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Flooding period influence early growth of *Grevillea robusta* nursery seedlings

Shadrack Kinyua Inoti [1, *], Alice Adongo Onyango [1, 2] and Jemimah Achieng Ocholla [1]

[1] *Department of Natural Resources, Faculty of Environment and Resources Development, Egerton University, P.O Box 536-20115, Egerton, Kenya.*
[2] *Kenya Forestry Research Institute, Rift Valley Ecoregion Research Programme, P.O. Box 382-20203, Londiani, Kenya.*

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Abstract

Flooding has become a common occurrence due to climate change leading to prolonged water-logging which suffocates plant rooting, thus reduced growth, yield or total loss. Limited research has been conducted on the same. This study is aimed at investigating the effect of flooding period on the early growth of *Grevillea robusta* nursery seedlings in Njoro, Kenya. An experiment was set up for 2 months in Egerton University Agroforestry tree nursery using a six months old Grevillea seedlings. Completely randomized block design (RCBD) with 4 treatments replicated 3 times was used. The treatments were: Non-flooding, 2 days flooding, 4 days flooding and 6 days flooding. Data was collected for shoot, foliage and root variables and analyzed using SAS statistical package while means were separated using least significance difference (LSD). Non-flooding recorded the highest performance for all the shoot and foliage variables while the least was 2 days flooding. On the other hand, 6 days flooding was the second in performance for most of the variables especially 3rd internode length (20.2 mm) and fresh shoot biomass (56.4 g) were significantly (P=0.002 and 0.05) higher respectively compared with 2 days flooding (13.5 mm and 46.7 g) respectively. In conclusion, flooding affects the growth of Grevillea seedlings negatively by reducing their growth and this was more pronounced in 2 days flooding. However, for 6 days flooding, the seedlings seem to adjust through development of adaptive strategies in the roots. Further research needs to be conducted on other species and also prolonged flooding period.

Keywords: Climate change; Flooding; Non-flooding; Grevillea seedlings; Waterlogging

1. Introduction

Flooding effect has been used to assess the waterlogging tolerance. Water stress associated with flooding has been shown to inhibit certain physiological and reproductive plant functions [1]. This interrupts the natural growth and establishment of plants. The threats and plant tolerance associated with waterlogging stress disturbances have been documented for agricultural crops such as, wheat, rice, maize, soy bean among others [2, 3, 4] but little work has been done on tree species in agricultural landscapes. Earlier studies have shown that waterlogging tolerance of higher plants increases with age and size up to maturity but also decreases with decreasing crown position [5, 6]. Very few forest species have demonstrated high tolerance to waterlogging stress [7].

Grevillea robusta (silky oak) has been widely planted in warm temperate, sub- tropical and tropical highland regions of many countries as a shade tree for tea and coffee and as an agroforestry tree in small scale farms [8]. The species is native in Australia but has successfully naturalized in Kenya where it is grown in the lowlands mostly preferred as a fast growing agroforestry tree species [9]. The growing of this species in agricultural systems releases pressure on reliability of conventional forest resources and, therefore, play a major role in sustaining the productivity of agricultural and forested landscapes. In these ecosystems, this species contributes to the stability of the environment by supplementing fodder, wood fuel, supporting water, soil, and biological diversity conservation, and mitigate climate change through carbon sequestration [10, 11]. *Grevillea* can be propagated by seed, cuttings, layering, grafting, and tissue culture.

* Corresponding author: Shadrack Kinyua Inoti

Propagation by seed for raising of seedlings in the nursery has been the most adopted method preferred by foresters and farmers as natural regeneration shows less success amidst challenges of climate change [12].

The Kenyan lowlands most often are vulnerable to environmental stresses, such as periodic drought and prolonged flooding. The majority of flood prone areas and dry lands are situated in these lowland zones with flat topography features [13]. The unpredictability of these disturbances makes it difficult for managers to respond or manage areas of significantly transformed soil moisture levels. In the case of flooding, the artificial disturbance brought by the abnormal water regimes could deepen the flood water and/or prolong the waterlogging duration. Some plants have shown some tolerance to waterlogging stress and have developed adaptations, such as hibernation, tolerating various degrees of inundation for some time and tolerating waterlogging indefinitely [14, 15]. Some studies have suggested that sustained waterlogging led to adventitious root formation in waterlogged plants and thus, improving oxygen availability in root system [16]. Morphological adaptive traits observed under the stimulus of prolonged waterlogging are, increased survival of secondary roots, emergence of secondary roots designated as soil water roots and physiologically, increased metabolism and aerobic respiration rates in the roots [17].

Seedling development stage is the most sensitive period of tree cycle in which measurements of soil water levels should be done for the growth and survival of planted trees [18]. Seed to seedling development and establishment greatly relies on the growing conditions as dictated by the environment. Soil waterlogging is deleterious to majority of terrestrial plants as it inhibits carbon gain, growth and increases the risk of early mortality in young plants. Seedling growth and survival depends on the responses to water stress. The current study is aimed at investigating the effect of flooding period on the early growth of *Grevillea robusta* nursery seedlings.

2. Material and methods

2.1. Study site description

The study was conducted at Agroforestry tree nursery, Egerton University, Njoro, Kenya, within the eastern Mau water-catchment. The study site lies on a latitude 0°22'11.0"S, Longitude 35°55'58.0"E and an altitude of 2,238 m [19]. The area falls in agro ecological zone Lower Highland 3. The experimental site receives mean annual rainfall of 1200 mm while the distribution of rain is bimodal with long rains between April and August and short rains between October and December. The temperatures lie between 10.2 and 22.0°C [21] while the soils are mollic andosols [20] with relatively high levels of phosphorus.

2.2. Experimental design

An experiment was set up for a period of 2 months in Egerton University Agroforestry tree nursery, Njoro, Kenya, using a six months old Grevillea seedlings. This experiment was conducted in January and February 2019 which are dry months. The experimental design was completely randomized block design (RCBD) with 4 treatments replicated 3 times [22]. The treatments were as follows: Non-flooding, 2 days flooding, 4 days flooding and 6 days flooding. Each treatment consisted of 3 replicates. Flooding water was artificially introduced in non-perforated plastic containers containing the seedlings. Water was added as per the treatments and then later drained accordingly.

On the other hand, each treatment and replicate consisted of 10 potted Grevillea seedlings. Out of these, 7 seedlings were sampled at random for data collection. Data was collected for shoot, foliage and root variables using a destructive technique.

2.3. Data analysis

Data was analyzed using SAS statistical package [23] while the means were separated using Least Significance Difference (LSD) at $P \leq 0.05$.

3. Results

3.1. Effect of flooding period on the shoot and foliage growth of *Grevillea robusta* nursery seedlings

The results showed that non-flooding resulted into significantly (P=0.04) higher height (51.7 cm) compared with 2 days flooding (43 cm) (Table 1).

Table 1 Effect of flooding period on the shoot and leaf growth of *Grevillea robusta* nursery seedlings

Flooding period (days)	Height (cm)	3rd Internode length (mm)	Fresh shoot biomass(g)	Fresh total biomass (g)	Seedling Shoot Volume (cm^3)	Leaf length (cm)	Leaf number
Non-flooding	51.7 a	28.1 a	58.2 a	83.5	30.9	33.2 a	19.3
2 days	43.0 b	13.5 c	46.7 b	74.9	26.4	26.3 b	17.0
4 days	48.0 ab	19.0 b	49.9 ab	72.7	29.5	28.3 b	17.0
6 days	48.3 ab	20.2 b	56.4 a	78.4	32.9	28.2 b	18.7
P value	0.04	0.002	0.05	0.100	0.208	<.001	0.528
%CV	5.5	12.0	8.2	8.3	11.0	3.5	12.6
LSD	5.275	4.862	8.61	13.28	6.585	2.025	4.529

Note: Mean values within a column followed by the same letter (s) are not significantly different at $P \leq 0.05$.

On the other hand, 3rd internode length was significantly higher in non-flooding (28.1 mm) compared with 2, 4 and 6 days flooding (13.5, 19 and 20.2 mm) respectively. Generally, non-flooding recorded the highest performance for all the shoot and foliage variables while the least was 2 days flooding. On the other hand, 6 days flooding was ranked as the second in performance for most of the variables and especially 3rd internode length (20.2 mm) and fresh shoot biomass (56.4 g) were significantly (P=0.002 and 0.05) respectively higher compared with 2 days flooding (13.5 mm and 46.7 g) respectively. Non-flooding showed significantly (P<.001) higher leaf length (33.2 cm) compared with all the other treatments.

3.2. Effect of flooding period on the root growth of *Grevillea robusta* nursery seedlings

Six days flooding showed significantly (P=0.05) higher root collar diameter (11.4 mm) compared with all the other treatments (Table 2 and Figure 1).

Table 2 Effect of flooding period on the root growth of *Grevillea robusta* nursery seedlings

Flooding period (days)	Root collar diameter (mm)	Root length (cm)	Root biomass (g)	Root to shoot ratio
Non-flooding	10.7 b	44.8	25.4 ab	0.44 b
2 days	10.8 b	40.2	28.3 ab	0.60 a
4 days	10.8 b	44.5	22.8 b	0.46 b
6 days	11.4 a	37.7	31.0 a	0.55 ab
P value	0.05	0.218	0.05	0.01
%CV	0.68	10.1	11.4	8.1
LSD	0.3	8.45	6.12	0.08

Note: Mean values within a column followed by the same letter(s) are not significantly different at $P \leq 0.05$.

On the other hand, 6 days flooding showed the highest root biomass (31 g) which was significantly (P=0.05) superior compared with 4 days flooding. For root to shoot ratio, 2 days flooding (0.6) showed significantly (P=0.01) the highest value compared with non-flooding (0.44) and 4 days flooding (0.46).

Key: From left, 1- Non-flooded, 2-Two-day flooding, 3- Four-day flooding and 4- Six days flooding

Figure 1 Growth performance of flooded Grevillea seedlings

4. Discussion

4.1. Effect of flooding period on the shoot and foliage growth of *Grevillea robusta* nursery seedlings

The study showed that non-flooding resulted into a significantly higher height compared with 2 days flooding. The results were similar to earlier findings [24] which demonstrated that rice seedling height grown in Japan were higher in conventional farming (non-flooding) than in winter organic flooding. Other studies also concur with this study that seedling growth height in nurseries is decreasing with increase in submergence depth and duration [25]. Therefore, increase in flooding period results into decline in seedling growth and survival [26, 27, 28].

Shoot growth in plants is thus, related to root system health [29]. Therefore, poor root system consequently results into poor shoot growth due to inhibition of mineral and water uptake/transportation. Flooding consequently, leads to suppression of shoot elongation [27, 30]. The current findings were, however, contrary to more recent findings [31] which reported higher shoot height in 7 days flooding compared with non-flooding. Other studies also on the contrary report increase in seedling height with increase in flooding periods of up to 150 days [32].

Third internode length was highest in non-flooding compared with the flooding under different periods, but gradually began to increase with increase in flooding period. This phenomenon could be attributed to seedling resilience to flooding as demonstrated by other studies [25, 29]. Similar findings were shown by other studies which showed that second internode in maize plants increases with decrease in flooding period due to decline in stem diameter and length [33]. However, a study done on wild rice reported that rice internode length and number increases with increase in flooding period [34].

The current study reported higher fresh shoot and total biomasses in non-flooding followed by 6 days flooding compared with the other flooding periods. These results were congruent with other studies that increase in flooding period reduces fresh total biomass and leaf dry mass [25]. Similar results were also exhibited by other studies which demonstrated increased biomasses in control (non-flooding) compared with the flooding [32]. This could be attributed to leaf reduction associated with leaf defoliation as a result of excess water [25, 26]. However, increase in fresh total biomass in 6 days flooding period compared with the other flooding period was contrary to other studies [25] and this could be attributed to the seedling resilience to flooding even though prolonged flooding results into excessive leaves defoliation which leads to less biomass weight of leaves. Tolerance to flooding can also be associated with development of adventitious roots in the submerged stems by some plants [29].

Seedling shoot volume was recorded high in 6 days flooding compared with other flooding periods and non-flooding. This was not in one accord with previous studies [35] which demonstrated reduced shoot volume due to leaf loss. Shoot volume reduces with increase in flooding level and period [30] which was contrary to this study. Leaf length was recorded high in non-flooding compared with the flooding under different periods. The results were similar to other studies that flooding inhibits leaf expansion due to its effects on chlorophyll content, hence low photosynthesis [30]. Similar studies were also done by other researchers [26] who reported that increased duration of flooding has an adverse impact on leaf chlorophyll content, hence reduced leaf length and size.

Leaf number was recorded higher in non-flooding which was contrary to other studies [24] which reported higher number of leaves in flooded soils as well as shoot dry weight to plant height. Another study also reported a reduced number of apple seedling leaves in flooding/waterlogging due to defoliation [35]. However, other studies record no significant difference in the number of epicormic shoots and leaves in flooded and non-flooded seedlings [30]. The results, however, corroborated with those reported by earlier studies [25, 32] which stated that increased flooding duration results into leaf defoliation. This can result into new leaf budding to replace the defoliated ones [26, 31].

4.2. Effect of flooding period on the root growth of *Grevillea robusta* nursery seedlings

Root collar diameter *of Grevillea robusta* was recorded higher in 6 days flooding compared with non-flooding and other treatments. The results were, therefore, similar to other studies which demonstrate increase in root collar diameter with increase in flooding period. However, root collar diameter tends to remain similar in short flooding periods and non-flooding, according to previous studies [32].

Root length was recorded high in non-flooding compared with the flooding under various periods. The findings were similar to previous studies [26] which demonstrated that increasing flooding duration in *Distylium chinense* nursery seedlings affects root length and number due to rotting. The results were again congruent with other studies that seedlings invest more in roots and stem development in non-flooding environments [25]. Flooding is therefore, known to cause poor soil aeration and deplete oxygen in the soil which reduces the growth and development of root system [26]. This is attributed to increasing demand for oxygen as well as increased accumulation of phytotoxic compounds in the soil, such as reduced forms of nutrients such as, iron, manganese, lactic acid among others which are detrimental to root metabolism [30].

Root biomass was recorded higher in 6 days flooding compared with the other three treatments. Similar results were also reported by other studies that root dry mass decreases with increase in flooding period [25, 30]. This was, however, contradictory to the recent findings [31] which demonstrated reduced root biomass of Prunus ovium, P. padus and P. mahaleb in waterlogged soils compared with non-flooded. Likewise, the study was against other findings which reported decrease in root biomass with increase in flooding period [32].

Root to shoot ratio was higher in 2 days flooding than in other periods of flooding and non-flooding. This was, however, contrary to other findings [31] which reported a reduced root to shoot ratio in waterlogged soils. Similarly, other studies also demonstrated that root to shoot ratio is high in non-flooding compared with the submerged in 30-60 days and much lower in 90-120 [25, 30], hence corroborating with the current study.

5. Conclusion

In conclusion, flooding affects the growth of Grevillea seedlings negatively by reducing their growth and this was pronounced in 2 days flooding, however, for 6 days flooding, the seedlings seem to adjust through development of adaptive strategies in the roots which are shown by significantly larger root collar diameter, root biomass and root to shoot ratio. Further research needs to be conducted on other species and also prolonged flooding period.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors wish to state that there was no conflict of interest as concerns the current research.

References

[1] Moustafa-Farag M, Mahmoud A, Arnao MB, Sheteiwy MS, Dafea M, Soltan M. Melatonin-induced water stress tolerance in plants: Recent advances. Antioxidants. 2020, 9(9): 1-23. https://doi.org/10.3390/antiox9090809

[2] Ashraf MA. Waterlogging stress in plants: A review. African Journal of Agricultural Research. 2012, 7(13):1976–81. https://doi.org/10.5897/ajarx11.084

[3] Tong C, Hill CB, Zhou G, Zhang XQ, Jia Y, Li C. Opportunities for improving waterlogging tolerance in cereal crops—physiological traits and genetic mechanisms. Plants. 2021, 10(8):1-22. https://doi.org/10.3390/plants10081560

[4] Sathi KS, Masud AAC, Falguni Mr, Ahmed N, Rahman K, Hasanuzzaman M. Screening of soybean genotypes for waterlogging stress tolerance and understanding the physiological mechanisms. Advances in Agriculture. 22022:1–14. https://doi.org/10.1155/2022/5544665

[5] Song Z. Effects of tree age and waterlogging duration on the form factors of eastern cottonwood (Populus deltoides Bartr. ex Marsh.). Forestry Studies. 2019, 70(1):58–67. https://doi.org/10.2478/fsmu-2019-0005

[6] Kreuzwieser J, Rennenberg H. Molecular and physiological responses of trees to waterlogging stress. Plant, cell & environment. 2014, 37(10):2245–59.

[7] Niinemets Ü, Valladares F. Tolerance to shade, drought, and waterlogging of temperate northern hemisphere trees and shrubs. Ecological monographs. 2006, 76(4):521–47.

[8] Frezghi H, Abay N, Yohannes T. Effect of mulching and/or watering on soil moisture for growth and survival of the transplanted tree Seedlings in Dry Period. American Journal of Plant Sciences. 2021, 12(02):221. https://doi.org/10.4236/ajps.2021.122013

[9] Owate OA, Mware MJ, Mwangi JK. Allometric equations for estimating silk oak (Grevillea robusta) biomass in agricultural landscapes of Maragua Subcounty, Kenya. International Journal of Forestry Research. 2018. https://doi.org/10.1155/2018/6495271

[10] Hauxwell C, Mayhew J, Newton A. Silvicultural management of Hypsipyla species. In: ACIAR PROCEEDINGS. ACIAR, 1998, 2001. p. 151–63.

[11] Rono J, Koech E, Kireger E, Mburu F. Effects of micro-catchment rain water-harvesting on survival and growth of multipurpose trees and Shrubs in Nyando District, Western Kenya. International Journal of Agronomy and Agricultural Research, 2013, 3(1), 17–25.

[12] Shejuti, A. Monograph on Silver Oak (Grevillea robusta). Khulna University. 2006.

[13] Nyingi DW, Gichuki N, Ogada MO. Freshwater ecology of Kenyan highlands and lowlands. In: Developments in Earth Surface Processes. Elsevier, 2013. p. 199–218. https://doi.org/10.1016/B978-0-444-59559-1.00016-5

[14] Niinemets Ü. Responses of forest trees to single and multiple environmental stresses from seedlings to mature plants: past stress history, stress interactions, tolerance and acclimation. Forest Ecology and management. 2010, 260(10):1623–39.

[15] Narayan Bhusal, Hyun Seok Kim, Su-Gon Han, Tae-Myung Yoon. Photosynthetic traits and plant–water relations of two apple cultivars grown as bi-leader trees under long-term waterlogging conditions. Environmental and Experimental Botany. 2020, 176, 1-13. https://doi.org/10.1016/j.envexpbot.2020.104111.

[16] Copolovici L, Niinemets Ü. Flooding induced emissions of volatile signaling compounds in three tree species with differing waterlogging tolerance. Plant, Cell & Environment. 2010, 33(9):1582–94. https://doi.org/10.1111/j.1365-3040.2010.02166.x

[17] Hook DD. Waterlogging Tolerance of Lowland Tree Species of the South^1. Southern Journal of Applied Forestry. 1984, 8(3):136–49.

[18] Herbohn J, Gregorio N, Harrison S, Vanclay J, Bosch A. project Enhancing tree seedling supply via economic and policy changes in the Philippines nursery sector. 2011. https://doi.org/10.3832/ifor3089-012

[19] Jaetzold R, Schmidt H. Farm Management Handbook of Kenya Vol. II: Natural Conditions and Farm Management Information (Part A: West Kenya, Part B: Central Kenya, Part C: East Kenya). Nairobi: Ministry of Agriculture. 1983.

[20] Kinyanjui, H.C. Detailed soil survey of Tatton farm, Egerton College, Njoro. Ministry of Agriculture- National Agricultural Laboratories, Nairobi, Kenya. 1979

[21] Ngetich KF, Mucheru-Muna M, Mugwe JN, Shisanya CA, Diels J, Mugendi DN. Length of growing season, rainfall temporal distribution, onset and cessation dates in the Kenyan highlands. Agricultural and Forest Meteorology. 2014, 188:24–32.

[22] Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd edition, John wiley & sons, 1984. Newyork, 680pp.

[23] SAS. Statistical Analytical System. SAS Users Guide. 5th edition. SAS Inc, Cary N.C. 1996

[24] Uno T, Tajima R, Suzuki K, Nishida M, Ito T, Saito M. Rice yields and the effect of weed management in an organic production system with winter flooding. Plant Production Science. 2021 Oct 2, 24(4):405–17. https://doi.org/10.1080/1343943X.2020.1865823

[25] Sun L, Li X, Wang X, Xiang L, Yang J, Min Q. Growth and respiratory metabolic adaptation strategies of riparian plant Distylium chinense to submergence by the field study and controlled experiments. Plant Physiology and Biochemistry. 2020 Dec 1, 157:1–12. https://doi.org/10.1016/j.plaphy.2020.10.006

[26] Xiaoling L, Ning L, Jin Y, Fuzhou Y, Faju C, Fangqing C. Morphological and photosynthetic responses of riparian plant Distylium chinense seedlings to simulated Autumn and Winter flooding in Three Gorges Reservoir Region of the Yangtze River, China. Acta Ecologica Sinica. 2011 Feb 1, 31(1):31–9. https://doi.org/10.1016/j.chnaes.2010.11.005

[27] Tian L xin, Bi W shuang, Ren X song, Li W long, Sun L, Li J. Flooding has more adverse effects on the stem structure and yield of spring maize (Zea mays L.) than waterlogging in Northeast China. European Journal of Agronomy. 2020 Jul, 117:126054.

[28] Yang WC, Lin KH, Wu CW, Chang YJ, Chang YS. Effects of Waterlogging with Different Water Resources on Plant Growth and Tolerance Capacity of Four Herbaceous Flowers in a Bioretention Basin. Water. 2020 Jun 6, 12(6):1619.

[29] Bell DT. Australian Trees for the Rehabilitation of Waterlogged and Salinity-damaged Landscapes. Aust J Bot. 1999, 47(5):697. https://doi.org/10.1071/BT96110

[30] Iwanaga F, Yamamoto F. Effects of flooding depth on growth, morphology and photosynthesis in Alnus japonica species. New Forests. 2008 Jan 1, 35(1):1–14. https://doi.org/10.1007/s11056-007-9057-4

[31] Wiström B, Emilsson T, Sjöman H, Levinsson A. Experimental evaluation of waterlogging and drought tolerance of essential Prunus species in central Europe. Forest Ecology and Management. 2023 Jun 1, 537:120904. https://doi.org/10.1016/j.foreco.2023.120904

[32] Kissmann C, Veiga EBD, Eichemberg MT, Habermann G. Morphological effects of flooding on Styrax pohlii and the dynamics of physiological responses during flooding and post-flooding conditions. Aquatic Botany. 2014 Oct, 119:7–14. https://doi.org/10.1016/j.aquabot.2014.06.007

[33] Liu J, Wang Z, Guo X. Stem Characteristic Associated with Lodging Resistance of Rice Changes with Varied Alternating Drought and Flooding Stress. Agronomy. 2022 Dec, 12(12):3070. https://doi.org/10.3390/agronomy12123070

[34] Sasayama D, Niikawa M, Hatanaka T, Fukayama H, Azuma T. Adaptive responses to flooding in wild rice species with various genomes other than AA. Plant Production Science. 2022 Jul 3, 25(3):350–8. https://doi.org/10.1080/1343943X.2022.2073896

[35] Zhou P, Qian J, Yuan W, Yang X, Di B, Meng Y. Effects of Interval Flooding Stress on Physiological Characteristics of Apple Leaves. Horticulturae. 2021 Oct, 7(10):331. https://doi.org/10.3390/horticulturae7100331