Cowpea (*VignaUnguiculata*) Fast Establishment Enhances its Potential for Food Security and Short-Term Rotations in Semi-Arid Areas in a Changing Climate

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Abstract: ***Cowpea (Vignaunguiculata L. Walp.) is a drought resistant, multipurpose legume commonly used for food, fodder and soil fertility improvement. Cowpea and commonly cultivated multipurpose shrubs (Calliandracalothyrsus and Leucaenaleucocephala) were evaluated for their early growth establishment abilities by assessing nodulation, shoot and root biomass, root to shoot ratios and total plant biomass. The main objective of the study was to investigate how cowpea early growth compares with that of commonly grown multipurpose leguminous tree shrubs and assess the potential of the test plants for use in short term rotations in semi-arid areas. The experiment was laid down as a completely randomized block design replicated five times. Results obtained indicated that cowpea maintained higher values for all parameters measured in the test plants throughout the sampling period. For instance, cowpea accumulated highest shoot biomass of 1.2g compared to 1.08g and 1.04g accumulated by Leucaena and Calliandra, respectively. Root biomass was also highest for Cowpea 1.5g, followed by Leaucaena 1.2g and finally Calliandra. 0.9g. Cowpea root to shoot ratio was significantly (p<0.05) higher than that of Calliandra. These results indicated that cowpea could be a potential short rotation legume for cropping systems in the semi-arid areas in a changing climate.***

Keywords: Biomass, Cowpea, Early growth, Nodules, Short rotations

1. Introduction

Crop yields in Sub-Saharan Africa are currently low ([1]).The commonest constraints facing crop production in most parts of Sub-Saharan Africa includes soil nutrient deficiencies, soil physical constraints, pests and diseases as well as soil fertility management practices ([2], [3],[1]). Low soil fertility results from loss of soil organic matter because many farmers, especially smallholders, carry out farming practices which discourage organic matter accumulation in the soil. Such practices includes continuous cropping, removal and or burning of weeds, cutting and carrying off-farm of crop residues to feed livestock, overgrazing on the farms during the long dry spells, soil erosion by water and wind, and little or noaddition of organic or inorganic inputs to replenish soils ([4], [5]). Lack of organic inputs, which ties mineral elements into the soil, reduces the soil ability to respond to inorganic mineral fertilizers. Studies have shown that combination of both organic and inorganic inputs have synergy and cause crops to perform better than either organic or inorganic fertilizers when singly added ([6], [7], [8]). Disadvantages of low fertility soils includes low agricultural yields, food insecurity, uneconomical agricultural investments, increased food prices, and reduced government revenue from agricultural produce ([9], [10]). This calls for sound soil management practices to enhance soil fertility and boost yields.

Farmers in Sub-Saharan Africa havehistoricallyused livestock manure to counter nutrient depletion and hence increase crop yields ([11],[12], [13],[14], [15], [16],[17], [18]). However, livestock manure are usually inadequate and vary in nutrient content depending on livestock feed and manure collection and storage methods ([18], [19], [20]).Fertilizers are also used but their use is limited by their high costs, scarcity, and cultural beliefs especially in developing countries ([21], [14]). Therefore, there has been continuous search for alternative and sustainable sources of soil nutrients especially nitrogen ([21], [22]). Studies on the use of leguminous plants to enhance soil nutrient are common ([23], [24], [25], [26]). These studies showed that leaves of leguminous plants release nutrients which can beused as mulches to enhance crop growth. This study therefore sought to investigate fast-establishing and growing multipurpose legume which in its early growth can provide high leafbiomass for food and soil fertility enhancement in the current changing climate in the semi-arid areas. In this study a comparison of early growth of commonly used leguminous shrubs for soil enrichment with that of a commonly cultivated drought resistant and fast growing grain legume, cowpea, was made. The ultimate goal was to establish which of the legumes can offer an option for short rotation mulches for enhanced soil fertility in the semi-arid areas of south eastern Kenya in the current changing climate.

2. Materials and Methods

This study was conducted at The South Eastern Kenya University, main campus tree nursery. The university is located in Kitui County along machakos-Kitui road, 15 km off Kwa-vonza shopping center in a semi-arid environment at Geographycal positioning 01.313358°S, 037.75546°E and 01.31422°S, 037.75576°E, 1173 m above sea level. Seeds of leguminous shrubs were obtained from Kenya Forest Research Institute (KEFRI) while cowpea seeds were obtained from South Eastern Kenya University farm. Clean undamaged seeds were soaked in hot water overnight and later pregerminated in water agar. As soon as the seedlings

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started germinating, they were pricked out into polythene pots filled with pre-watered forest soil. The experiment was laid down as a completely randomized block design replicated five times. Enough seedlings were planted to allow for destructive sampling of five pots per species over a period of four weeks. The pots were kept moist by watering twice a day depending on weather conditions. Data collection started from the third week after seedling prick out to the sixth week. From each block five pots were picked randomly each week and polythene pots cut carefully to slowly remove the seedling root system out of the pots. The seedlings were washed in a gentle flow of water and nodules counted. The root system was separated from the shoot system and both labelled, anddried separately after which biomass of both systems were recorded. Data collected included nodule numbers, root and shoot biomass. Data generated from the collected data included total root and total shoot biomass, total plant biomass and root to shoot ratio. The data was analyzed using GenStat for Windows.

3. Results

All test species showed ability to nodulate with the native rhizobia without prior inoculation (Figure 1). Nodule numbers generally increased with time over the assessment periodand more nodules were recorded during the 6th week of nodule assessment (Figure 1). In overall, cowpea formed more nodules compared to either Leucaenaor Calliandra with a maximum of 27 nodules compared to 18 and 15 nodules recorded in Leucaena and Calliandra, respectively. With respect to nodule formation, cowpea significantly ($p<0.05$) recorded more nodules compared to Calliadra all through the assessment period. However, during the 6th week, cowpea significantly ($p<0.05$) formed more nodules compared to both Leucaena and Calliandra (Figure 1).

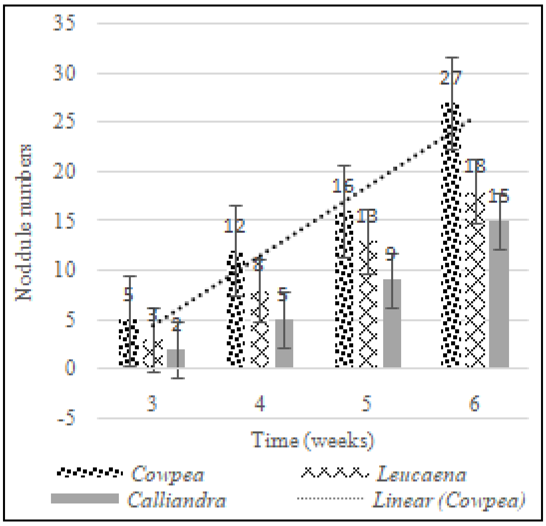

Figure 1: Nodule numbersrecorded in selected leguminous plants over a 4 week period

As expected, plant shoot biomass increased with time over the assessment period (Figure 2). However, cowpea biomass was generally higher than that of other test leguminous species recording. All through the assessment period, cowpea recorded a significantly ($p<0.05$) higher biomass compared to Calliandra. In addition, all the species showed a very fast growth between weeks 5 and 6 with Callindra recording significant ($p<0.05$) growth increase of 0.9 g.plant^{-1} while Leucaena biomass doubled over the same period.

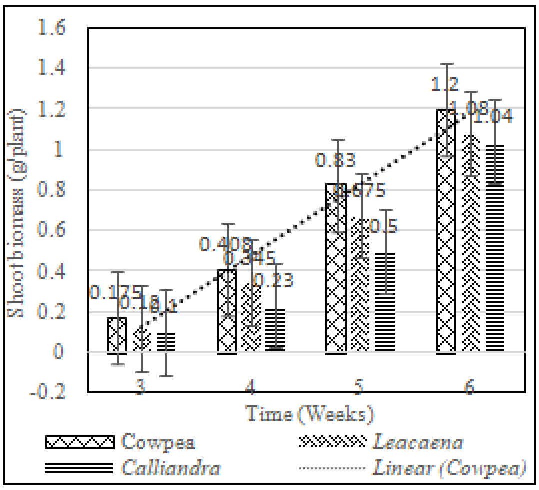

Figure 2: Shoot biomass recorded over a four week period for three selected test species

The root biomass of all species increases with time as expected (Figure 3). However, the root biomass of the cowpea consistently recorded higher biomass all through the assessment period (Figure 3) relative to the biomas of other test species. As observed with shoot biomass (Figure 2), cowpea root biomass was consistently significantly ($p<0.05$) higher than that of Calliandra throughout the assessment period. As also noted with the shoot biomass, root biomass significantly ($p<0.05$) increased in all test species between week 5 and 6, recording the fastest growth during the assessment period.

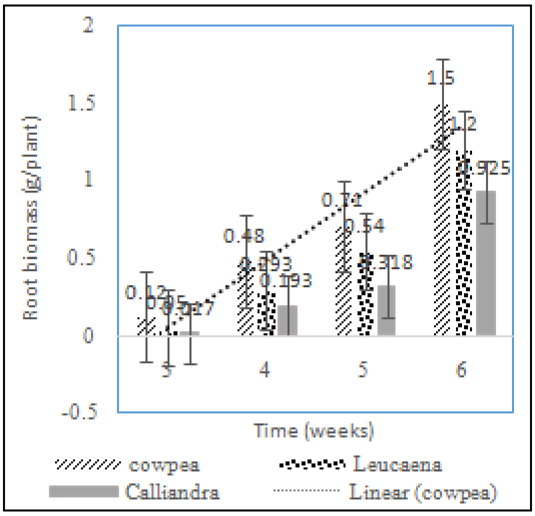

Figure 3: Trends in root biomass growth recorded in three selected leguminous species

Total root and total shoot biomass accumulated by the test species over the assessment period showed that cowpea in overall accumulated more both root and shoot biomass (root 2.81 and shoot 2.61 g.plant^{-1}) followed by Leucaena(root 2.08and shoot 2.22 g.plant^{-1}) and finally Calliandra (root 1.45 and shoot 1.7 g.plant^{-1}) (Figure 4). It was also observed that cowpea accumulated slightly more root than shoot biomass over the assessment period. Further, there were no significant differences between total root and shoot biomass accumulated by all species during the assessment period.

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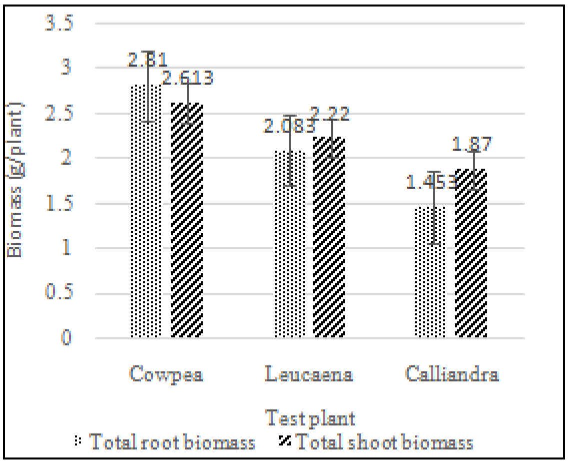

Figure 4: Total shoot and total root biomass accumulated over biomass assessment period

Plant total biomass, derived from total of root and total shoot biomass over the assessment period indicated that in overall cowpea accumulated most biomass of 5.423 $g.plant^{-1}$ over the sampling period. This was followed by Leucaena with 4.303 $g.plant^{-1}$ and finally Calliandra with 3.325 $g.plant^{-1}$. However, there was a significant difference ($p<0.05$) between the overall biomass accumulated by cowpea and that accumulated by Calliandra. (Figure 5).

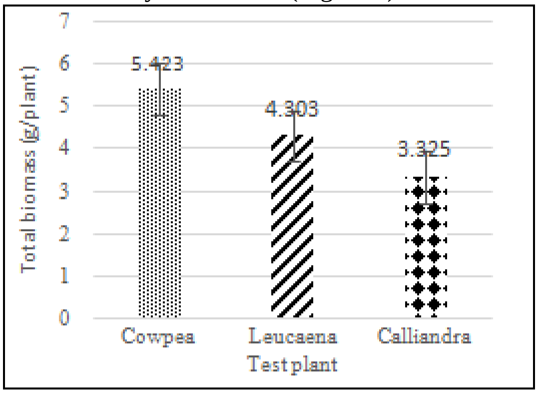

Figure 5: Total plant biomass accumulated over assessment period

Cowpea recorded highest root to shoot ratio (1.08) followed by Leucaena (0.94) and finally Calliandra (0.82) (Figure 6). There was a significant difference ($p<0.05$) in root shoot ratio between cowpea and Calliandra but not Leucaena. The root to shoot ratio of cowpea was more than 1 indicating that the root system of cowpea grew faster than the shoot system most probably contributing to the shoot and root growth trends observed in the species over the assessment period.

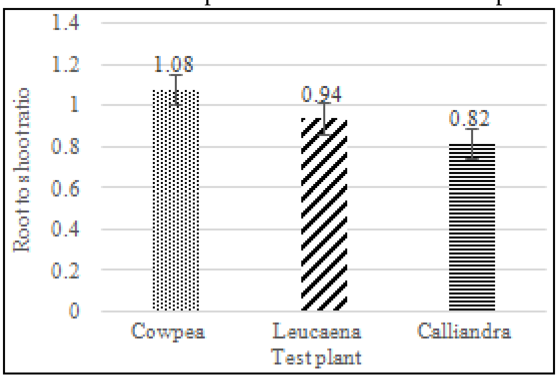

Figure 6: Root toshoot biomass ratio of the test plant species.

4. Discussion

All the three test plants, cowpea, Leucaena and Calliandra, showed potential tonodulate with indigenous soil rhizobia in nursery soils used for the study without prior inoculation. The soils used were collected from the surrounding forest which was dominated with indigenous Acacias implying the soils contained promiscuous rhizobia which also nodulated the test species. Amongst the three test plants cowpea accumulated highest nodule biomass throughout the assessment period implying it was the best nodulator with the indigenous rhizobia.

Cowpea recorded highest shoot biomasscompared to the other test speciesfor a similar growth period indicated its ability to grow faster than the test multipurpose shrubs. Thus, cowpea fast growth in its earlier growth days is crucial for its multiple uses which includes food as green vegetable, fodder and soil fertility improvement([27], [28]).In addition, cowpea fast early growth displayed a fast establishment characteristicneeded for multipurpose species [(29],[6]). Due to this, among the three test species, cowpeacould be the most preferred species that could establish fast and escape drought in the drylands where rainfall is low and unreliable.

Cowpea accumulated highest total shoot and total root biomass as well as total plant biomass compared to the other leguminous multipurpose shrubs. This observation most probably indicated that cowpea would be suitable for use as a short rotation legume that would either provide leaves for both food and fodder or used as a mulch to enhancesoil fertility in the low fertility soils of the ASALs under the current changing climate. Cowpea highest root biomass compared to other test speciesmost probably confirmed its fast root development contributes to its characteristic drought resistance hence its ability to survive well in dry areas ([6], [30]). This is because well-established roots would absorb water and mineral salts in the soil during dry seasons to support growth and development ([31]).

Biomass allocation to roots and shootpermits seedling to withstand dry seasons during the first stages of life and allow plants to resprout from underground organs after the passage of fires.Root growth is critical in nutrient acquisition of all plant species especially during early growth and plant establishment ([32]). Relative growth of root to that of shoot is called root to shoot ratio. The root to rationmay be higher than one ([33]). In this study, results showed that root to shoot ratio of test species increased with plant growth and by end of assessment period cowpea acquired a root to shoot biomass ratio of one indicating the species root system grew faster relative to shoot thus confirming its ability to withstand harsh climates.Further, the root to shoot ratio obtained in Calliandra in this study, 0.82, were comparable to 0.7 recoded by ([30]) while investigating the root to shoot offour shrubs including Calliandra. However, the root to shoot ratio obtained in the current study was higher than those obtained by ([6]) n semi-arid eastern Kenya for cowpea at 50% flowering in different nutrient amendments. The high root to shoot ratio of cowpea obtained in its early growth in the current study confirmed the potential of the species to be a candidate for short food and fodder crop in the semi- arid areas. The results further suggests that multipurpose leguminous tree and shrubs maynot be suitable for short rotation in the semi- arid areas in the current changing climate.

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5. Conclusion

It was concluded that cowpea grows very fast in its early establishment accumulating both high root and shoot biomass. The root establishes very fast and overtakes the shoot indicating that the ability of cowpea to withstand drought lies largely on its fast root establishment. Thus cowpea would be a suitable candidate for short term biomass rotation in the changing climate of the Kenyan semi-arid areas. In addition, leguminous multipurpose trees and shrubs may not be suitable for short rotations because of their slow growth during their early establishment.

6. Future Scope

This study concentrated on establishing biomass accumulated by cowpea and selected multipurpose shrubs during their early growth. However, it did not establish nutrient contents of the test legume which should be done in a future study. The rates of nutrient release by the leaves of the study legumes should also be established in a future study to further select on nutrient release to the soil in short rotations soil fertility management systems.

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