Influence of charcoal, manure and fertilizer soil amendment on growth of *Grevillea robusta*nursery seedlings.

Abstract

Soil amendment is vital especially in tree nurseries that are located away from the forest areas. Grevillea robusta seedlings are high nutrient demanders. An experiment was set up for a period of 8 months in 2021 at Egerton University, Njoro, Kenya to determine the effect of soil amendment on the early growth of Grevillea nursery seedlings. The experimental design was aCRD with 12 treatments replicated 3 times. The soil amendments included; manure, charcoal and artificial fertilizer combined with agricultural soil as well as their other combinations while forest soil was used as a check. The pot size was 9 by 12 cm in width and length respectively. Routine weeding and watering was done during the experimental period. The data was analyzed using SAS statistical packageand the significance differences between means were separated using LSD at $P \leq 0.05$. The results showed that forest soiland agricultural soil gave significantly ($P \leq 0.05$) the highest survival (84 and 81%) respectively compared with charcoal + manure + fertilizer combination (37%) which was the least. On the other hand, Forest soil had significantly the highest height (14.6cm) compared to all the other variables. Similarly, forest soil showed the highest root collar diameter (4.5 mm) which was significantly different from all the other variables measured except agricultural soil alone, agriculturalsoil + manure + fertilizer and agricultural soil + charcoal + manure which were similar.On the other hand, charcoal alone showed the highest root: shoot ratio (3.2), as well as root biomass which were significantly higher compared with agricultural soil + manure and charcoal + fertilizer.In conclusion, forest soil was superior in supporting the growth of both shoot, foliage and root collar diameter of grevillea seedlings. On the other hand, charcoal showed higher root to shoot ratio as well as root biomass. Forest soil is therefore recommended to be used in raising Grevillea nursery seedlings in areas nearby the forest. Further research is recommended on using the same soil mixtures on other tree species which are less demanding in nutrient uptake.

Keywords: Grevillea, nursery seedlings, soil amendments, growth

1.0 Introduction

Seedling production nurseries are vital in meeting the increasing demand for *Grevillea robusta*seedlings in agroforestry systems in farmlands. Earlier works [1,2] showed that over 50% of smallholder seedlings planted were from tree nurseries in close proximity to the farmlands. Previous studies showed that large scale nurseries have an edge over many smallholder nurseries in terms of seedlings performance based on quality seed [3].However, smallholder tree farmers have been documented in several studies to face challenges in availability of quality planting materials which in turn, affect the quality of the tree seedlings established [4,5]. Kenya Forestry Research Institute has the mandate to supply high qualitytree seed in Kenya and beyond [6].

Choosing the right growing media is critical in early seedlings performance. However, several studies have shown that several materials can be used as a growing media, but the final choice is based on the ability of the media to sustain plant growth [7]. On the other hand, more recent studies [8,9] documented that majority of the smallholder farmers lack adequate knowledge on the effects of various soil mixture composition on the seedling growth performance.

Growing nursery media is of major concern to agroforesters since this is where most variation in seedling performance occurs [10,11]. The variations in nursery growing media emerge from the different soil types and their amendments[12,13]. The influence of the growing media on the performance of commercial tree species is an important factor since it forms the basis of adjustments to tree nursery practices [14,15].

On the other hand, organic matter content of soil, which is a very importantcomponent, influence the physical condition, water holding capacity and the temperature of the soil, especially the soil bacteria processes, which in turn affect the availability of nutrients forplant growth[16].It further reduces adverse effect of excessive alkalinity, acidity and over-fertilization [17]. The cation exchange capacity (CEC) of the soil is increased, enabling the soil to hold more plant nutrient for a longer period. The organic matter produces organic acid which reduce the amount ofaluminum ions, further decreasing their ability to fix the phosphates, hence making P available for root development[18]. Recent studies [19,20] showed that synthetic fertilizer combined with manure and also lime especially in acidic soils, increases soil fertility and crop yields compared with sole chemical fertilizer.

Manure possesses enormous potentials which eventually lead to enhancement of soil fertility for luxuriant plant growth. Enhancement of soil fertility is the key to the production of high quality seedlings required for plantation establishment[21].

Similarly, charcoal waste has been used in soil amendment and earlier work [22] stated that charcoal can improve the physical, chemical and nutritional nature of the soil inducing better plant growth and development. Charcoal has very low N, but high P and K. Soil nutrient status is one important growth factor that affects assimilation ability, which is a vital determinant for growth and survival of seedlings. In addition to assimilation, respiration is a critical determinant of net carbon gain inseedlings[22].

Woody plants growing on Alfisols and Ultisols under kiln charcoal were reported to have better seed germination (30 % increase), shoot heights (24 %), and biomass production (13 %) [23]. Related studies working with sugi trees (*Cryptomeria japonica*) on clay loam soils, and five years of charcoal application at the rate of 0.5 Mg ha^{-1}, reported theheightsof sugitreesincreasedbyafactorof1.26– 1.35while thebiomassproductionincreasedbyafactorof 2.31–2.36[24].Other works [25] also reported that the fresh weight of the root, shoot and the whole tree, one year after replanting, increased in response to charcoal application at the rate of 2 % (w/w).

However, root dry weight was not significantly affected by the charcoal application. The probable reason for the lack of root growth response to this charcoal addition was due to the sufficient soil fertility level.

Charcoal application significantly influenced soil pH, C organic, N, P, K, C/N, exchangeablebases,CEC,BS,Al,andH, henceimproving the fertility of highlyweatheredtropicalsoils [26,22]. Charcoal application also led to the reduction in acidic cations and the increased in basic cations, and in turn, resulted in an increase in soil pH [27]. This further increased the exchangeable bases (Ca, Mg, K, and Na). Consequently, the base saturation also increased and becoming three to four fold higher aftercharcoalapplication.

Charcoal addition to soil at the rate up to 20 % also increased organic C and total N. The trend of organic C and total N increased as the rate of charcoal application increased [28]. Equally, potential P considerably increased as charcoal was added to the soils at the rate of 10 %. These data are apparent since charcoal contains some amounts of elemental C, N, P, and others[22].

Limited studies have previously focused on growing medium for Grevillea tree species and its early growth performance whose smallholder farmers' preferencewas observed to be high in agroforestry systems within the Kenyan highlands [29,30]. On the other hand, recent studies [31,32] showed that higher concentration was done on large scale nurseries with less attention on smallholder tree nurseries and also the growing media variation.

This present study sought to analyze the effect of different soil amendments on early growth performance of *Grevillea robusta* nursery seedlings. The specific objectives were i) to determine the effect of varying soil amendments on survival, height and foliage growth ii) to determine the effects varying soil amendments on root growth. This will provide the best soil amendment that can be recommended for raising *Grevillea* seedlings in the nursery, since it is a heavy nutrient demander.

2.0 Materials 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. 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 [33] while the soils are mollic andosols [34] with relatively high levels of phosphorus.

2.2 **Experimental design**

The experiment was laid down in a complete randomized design (CRD) with 12 treatments replicated 3 times giving a total of 36 experimental units. Each unit consisted of 10 seedlings raised in polythene pots of 9 by 12 cm in width and length respectively. The treatments were as follows; Forest soil, agricultural soil, manure, charcoal, artificial fertilizer and other amendment combinations. The experiment was set up for a period of 8 months from October 2020 to May 2021 at Egerton University, Njoro, Kenya. Forest soil was used as a check since it is preferred in raising tree seedlings in forest nurseries. Forest was collected from the indigenous forest near the nursery site while the agricultural soil was also attained within the cultivated area at 30 cm depth. Routine weeding and watering was done during the growth period. The soil combinations were in the ratio 2: 1 for agricultural soil + manure andagricultural soil + charcoal. However, other combinations of charcoal + manure were in the ratio 1:1. On the other hand, artificial fertilizer in form of Diammonium phosphate (DAP) combinations were applied in small quantities of 10g per pot.

The nutrient composition of soils and manure (Table 1) and chemical composition of charcoal (Table 2) are indicated.

Table 1: Nutrient composition of the soil amendments used

Nutrient content	Manure	Agricultural soil	Forest
Nitrogen %	1.86	0.93	1.05
Phosphorus %	0.25	0.21	0.15
Potassium %	1.29	0.96	0.89
Calcium %	1.62	2.02	1.42
Magnesium %	0.4	0.56	0.25
Iron mg/kg	807	1285	1085
Copper mg/kg	8.33	15	15
Manganese mg/kg	41.7	40	25
Zinc mg/kg	21.7	13.3	16.7

Source:[35]

Table 2. Some important chemical properties of charcoal

Chemical properties	Values
pH (H_2O)	8
C – Organic, %	55
N – Kjeldahl, %	0.1
C/N ratio	131
P – available (Bray, P_2O_5), ppm	69
K – available (Morgan, K_2O), ppm	133
Ca (1 N NH4Oac, pH 7.0 extraction), me/100 g	28
Mg (1 N NH4Oac, pH 7.0 extraction), me/ 100 g	8
Na (1 N NH4Oac, pH 7.0 extraction), me/100 g	2

Total (1 N NH4Oac, pH 7.0 extraction), me/100 g	55
CEC (1 N NH4Oac, pH 7.0 extraction), me/100 g	19

Source: [22]

2.3 Data analysis: Analysis of variance (ANOVA) model was used to test differences of treatment means using SAS statistical package [36] while the significantly different means were separated by using Least Significance Difference (LSD) at p $\leq$0.05 [37].

3.0 Results and discussion

3.1 Effect of soil amendment on survival, shoot and foliage growth of Grevillea nursery seedlings.

Forest soil and agricultural soil gave significantly (P $\leq$ 0.05) the highest survival (84 and 81%) respectively compared with charcoal (55%), agricultural soil + fertilizer (40%), agricultural soil + charcoal + fertilizer (51%) as well as charcoal + manure + fertilizer (37%) which was the least (Table 3).

Table 3: Effect of soil amendments on survival, shoot and foliage growth of *Grevillea robusta* nursery seedlings

Treatment	**Su al %**	**Height(c (cm)**	**N f l s**	**Leaf Length (cm)**	**Sh Bi ss (g)**	**Tota Plan bio s (g)**
1.Forest soil	84	14.6a	1	10.3a	3.	7.03
2.Agric soil	81	11.4b	1	6.9b	1.	4.10

3.Charcoal	55	8.7d	1	5.0cd	1.	5.16
4.Agric soil+ Manure	62	11.0bc	1	6.5bc	1.	3.86
5.Agric soil+ Fertilizer	40	10.0bcd	1	5.9bcd	2.	5.23
6.Agricsoil+Manure + Fertilizer	40	11.7b	1	5.9bcd	2.	5.20
7.Agric soil+Charcoal	62	10.2bcd	1	6.3bcd	2.	4.93
8.Agric soil+ charcoal+manure	62	12.2b	1	6.5bc	2.	4.80
9.Agric soil + charcoal+fertilizer	51	11.8b	1	6.4bcd	2.	5.46
10.Charcoal+Fertilizer	62	8.9cd	1	4.3bcd	1.	3.63
11.Charcoal+Manure	62	8.8cd	1	3.8d	1.	4.13
12.Charcoal+ manure+Fertilizer	37	10.0bcd	1	5.2bcd	1.	4.63
$P \leq 0.05$	0.0	0.05	0	0.05	0.	0.05
LSD	22.	2.3	2	2.6	0.	1.8
% CV	22.	12.7	8	25.9	24	22.0

Note: Values within a column followed by same letter (s) are not significant at $p \leq 0.05$

On the other hand, Forest soil had significantly ($P \leq 0.05$) the highest height (14.6cm) compared to all the other variables. Similarly, the lowest height was showed by charcoal (8.7cm), which was significantly different from all the other variables except most of the charcoal combinations. The current resultscorroborate with recent work [35] showed that forest soil gave highest survival as well as height in both Grevillea and cypress nursery seedlings. Other recent works [38] stated that Grevillea survival in the field was 57% under high rainfall conditions.

The highest number of leaves were showed by; agricultural soil + charcoal + manure (16), agricultural soil + charcoal + fertilizer (16), and charcoal + manure + fertilizer (16) which were significantly ($P \leq 0.05$) different from all the other variables except agricultural soil + manure and charcoal + manure. Forest soil showed the highest leaf length (10.3cm) and shoot biomass (7.3g), which were significantly higher compared with all the other variables. However, the only exception was in total plant biomass where only agricultural soil + fertilizer (5.2g) showed similar trend compared with forest soil.The current results are contradictory to earlier work by[22]thatstated that the best charcoal amount is (10 – 20) % in mixture for better height,stem diameter, leaf and shoot biomass in tree seedlings. He further stated that higher amounts of charcoal have little effect on growth and this therefore agrees with the current study.Earlier works [24,39] affirm that charcoal application at high rate may produce detrimental effects on crop growth.More recent work [40] stated that excess charcoal in the soil adsorbs nutrients leading to stunted plant growth and this corroborates with the current studies.

3.2 Effect of soil amendment on the root growth of *Grevillea robusta*nursery seedlings.

Results showed that forest soil gave the highest root collar diameter (4.5 mm) which was significantly ($P \leq 0.05$) different from all the other variables measured except agricultural soil alone, agricultural + manure + fertilizer and agricultural soil + charcoal + manure which were similar (Table 4). Forest soil has more balanced levels of NPK, and therefore able to support adequate growth of seedlings. Recent studies by [41] recommended that tree nurseries located far from forests can use a potting soil mixture of agricultural soil + manure in raising Grevillea seedlings since this gives similar growth performance with forest soil. The current studyalso agrees with these studies since manure mixtures were superior in supporting root growth.

Table 4: Effect of soil amendments on root growth of *Grevillea robusta* nursery seedlings

Treatment	Root collar diameter (mm)	Root length (cm)	Root biomass (g)	Root to shoot ratio
1.Forest soil	4.5a	19.7	3.4ab	1.0c
2.Agric soil	4.1ab	18.3	2.3ab	1.3c
3.Charcoal	2.6de	19.7	3.9a	3.2a
4.Agric soil+ Manure	3.3bcd	19.2	2.1b	1.2c
5.Agric soil+ Fertilizer	3.2bcd	16.8	3.2ab	1.8bc
6.Agric soil+Manure+ Fertilizer	3.8ab	21.0	3.1ab	1.5c
7.Agric soil+Charcoal	3.5bc	20.3	2.9ab	1.5c
8.Agric soil +charcoal+ manure	3.9ab	20.3	2.6ab	1.2c
9.Agric soil+charcoal+ fertilizer	3.4bcd	19.9	3.3ab	1.5c
10.Charcoal+Fertilizer	2.7cde	18.8	2.1b	1.4c

11.Charcoal+Manure	2.3e	21.6	3.0ab	3.0ab
12.Charcoal+ manure+Fertilizer	2.8cde	17.8	2.9ab	1.6c
P≤0.05	0.05	NS	0.05	0.05
LSD	0.9	4.9	1.7	1.3
% CV	16.4	15.0	34.9	44.0

Note: Values within a column followed by same letter (s) are not significant at $p \leq 0.05$

On the other hand, charcoal alone showed the highest root: shoot ratio (3.2), which was significantly higher compared with agricultural soil + manure (2.1g) and charcoal + fertilizer (2.1g).This could be explained by the porous nature and high levels of P contained in the charcoal media as earlier reported [22]. High P level favors the growth of roots, which in absence of N cannot increase vegetative plant growth. Earlier studies by [25] contradicts the current studies since their results showed that charcoal did not increase root development.

According to [35] agricultural soil should be sourced from the well managed farms which are not exhausted through continuous cropping and subsequent nutrient mining, and probably from fallow land.

Conclusion and recommendations

Forest soil was superior in supporting the growth of both shoot, foliage and also root collar diameter of grevillea seedlings while, the least growth was shown by charcoal alone and also other charcoal combinations.On the other hand, charcoal is quite porous and might have allowed excessive nutrient leaching from the media compromising overall seedling growth. Charcoal alone also resulted in higher root to shoot ratio and also root biomass.Forest soil is therefore recommended for use in raising Grevillea seedlings since they are high nutrient demanders. However, further research isrecommended on using the same soil mixtures on other tree species which are less demanding in nutrient uptake and also adding other mixtures with higher nitrogen levels.

References

1. Jemmimah H. Financial analysis of smallscale tree nurseries: A case of KibogaTownCouncil [internet].Makerere University; Available:http://www.dissertations.mak.ac.ug/bitstream/handle/20.500.12281/5660/Jemmimah-CAESBachelors.pdf?sequence=3&isAllowed=y.2018.
2. Beltrán ER. Silvicultural management of smallholder commercial tree plantations in the Southern Highlands of Tanzania: characterization and influencing factors [internet]. [place unknown]: University of Helsinki;Available:https://helda.helsinki.fi/bitstream/handle/10138/301688/Rams_Elisabet_pro_gradu_2019.pdf?sequence=2&isAllowed=y. 2019.
3. Irawan US, Purwanto E, Roshetko JM, Iriantono D, Harum F, Moestrup S. Smallholder nursery practices in southeast Sulawesi: seedling for planting and business. J Agric Stud. 2017;5(2):126. DOI: 10.5296/jas.v5i2.11450.
4. Dedefo K, Derero A, Tesfaye Y, Muriuki J. Tree nursery and seed procurement characteristics influence on seedling quality in Oromia, Ethiopia. Forests, Trees and Livelihoods. 2017;26(2):96-110. DOI: 10.1080/14728028.2016.1221365.
5. Odoi JB, Buyinza J, Okia C. Tree seed and seedling supply and distributionsystem in Uganda. Small-scale Forestry.2019 Sep;18(3):309-21. DOI: 10.1007/s11842-019-09420-w.
6. Kenya Forestry Research Institute, Research and Development Procedures Manual. KEFRI/SOP/R&D/04. Feb. 2018. Pp. 74.https://www.kefri.org/assets/publications/staffdownloads/QMS/R%26Dproceduresmanual.pdf
7. Larnyo A, Atitsogbui PJ. Effect of temperature treatments on seed germination and seedling growth of jute mallow (Corchorus olitorius). International Journal of Environment, Agriculture and Biotechnology. 2020;5(6). DOI: 10.22161/ijeab.56.29.

8. Kitonga K, Jamora N, Smale M, Muchugi A. Use and benefits of tree germplasm from the World Agroforestry genebank for smallholder farmers in Kenya. Food Security. 2020;12(5):993-1003. DOI: 10.1007/s12571-020-01047-6.
9. Hirpa A. Effects of Pot Size and Planting Media on the Early Seedling Growth Performance of Azadirachta indica A. Juss. Journal of Plant Sciences.2021;9(4):208-13.DOI: 10.11648/j.jps.20210904.21.
10. Hubbel KL, Ross-Davis AL, Pinto JR, Burney OT, Davis AS. Toward Sustainable Cultivation of Pinus occidentalis Swart z in Haiti: Effects of Alternative Growing Media and Containers on Seedling Growth and FoliarChemistry.Forests. 2018;9(7):422. DOI: 10.3390/f9070422.
11. Marler TE. Repetitive pruning of Serianthes nursery plants improves transplant quality and post-transplant survival. Plant signaling & behavior. 2019;14(8):1621246.DOI: 10.1080/15592324.2019.1621246.
12. Sax MS, Scharenbroch BC. Assessing alternative organic amendments as horticultural substrates for growing trees in containers. Journal of Environmental Horticulture. 2017;35(2):66-78.DOI: 10.24266/0738-2898-35.2.66.
13. Jim CY, Ng YY. Porosity of roadside soil as indicator of edaphic quality for tree planting. Ecological engineering. 2018; 120:364-74.DOI: 10.1016/j.ecoleng.2018.06.016.
14. Aderounmu AF, Asinwa IO, Adetunji AO. Effects of seed weights and sowing media on germination and early growth of Afzeliaafricana Smith ex Pers. Journal of Agriculture and Ecology Research International.2019;19(3):1-11. DOI: 10.9734/jaeri/2019/v19i330086.
15. Taylor AG, Amirkhani M, Hill H. Modern seed technology. Agriculture. 2021;11(7):630. DOI: 10.3390/agriculture11070630.
16. Thomas EY, Aluko AP. Effect of poultry manure on early growth of (Treculiaafricana) (Decne) seedlings and its impact on the soil chemical properties. Nigerian Journal of Soil Science. 2016; 26:181-9.

17. Bali RS, Chauhan DS, Todaria NP. Effect of growing media, nursery beds and containers on seed germination and seedling establishment of Terminalia bellirica(Gaertn.) Roxb., a multipurpose tree. Tropical Ecology. 2013;54(1):59-66.
18. Opala PA, Okalebo JR, Othieno CO, Kisinyo P. Effect of organic and inorganic phosphorus sources on maize yields in an acid soil in western Kenya. Nutrient cycling in agroecosystems. 2010; 86:317-29.
19. Iqbal A, Ali I, Yuan P, Khan R, Liang H, Wei S, Jiang L. Combined application of manure and chemical fertilizers alters soil environmental variables and improves soil fungal community composition and rice grain yield. Frontiers in Microbiology. 2022; 13:856355. DOI:10.3389/fmicb.2022.856355
20. Esilaba AO, Mangale N, Kathuku-Gitonga AN, Kamau DM, Muriuki AW, Mbakaya D, Zingore S. Overcoming Soil Acidity Constraints Through Liming and Other Soil Amendments in Kenya. A Review. East African Agricultural and Forestry Journal. 2023;87(1 & 2):9-9.
21. Afa FD, Bechem E, Andrew E, Genla FA, Ambo FB, Ndah NR. Effects of organic and inorganic fertilizers on early growth characteristics of Khaya ivorensis Chev (African mahogany) in nursery. African Journal of Plant Science. 2011;5(12):722-9.
22. Siregar CA. Effect of charcoal application on the early growth stage of Acacia mangium and Micheliamontana. Indonesian Journal of Forestry Research. 2007;4(1):19-30.
23. Chidumayo EN. Effects of wood carbonization on soil and initial development of seedlings in miombo woodland, Zambia. Forest ecology and management. 1994;70(1-3):353-7.
24. Kishimoto S, Sugiura G. Application of biochar technologies to wastewater treatment. Int Achieve Future. 1985; 5:12-23.
25. Ishii T, Kadoya K. Effects of charcoal as a soil conditioner on citrus growth and vesicular-arbuscular mycorrhizal development. Journal of the Japanese Society for Horticultural Science. 1994;63(3):529-35.
26. Sanchez PA, Villachica JH, Bandy DE. Soil fertility dynamics after clearing a tropical rainforest in Peru. Soil Science Society of America Journal. 1983;47(6):1171-8.
DOI: 10.2136/sssaj1983.03615995004700060023x

27. Foth HD. Fundamentals of soil science. John Wiley & Sons, NewYork United States of America; 1951; 435pp
28. Glaser B, Lehmann J, Zech W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review. Biology and fertility of soils. 2002; 35:219-30. DOI 10.1007/s00374-002-0466-4
29. Kung'u JB, Kihara J, Mugendi D, Jaenicke H. Effect of small scale farmers' tree nursery growing medium on agroforestry tree seedlings' quality in Mt Kenya region. African Journal of Environmental Studies and Development. 2008;1(1):16-22.
30. Ashiono FA. Effects of Sawdust and Cow Manure Mixtures on Growth Characteristics of Blue Gum (Eucalyptus saligna) Seedlings in South Kinangop Forest, *Kenya* (Doctoral dissertation, Karatina University). 2020. https://karuspace.karu.ac.ke/bitstream/handle/20.500.12092/2483/Ashiono%20final2.docx%20(1).pdf?sequence=1
31. Kipkemboi K, Odhiambo KO, Odwori PO. Adoption of tree nursery practices as strategic enterprise at millenium villages project, Siaya County, Kenya. Africa Environmental Review Journal. 2019;3(2):26-34.
32. Panda MR, Pradhan D, Dey AN. Effect of different growing media on the performance of teak (tectona grandis linn.) stump in nursery. Indian Journalof Ecology.2021;48(4):1051-5. Available:https://www.researchgate.net/publication/355041246.
33. 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 ForestMeteorology.2014;188:24-32. https://doi.org/10.1016/j.agrformet.2013.12.011
34. Kinyanjui HC. Detailed soil survey of Tatton Farm, Egerton College, Njoro. Ministry of Agriculture-National Agricultural Laboratories. Nairobi, Kenya. 1979.
35. Owino JO, Onyango AA, Angaine PM, Inoti SK. Effect of Soil Mixtures on Early Growth Performance of Grevillea robusta and Cupressus lusitanica Seedlings in the Highlands of Kenya.

International Journal of Plant & Soil Science. 2022;34(22):597-609. DOI: 10.9734/IJPSS/2022/v34i2231413

36. Statistical Analytical System. SAS Users Guide. 5th edition. SAS Inc, Cary N.C; 1996.
37. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John wiley& sons; 1984.
38. Abrha G, Hintsa S, Gebremedhin G. Screening of tree seedling survival rate under field condition in Tanqua Abergelle and Weri-Leke Weredas, Tigray, Ethiopia. Journal of Horticulture and Forestry. 2020;12(1):20-6. DOI:10.5897/JHF2019.0618.
39. Siregar CA. Application of mycorrhizal fungi, organic fertilizer and charcoal to improve the growth of indicator plant in tailing soils contaminated with Pb and Fe in gold mining of PT Aneka Tambang, Pongkor. Proceeding: Rehabilitation and Forest Conservation. Forest Research and Development Agency. Bogor, Indonesia. Center for International Forestry Research (CIFOR) didirikan pada tahun. 1993.
40. Hughes, T. The impact of activated charcoal on soil P^H: Exploring benefits and potential risks. Grilling Techniques.2023. https://lahinchtavernandgrill.com/the-impact-of-activated-charcoal-on-soil-ph-exploring-benefits-and-potential-risks/#:~:text=When%20activated%20charcoal%20is%20used,levels%20similar%20to%20agricultural%20lime.
41. Inoti SK, Ocholla JA. Manure soil amendment for Grevillea robusta seedlings in the Kenyan highlands. Open Access Research Journal of Life Sciences, 2022; 4(2): 043-049.
DOI: https://doi.org/10.53022/oarjls.2022.4.2.0077