the case, then root data for plants grown in bags become meaningless.

In this study, a high percentage of survival for *P. americana* and *V. infausta* seedling was obtained from water application frequency rather than water application

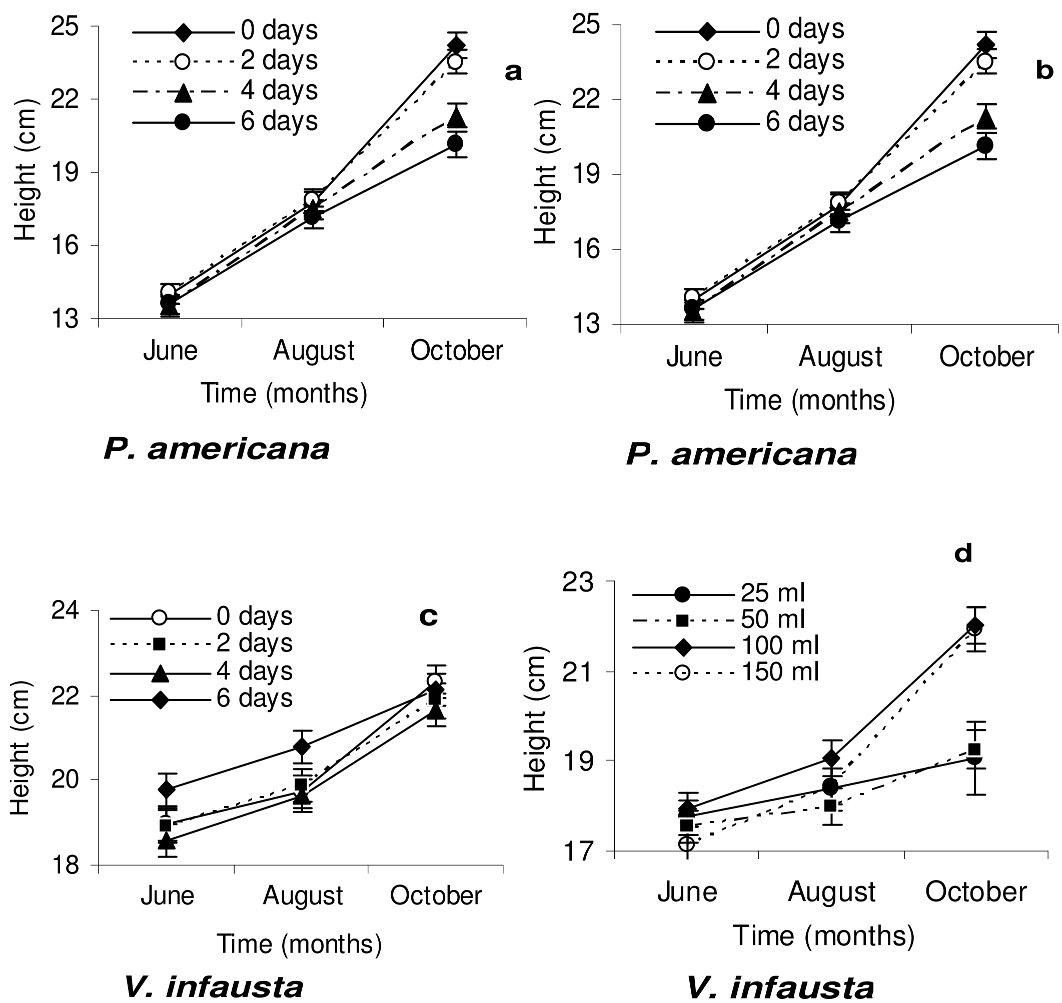

Figure 2. Response (height) of *P.americana* and *V. infausta* seedlings to water application rate and frequency.

rate experiment. For the latter experiment, a low amount (25 ml) of water applied to both species greatly reduced seedling survival by below 40%. Comparatively, a better seedling percentage survival (> 90%) was obtained with 100 ml of water application and this was sufficient to support *P. americana* and *V. infausta* seedling growth and survival. The current findings indicate that both species were more responsive to water application rate than to watering frequency. The reason could be due to too much water (500 ml) being applied at once, hence, this reduced root respiration (Biernbaum and Versluys, 1998).

Seedling growth in height shows that 100 ml was optimal when compared with the rest of water application rates for both species. With respect to water application frequency, 500 ml of water applied to *P. americana* at daily or two day interval improved growth (height), but marginally superior for *V. infausta* when compared with the rest of the water application frequency treatments. The findings suggest that *V. infausta* seedlings would tolerate water stress for a longer time (at least 6 days). This seems consistent with its evolution in the Miombo woodlands, whose natural range of distribution stretches from the semi-arid regions (Eastern Botswana and Namibia) to the wet subtropical forests in the DRC (Frost, 1996).

In terms of root collar diameter (RCD), the present findings indicate that either 100 or 150 ml of water application rate greatly increased RCD when compared with the rest, but 150 ml is superfluous. RCD thickness is critical for graft success as rootstock diameter plays a key role in graft success (Mng'omba et al., 2010). Either daily or two day water application frequency to *P. americana* increased RCD growth. For *V. infausta*, growth in RCD remains the same irrespective of the different water application frequencies. According to Thompson (1984), RCD is considered as one of the best indicators of field survival and growth. Therefore, our findings suggest that water application treatments used in this trial has similar effects on *V. infausta* field survival and

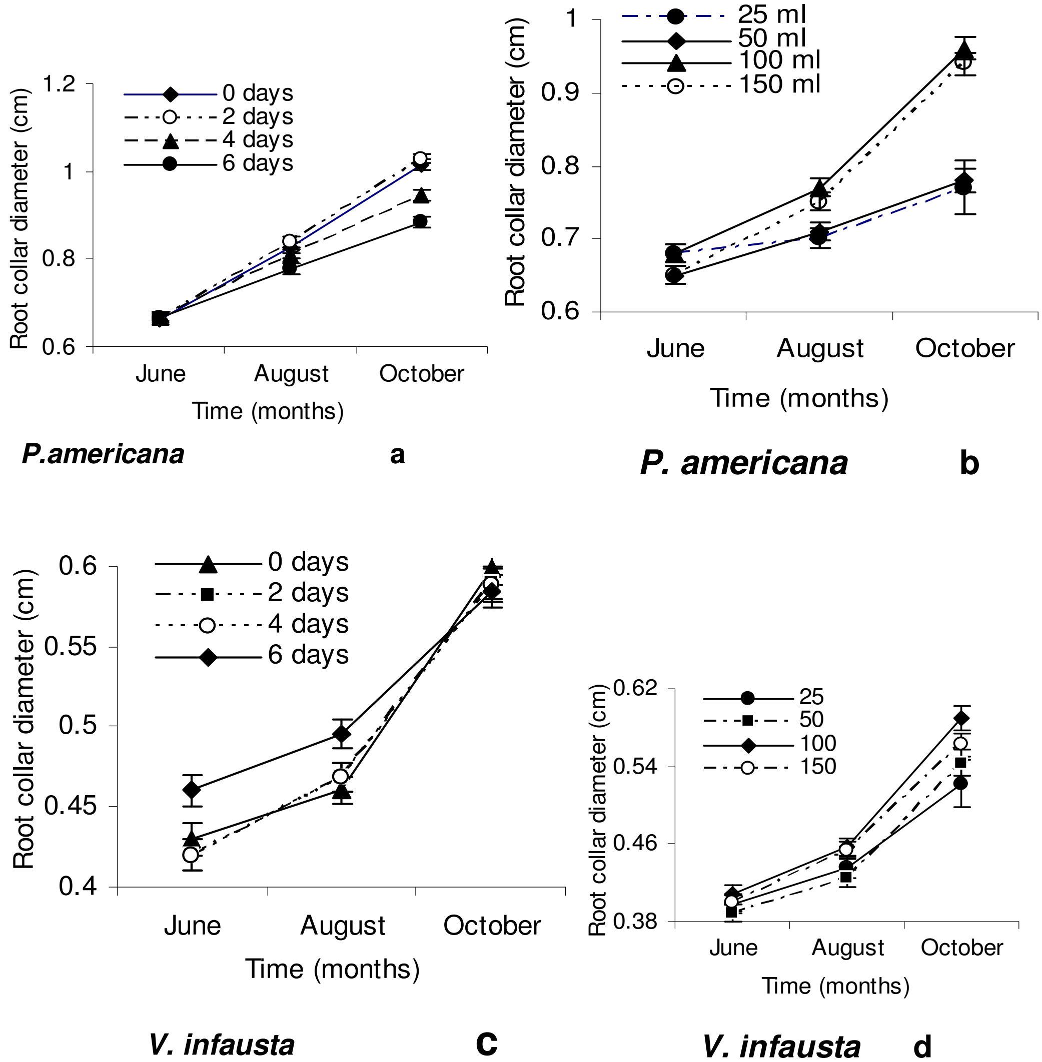

Figure 3. Response of *P. americana and V. infausta* seedlings (root collar diameter) to water application rate and frequency.

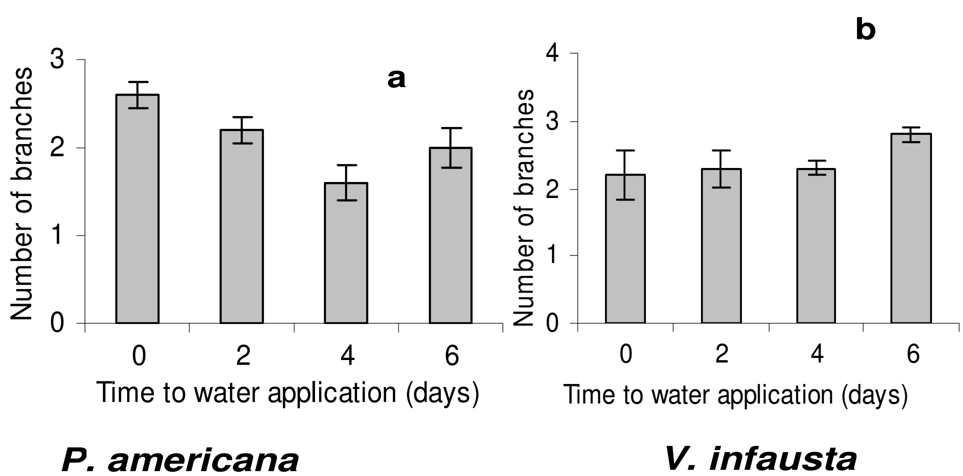

Figure 4. Response (number of branches) of *P. americana* and *V. infausta* seedlings to water application frequency.

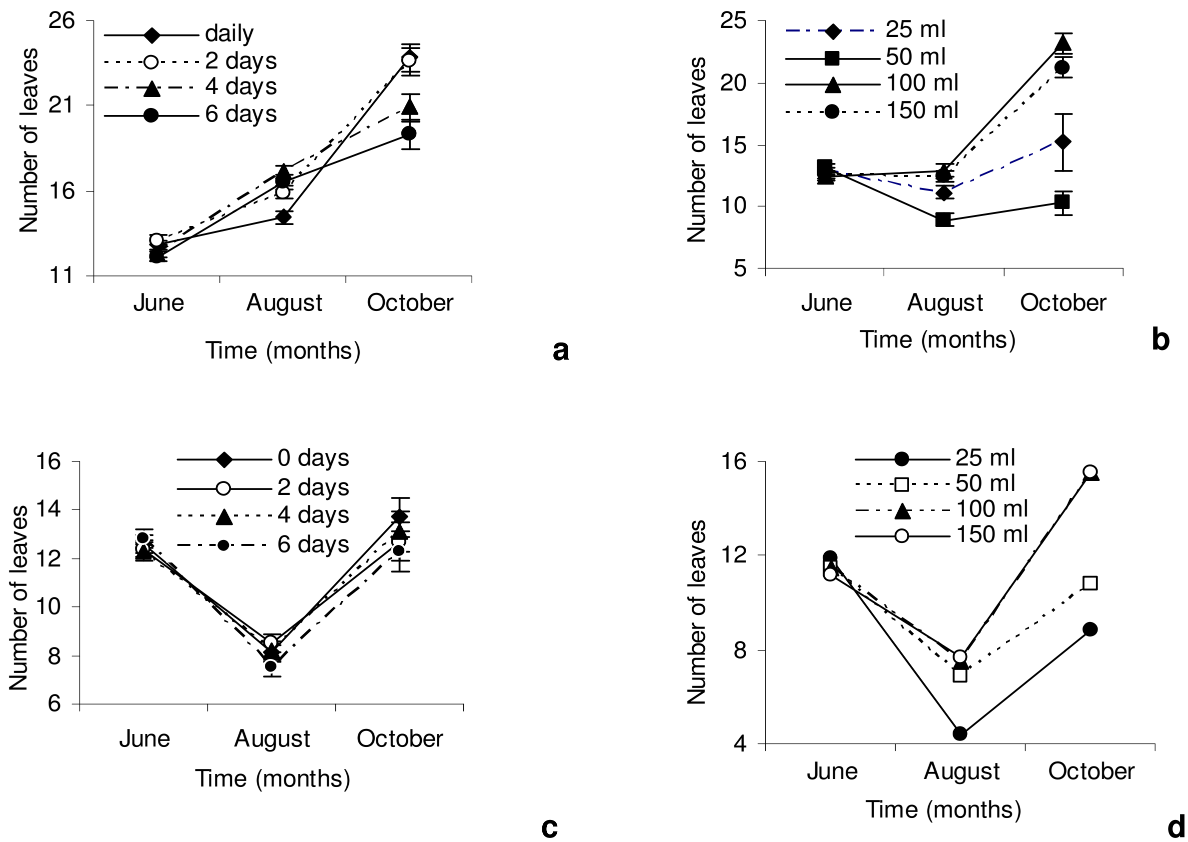

Figure 5. Number of leaves under four different water amount and application time for *P. americana* (a and b) and *V. infausta*(c and d).

growth, while 100 ml of water application rate would give the highest field survival of *V. infausta* and better plant growth. According to Akinnifesi et al. (2008), there was growth increase in RCD of *V. infausta* trees when fertilezer and irrigation was applied.

In this study, daily water application increased the number of *P. americana* branches, while a 6 day interval of water application increased number of *V. infausta* branches. The current findings suggest that, 500 ml of water applied daily was sufficient to support *P. americana* growth (including number of branches). For *V. infausta*, a positive response to infrequent water application could be attributed to its inherent wild growth. According to Akinnifesi et al. (2008), *V. infausta* grows faster in height and RCD than other miombo woodland trees.

Either daily or two day interval of water application increased the number of *P. americana* leaves when compared with the rest. Application of 100 or 150 ml of water increased the number of leaves for both species, but 150 ml is superfluous. The number of leaves is considered a measure of photosynthetic and transpiration area (Ritchie, 1984). The findings suggest that 100 ml of water improved photosynthetic and transpiration area due to increased number of leaves and hence, increased seedling height, survival and RCD. In contrast, 25 ml of water had a negative effect on seedling height, RCD and the number of leaves produced. The reduction in leaf number and possibly area under limited water quantity (25 ml) could be a mechanism to reduce transpiration so as to avoid wilting of seedlings.

Considering labor costs involved and based on the present results, it would be advisable for nursery operators to irrigate *P. americana* seedlings every two days under the prevailing conditions. This is because seedlings under different environmental conditions may have different water requirement (Biernbaum and Versluys, 1998). *V. infausta* seedlings needs infrequent watering and our findings indicate that, at least six day interval could support its growth and survival. Our findings agree with Akinnifesi et al. (2008) who reported that *V. infausta* performs better under minimal irrigation and manure combination. From this study, it is hypothesized that *V. infausta* could with-stand longer water stress period than six days.

Conclusion

This study concludes that water application of 100 ml per pot at two day interval improves growth in seedling height, number of leaves and root collar diameter of *P. americana* and *V. infausta*. Water application frequency of 500 ml to *P. americana* every two days is optimal, while *V. infausta* needs infrequent (at least six day interval) watering. These findings have implications on reduced labor costs, water wastage and maximizing profitability of production to fruit tree nursery operators in semi-arid areas.

REFERENCES

Akinnifesi FK, Mhango J, Sileshi G, Chilanga T (2008). Early growth and survival of three miombo woodland indigenous fruit tree species under fertilizer, manure and dry-season irrigation in southern Malawi. For. Ecol. Manage. 255: 546 - 557.

Akinnifesi FK, Mng'omba SA, Sileshi G, Chilanga TG, Mhango J, Ajayi OC, Chakeredza S, Nyoka BI, Gondwe FMT (2009). Propagule type affects growth and fruiting of *Uapaca kirkiana*, a priority indigenous fruit tree of southern Africa. Hort. Sci. 44(6): 1662 -1667.

Bargali K, Tewari A (2004). Growth and water relation parameters in drought-stressed *Coriaria nepalensis* seedlings. J. Arid Environ. 58: 505-512.

Biernbaum JA, Versluys NB (1998). Water Management. Hort. Technol. 8(4): 504-509.

Domínguez-Caraveo H, Jurado P, Melgoza-Castillo A (2010). Emergency and survival of blue grama with biosolids under greenhouse conditions. J. Arid Environ. 74: 87-92.

Frost P (1996). The Ecology of Miombo woodlands. In: Campbell B (ed). The Miombo in Transition: Woodlands and Welfare in Africa. CIFOR, Malaysia pp 11-55.

Goyne PJ, McIntyre GT (2003). Stretching water-Queensland's water use efficiency cotton and grains adoption program. Water SA, 48(7): 191-196.

Grossnickle SC, Major JE, Arnott JT, Lemay VM (1991). Stock quality assessment through an integrated approach. New Forest. 5: 77-91.

Mhango J, Akinnifesi FK, Mng'omba SA, Sileshi G (2008). Effect of growing medium on early growth and survival of *Uapaca kirkiana* Müell Arg. seedlings in Malawi. Afr. J. Biotechnol. 7(13): 2197-2202.

Mng'omba SA, Akinnifesi FK, Sileshi G, Mhango J, Ajayi OC, Chilanga TG, Jamnadass R (2010). Early soil and water management effects on *Uapaca kirkiana* and *Vangueria infausta* fruit productivity. A paper presented at the 2nd World Agroforestry congress 23-28 August 2009, Nairobi, Kenya.

Morrison J, Morikawa M, Murphy M, Schulte P (2009). Water scarcity & climate change: Growing risks for businesses and investors. A Ceres Report, Ceres, Boston.

Ritchie GA (1984). Assessing seedling quality. In: Duryea ML, Landis TD (eds). Forest Nursery Manual: Production of Bare Root Seedlings. Martinus Nijhoff Junk Publishers. The Hague, The Netherlands.

Shao H-B, Chu L-Y, Jaleel CA, Zhao C-X (2008). Water-deficit stress-induced anatomical changes in higher plants. CR Biol. 331: 215-225.

Thompson BE (1984). Seedling morphological evaluation-what you can tell by looking. In: Duryea ML (ed). Evaluating Seedling Quality: Principles Procedures and Predictive Abilities of Major Tests. Oregon State University, USA, pp. 59-72.

Villagra PE, Cavagnaro JB (2006). Water stress effects on the seedling growth of *Prosopis argentina* and *Prosopis alpataco*. J. Arid Environ. 64(3): 390-400.