Original Research Article

Optimal weeding interval for *Grevillea robusta* nursery seedlings

Abstract

Weeding for young tree seedlings is critical for their growth. Weeds offer stiff competition for water, nutrients, light and space with the companion crops. Most tree nurseries do not have a formal weeding interval, hence the need for the current research.A nursery experiment was set up to investigate the best weeding interval for *Grevillea robusta* seedlings for a period of 8 months in Njoro, Kenya. The experiment was laid down in a RCBD with 4 treatments replicated 3 times. The treatments were as follows: Continuous weeding, 1-month interval, 2-months interval and non-weeding. Data was analyzed using ANOVA while LSD was applied to separate the significantly different treatments at $P \leq 0.05$ Results showed that survival for non-weeding (83.33%) was significantly (P=0.044) lower compared with one month and two-months weeding interval (100 and 96.67%) respectively. Continuous weeding and one-month weeding interval showed significantly higher height (23 and 25.27cm) respectively compared with two-months interval and non-weeding (17.67 and 13.83cm) respectively. On the other hand, 1-month interval showed the highest root length (22.67cm) which was significantly different (P=0.05) compared with non-weeding (15.67cm). Root biomass was significantly higher (P=0.02) for 1-month weeding interval (4.67g) compared with non-weeding (2.50g). *Grevillea robusta* seedlings should be weeded at an interval of 1-month during the nursery period in order to attain favorable growth. Non-weeding compromises the seedling growth due to severe competition with weeds. Even though continuous weeding favors seedling growth, is not economical due to high labor demand. Further research should be conducted using different soil mixtures and other species.

Keywords: Weeding, Grevillea robusta, Seedling growth, Nursery

1.0 Introduction

Weeds pose one of the biggest challenges facing nursery industry globally, hence understanding their growth traits and period to flowering is vital for their effective control [1]. They significantly affect nursery tree values by adversely reducing their growth and salability, thus marketability[2,3]. Weedy plants have a considerable plasticity; adaptability, environmental resistance, periodic germination and large seed quantities[4]. Weeds in forestry are mostly herbs, shrubs and trees which in nurseries, stands and deforested areas, adversely threatens the growth and establishment of cultivated tree species. As a control method, various ways have been developed, such as; chemical [3]and non-chemical practices or even the combined[2].Weedy

plants in tree nurseries are usually different from those in forest plantations; they resemble those found in crop farms. The efficacy of weed control differs greatly depending on the weed species as well as the control criteria. Weed control, consequently enhances tree growth and development [4]. A lacuna, therefore, exist on at what interval should weeding be done in tree nurseries to achieve the best seedling growth.

Weeds creates a large mass of aboveground and underground organs which compete with the planted plants for the available resources[5], such as light, water, nutrients[1,2,3, 6]. Weeds can be propagated sexually from seeds or vegetative. The spread is usually via agents, such as animals, wind, water and man [4, 5]Weed damage to plants is considered to be more adverse than that of diseases and pests combined.They are known to grow faster in forests and displaces young plants, overshadow and deprive them of important resources[3,4, 7].Weeds can, therefore, be defined as plants species growing where they are not wanted, interferes with germination and growth of forest plants and management, hence interfering with man's activities [4]. Weeds in forestry can consequently result into growth retardation, chlorosis, death and low resistance to pests and diseases. Improper weed control in nurseries, therefore, result into poor quality nursery plants and reduced plant summation due to deterioration[7].

Many weed species are allelopathic to crops, pasture lands and nursery seedlings. They depress yields[7] and contaminate the planted plants in addition to competition[8].Some weeds release allelochemicals that interfere with the establishment and growth of other plants [6]. Allelopathy can both inhibit [9]and stimulate seed germination, overall growth, development, reproduction, biosynthesis, division of cells as well as disease/weed management [10]. Additionally, weeds negatively affects the establishment and reseeding success in plants through competition[5]. They also result into inefficiency in land use, increased cost of production, problems in water management and inefficient labor utilization. Moreover, they provide a conducive environment for pests, viral, fungal and bacterial diseases in plants, hence reduced quality and quantity in production[8].

Even though there are diverse ways to control weeds, weeds are still a challenge [5]. Weed control in tree nurseries is one of the crucial factors in raising healthy seedlings [1]. It includes; mechanical, which entail, ploughing [11], disking, tilling, weeding [5, 7] farrowing, mowing [4],

mulching [6]. Mulches are used to destroy weeds to prevent the sprouting of weed seeds [1,5]. and are more safe, cheap and sustainable, and are more effective when used with cover crops[12, 13, 14,15, 16].Another control measure is preventive measures[8],such as planting of pure tree seeds, weed destruction, keeping agricultural and forest machineries clean[13]. Another measure is physical, whereby flame and superheated steam (thermal weed control) is used to destroy the weeds and plants protected with metal shields during burning[12]. Biological weed control is also another measure, whereby natural weed enemies; bacteria, fungi, viruses and insects are used to break the spread of weeds [14].There is also cultural weed control methods [11],whereby crop rotation, cover cropping among others are used [7,14]. Every weed species can have its specific natural enemies which can exterminate it. Last but not least, is use of herbicides which are known to reduce weediness especially at the initial stages of development in the tree nurseries[3, 5, 7], thus increase in wood volume due to increase in yields[4].

Few studies exist to demonstrate on how weeding influence seedling growth and survival in tree nurseries. Hand weeding as one of the physical weed control is, therefore, the most significant care measure in forest nurseries[5,6]. It is a regular practice in tree nurseries especially during dry spells [7]and has its significance, such as; destruction of weeds, soil aeration and soil structuremaintenance[4,5]. Hand weeding is, therefore, easy and environmentally friendly but tedious and labor demanding [3,6,7,15,17, 18] increases soil moisture and increases decay of soil organic matter [15, 18]. In spite of its high efficacy, hand weeding can never be a long-term option to control and manage weeds unless repeatedly done to eradicate all weed types and parts. If this is not properly done, the survival, growth, quality and quantity of seedlings is compromised [5].Hand weeding is also difficult to achieve in large tracts of land. It is also difficult to eradicate underground reproductive parts of the weeds, hence not very effective [19].

Hand weeding frequency and period depends on weed emergence, climate and soil preparation. The first period of weeding is, therefore, crucial and care should be taken to avoid root, buds and shoot damages[5]. Since weeds grow fast, weeding frequency is important so as to combat the weeds[4]. Periodic weeding helps in destroying recently germinating weeds, prevent soil crusting,hence improve water percolation. Repeated weeding, therefore, gradually reduces weed population,thus allowing the target crop to attain better performance in growth and yield. Despite the problems posed by weeds in the early crop or tree growth, little research has been conducted

on the same. A nursery experiment was, therefore, set up to investigate the best weeding interval for *Grevillea robusta* seedlings throughout the nursery life in Njoro, Kenya.

2.0 Materials and methods

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 of0°22'11.0"S, longitude 35°55'58.0"E and an altitude of 2238 m. 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 lies between 10.2 and 22.0°C[20] while the soils are mollic andosols with relatively high levels of phosphorus [21].

Experimental design

A nursery experiment was set up to investigate the best weeding interval for *Grevillea robusta* seedlings for a period of 8 months (July 2022 to February 2023) in Njoro, Kenya. Young Grevillea seedlings were raised in pots of 9x12 cm (width and length) respectively. The experiment was laid down in a Randomized Complete Block Design (RCBD) with 4 treatments replicated 3 times. The four treatments were as follows; Continuous weeding, 1-month interval, 2-months interval and non-weeding (control). Each treatment had 3 replicates while each replicate consisted of 10 potted Grevillea seedlings giving a total of 120 seedlings. Out of the 10 seedlings, 7 were sampled at random per treatment per replicate for data collection on shoot, foliage and root variables using a destructive technique.

Data analysis

One-way analysis of variance (ANOVA) model was used to test differences between treatment means using SAS statistical package[22] while the significantly different treatment means were separated by F ratio using Least Significance Difference (LSD) at $P \leq 0.05$ [23].

3.0 Results and discussion

3.1 Effect of weeding interval on the survival, shoot and foliage growth of *Grevillea robusta* nursery seedlings

Survival of Grevillea seedlings was affected by weeding. Results showed that survival for non-weeding (83.33%) was significantly (P= 0.044) lower compared with one-month and two-months weeding intervals(100 and 96.67%) respectively (Table 1). Weeds significantly lowers plant survival and can lead to seedling mortality, hence population associated with competition, therefore, corroborating with the present study[24].

Table 1: Effect of weeding interval on the survival, shoot and foliage growth of *Grevillea robusta* nursery seedlings

Weeding interval	Survival (%)	Height (cm)	Internode length (mm)	Number of leaves	Leaf length (cm)	Shoot biomass (g)	Total plant biomass (g)
Continuous weeding	93.33ab	23.00a	11.00a	16.67a	17.00a	8.67a	12.33ab
1-month	100.00a	25.27a	8.00ab	15.33a	16.33a	9.00a	13.67a
2-months	96.67a	17.67b	5.67bc	14.00a	12.57b	5.33b	8.50bc
Non-weeding	83.33b	13.83b	3.33c	9.33b	10.00c	3.00b	5.50c
***P* – value**	**0.044**	**0.005**	**0.010**	**0.003**	**0.001**	**0.004**	**0.014**
% CV	**5.9**	**12.7**	**26.0**	**10.2**	**8.3**	**20.7**	**21.9**
LSD	**11.05**	**5.056**	**3.632**	**2.806**	**2.325**	**2.685**	**4.380**

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

Similar results were reported by previous studies which demonstrated that hand weeding registered higher number of *Oryzasativa L.* seedlings which germinated and got transplanted [3]. Therefore, continuous weeding reduces weed count due to constant soil turn over, hence killing weeds seeds in the soil [25]. This reduces competition for resources, such as light, nutrient, moisture among others [8, 14]. The study was again congruent with other studies which reported higher growth of plants that were free from weeds [17, 19]. However, continuous weeding recorded the second least in seedling survival. This could be in line with other previous findings on weeding effects on guava plants due to continuous disturbances on root system [13, 19]. Other studies also recommend that hand weeding is good and that in 42 days, it should be done three times. Weeding, therefore, reduces seedling mortality associated with completion for resources by weeds [16, 25]. Weeding is, thus recommended as it results into increase in productivity and survival of seedlings [5, 26, 27].

Continuous weeding and one-month weeding interval showed significantly higher height (23 and 25.27cm) respectively compared with 2-months interval and non-weeding (17.67 and 13.83cm) respectively. The results were in conformity with previous studies [19,27, 28] which demonstrated increased plant height under weed control. This could be attributed to weed management which consequently creates a conducive environment for seedling growth and development due to reduced competition [19]. Moreover, seedling height was higher in one-month weeding period interval compared with continuous weeding. This could be explained by destruction of soil structure, reduction in soil organic matter, reduced water percolation and infiltration as well as increased soil compaction in continuous cultivation, thus reduced seedling height [1, 27].

Continuous weeding showed significantly ($P = 0.010$) higher internode length (11mm) compared with two-months (5.67mm) and non-weeding (3.33mm). One-month interval was also significantly higher for internode length (8mm) compared with non-weeding. This was congruent with previous studies that weeds reduce internode length and number in wheat plant [19, 28].

Number of leaves were significantly lower for non-weeding (9.33) compared with all the other treatments for weeding. Continuous weeding presented the highest number of leaves compared with the other treatments. The results were in conformity with other studies that weed management results into increased number of leaves compared with non-weeding [19].

Continuous weeding and one-month weeding interval showed significantly (*P*= 0.001) superior leaf length (17.0 and 16.33cm) respectively compared with 2-months interval (12.57cm) and non-weeding (10.0cm). On the other hand, 2-months interval was also significantly higher compared with non-weeding.Leaf length was also reported highest under continuous weeding compared with the other treatments which corroborates with other previous findings [19, 24].

On the other hand, one-month interval showed the highest total plant biomass (13.67g) which was significantly different (*P* = 0.014) compared with two-months interval and non-weeding (8.50 and 5.50g) respectively. Similarly, continuous weeding showed significantly higher total plant biomass (12.33g) compared with non-weeding. The results were in agreement with other previous studies which reported similar results under weed management in sweet corn [19]. Weed competition has also been reported to decrease dry weight of plants [14,17]. The results further corroborates with other studies that the above ground biomass are higher in weed free treatments as shoot and total biomass were highest in weeded than in non-weeded soils attributed to dramatic seedling suppression by weeds [13, 25].

Generally, 1-month weeding interval ranked the highest for most variables recorded except for foliage and internode length where continuous weeding was superior.On the other hand, non-weeding ranked the lowest in all the variables recorded for survival, shoot and foliage. To effectively clear weeds in nursery, regular weeding is recommended for weed eradication as demonstrated by previous studies [5, 25].

3.2 Effect of weeding interval on root growth of *Grevillea robusta* nursery seedlings

Continuous weeding showed the highest root collar diameter (5.67mm) which was significantly different (*P*= 0.02) from 2-months (3.67mm) and non-weeding (2.67mm) (Table 2). These results were similar to a study done by Gallo et al. [27]which shows that weeding increases root collar diameter and length in plants. These results were also in agreement with previous studies by [28]which reported that plant root diameter increases where there is no competition for water and nutrients by unwanted plants. However, care should be taken as hand weeding can result into root injury, consequently affecting the entire seedling [19]. Similar results were demonstrated by other studies that weeds reduce seedling root collar diameter [24].

Table 2: Effect of weeding interval on root growth of *Grevillea robusta* nursery seedlings

Weeding interval	Root collar diameter (mm)	Root length (cm)	Root biomass (g)	Root: shoot ratio
Continuous weeding	5.67a	22.00a	3.67ab	0.43c
1-month interval	5.00ab	22.67a	4.67a	0.50bc
2-months interval	3.67bc	21.67a	3.50ab	0.67ab
Non-weeding	2.67c	15.67b	2.50b	0.83a
P – value	**0.02**	**0.05**	**0.02**	**0.02**
% CV	**19.2**	**8.4**	**28.3**	**18.8**
LSD	**1.631**	**3.460**	**2.025**	**0.2283**

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, 1-month interval showed the highest root length (22.67cm) which was significantly different (P= 0.05) compared with non-weeding (15.67cm). However, continuous and 2-months weeding interval were similar to 1-month interval. This corroborated with earlier studies done on sweet corn which reported increased root length under chemical weed control attributed to lack of competition for the resources by weeds [19]. Weeding may have an adverse effect on plant root system by destroying roots near the soil surface, thus reduced root numbers [5].

Root biomass was significantly higher (P = 0.02) for 1-month weeding interval (4.67g) compared with non-weeding (2.50g). The findings agrees with other earlier studies which demonstrated that weeds lowers plant root performance [13, 26]. Root dry weight is also affected by weeds, whereby dry weight has been reported to reduce plant root dry weight [17, 27].

Root to shoot ratio was significantly higher for non-weeding (0.83) treatment compared with 1-month interval (0.5) and continuous weeding (0.5).This showed that non-weeding compromised shoot growth more than the root growth. This could be explained by the shading effect from the weeds.The results were contrary to previous studies which demonstrated that root to shoot ratio is greatly reduced in non-weeding soils due to resource competition [17, 28]. The results could

be attributed to plant root destruction during mechanical weeding which could have reduced plant root length and heightunder continuous weeding [1].

Conclusion

Grevillea robusta seedlings should be weeded at an interval of one month during the nursery period in order to attain favorable growth. Non-weeding compromises the seedling growth due to severe competition for space, light, nutrients and water. On the other hand, continuous weeding, though favoring seedling growth, is not economical due to high labor demand. Further research should be conducted using different soil mixtures and other species.

References

1. Altland JE&and Oregon State University. Extension Service. Weed control in nursery field production. Corvallis, Or.: Extension Service, Oregon State. 2005; 1-16

2. Yu P, Marble SC. Practice in Nursery Weed Control—Review and Meta-Analysis. Frontiers in Plant Science [Internet]. 2022 [cited 2023 Jun 15];12. Available from: https://www.frontiersin.org/articles/10.3389/fpls.2021.807736

3. Vala JR, Bhanvadia AS. Effect of weed management practices on growth and weed parameters in rice (Oryza sativa L.) nursery. 2022;

4. Vasic V, Konstantinovic B, Orlovic S. Weeds in forestry and possibilities of their control. In: Weed control. IntechOpen; 2012.

5. Kisambo BK, Ogillo BP, Musyimi D. Effects of weed control methods on weeds and productivity of range grasses in semi-arid Kenya. 2023;

6. Nyamwamu CN, Jeruto P. Assessment of Weed Species Traits, Germination to Flowering duration and Crops Affected on Farms in Kisii Central Sub County, Kisii County, Kenya. African Journal of Education, Science and Technology. 2023;7(3):166–73.

7. Xu Y, Chen X, Ding L, Kong CH. Allelopathy and allelochemicals in grasslands and forests. Forests. 2023;14(3):562.

8. Muoni T, Mhlanga B. Weed management in Zimbabwean smallholder conservation agriculture farming sector. Asian Journal of Agriculture and Rural Development. 2014;4(393-2016–23782):267–76.

9. Osipitan OA. Weed interference and control in cowpea production: A review. Journal of Agricultural science. 2017;9(12):11–20.

10. Sathishkumar A, Srinivasan G, Subramanian E, Rajesh P. Role of Allelopathy in Weed Management: A Review. AG [Internet]. 2020 Oct 24 [cited 2023 Jul 21] ;(Of). Available from: http://arccjournals.com/journal/agricultural-reviews/R-2031

11. Bachheti A, Sharma A, Bachheti RK, Husen A, Pandey DP. Plant allelochemicals and their various applications. Co-evolution of secondary metabolites. 2020;441–65.

12. Uddin KMD, Juraimi SA, Ismail RM. Weed management in tropical turfgrass areas: A review. Archives of Biological Sciences. 2012;64(2):597–603.

13. Kour A, Gupta N, Brar SK. Integrated weed management practices in guava nursery. Journal of Pharmacognosy and Phytochemistry. 2019;8(2):982–5.

14. Mia MJ, Massetani F, Murri G, Neri D. Sustainable alternatives to chemicals for weed control in the orchard - a Review. Hortic Sci. 2020 Mar 31;47(1):1–12.

15. Travlos IS, Cheimona N, Roussis I, Bilalis DJ. Weed-Species Abundance and Diversity Indices in Relation to Tillage Systems and Fertilization. Frontiers in Environmental Science [Internet]. 2018 [cited 2023 Jul 21];6. Available from: https://www.frontiersin.org/articles/10.3389/fenvs.2018.00011

16. Mechergui T, Pardos M, Jhariya MK, Banerjee A. Mulching and weed management towards sustainability. Ecological intensification of natural resources for sustainable agriculture. 2021;255–87.

17. Hanson BD, Schneider SA. Evaluation of Weed Control and Crop Safety with Herbicides in Open Field Tree Nurseries. Weed Technology. 2008 Sep;22(3):493–8.

18. Sahu MP, Kewat ML, Jha AK, Sondhia S, Choudhary VK, Jain N. Weed prevalence, root nodulation and chickpea productivity influenced by weed management and crop residue mulch. AMA, Agricultural Mechanization in Asia, Africa and Latin America. 2022;53(6):8511–21.

19. Fayaz S, Teeli NA, Hussain A, Ganai MA, Mir SA, Zahoor A. Response of sweet corn hybrid to establishment methods and weed management practices under temperate conditions. International Journal of Current Microbiology and Applied Sciences. 2019;8(2):1301–9.

20. 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.

21. Kinyanjui HC. Detailed soil survey of Tatton Farm, Egerton College, Njoro. Ministry of Agriculture-National Agricultural Laboratories Nairobi, Kenya. 1979 Sep 12;2–19.

22. SAS (1996). Statistical Analytical System. SAS. - Google Scholar [Internet]. [cited 2023 Jun 8]. Available from: https://scholar.google.com/scholar?hl=en&as_sdt=0,5&q=5.+SAS+(1996).+Statistical+Analytical+System.+SAS+Users+Guide.+5th+edition.+SAS+Inc,+Cary+N.C.&scisbd=1

23. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John wiley & sons; 1984.

24. N.S E, J.L K, K.M L. Appropriateness of Non-Destructive Measures of Young Pine Tree Performance in Weeding Experiments [Internet]. Research Note. 1997 [cited 2023 Jul 14]. Available from: https://www.tandfonline.com/doi/epdf/10.1080/10295925.1997.9631135?needAccess=true&role=button

25. Hendawy. Winter weeds and its control in the medicinal plants in Egypt: a survey study [Internet]. [cited 2023 Jun 30]. Available from: https://www.epj.eg.net/article.asp?issn=1687-4315;year=2019;volume=18;issue=1;spage=16;epage=26;aulast=Hendawy

26. Passaretti RA, Pilon NAL, Durigan G. Weed control, large seeds and deep roots: Drivers of success in direct seeding for savanna restoration. Bernhardt-Römermann M, editor. Appl Veg Sci. 2020 Jul;23(3):406–16.

27. Gallo J, Baláš M, Linda R, Kuneš I. The effects of planting stock size and weeding on survival and growth of small-leaved lime under drought-heat stress in the Czech Republic. Austrian Journal of Forest Science. 2020;137(1).

28. Dos Santos TA, De Resende AS, Da Silva FF, Machado AFL, Chaer GM. Weed interference factor that affect the growth on an Atlantic Forest tree species. 2019;