

Agroforestry potential of *Ricinodendron heudelotii* (Baill.) Pierre ex Pax in Nigeria

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With the current geometric increase in Nigerian population and the depleted soil nutrients vis-à-vis decreased agricultural outputs. It becomes pertinent to identify important indigenous multiple agroforestry trees that would be compatible with food crops on the same piece of land for multiple outputs. This study aimed at determining the agroforestry potential of *Ricinodendron heudelotii* with focus on the *ex-situ* growth rate of the tree, compatibility with maize as a test crop, coping ability and its impact on soil nutrients.

The experiment was sited at the Teaching and Research Farm, University of Ibadan, Nigeria, utilizing two alley widths (3 and 6 m) and control (15 × 10 m). Maize plants were intercropped with trees at two different seasons (dry and rain), six months after tree planting, but only the rain season maize survived for further analysis. Data were collected on the height, collar diameter and number of leaves of the trees and maize. Soil analysis was carried out before and after the experiment. The data were subjected to descriptive statistics, ANOVA, *t*-test, Kruskal Wallis and Mann–Whitney U Test.

The results showed that the effect of alley treatment was significant ($p < 0.05$) on tree and maize growth with the 6 m alley having the highest values. The effect of planting distance was not significant on maize growth. The alley agroforestry practice significantly ($p < 0.05$) improved the soil properties of the site, especially for pH, available phosphorus, magnesium and sodium.

The findings from this study indicated that it is possible to incorporate maize into the alley of *Ricinodendron heudelotii* for multiple productions.

Keywords: agroforestry, alley cropping, *Ricinodendron heudelotii*, maize, soil nutrients

INTRODUCTION

Ricinodendron heudelotii (Baill.) Pierre ex Pax is a tree species commonly known as African Wood-Oil Nut Tree, which has been widely useful for human existence. Virtually all its parts are utilized for one purpose or the other (Tiki-Manga et al., 2000; Plenderleith, 2004; Udo, Ependi, 2009; Facheux et al., 2012; Nzali et al., 2016; Ndumbe et al., 2018; Zerrotabou, 2019). According to Tiki-Manga et al. (2000), the three most significant uses of *R. heu-*

delotii are food, medicinal and cultural purposes. Ngo-Mpeck et al. (2003) asserted that the nut of the species is one of the major flavouring agents that the rural dwellers cannot do without in their local dishes. This is due to its contribution to their balanced diet. It has equally been established that oil generated from *R. heudelotii* seeds is good to produce paints for surface coating (Yirankinyuki et al., 2018). Its ethnomedicinal importance cannot be overemphasized. Several diseases have been cured using decoction prepared from different

parts of the plant. For instance, extracts made from the leaves are used for the treatment of fever, malaria, anaemia, stomach pain, headache, toothache and to provide easy child delivery (Tchoundjeu, Atangana, 2006). Socioculturally, the seeds are used by Ibos in Nigeria for the 'Okwe' game, while the wood is traditionally used to produce drums (Fondoun et al., 1999; Tchoundjeu, Atangana, 2006; Fuashi et al., 2011; FAO, 2012; Cosyns et al., 2014). There are shreds of evidence that *R. heudelotii* stands are purposively speared on the plots when forests are newly cleared for agricultural purposes in many parts of Kenya and Nigeria (Tengnas, 1994; Oke, Odebiyi, 2007). This is because the leaves are variously utilized as good quality fodder for sheep and goats during the dry season (Anigbogu, 1996; Nzali et al., 2016). Despite these mentioned benefits derived from *R. heudelotii*, its agroforestry potential is yet to be studied.

According to Tengnas (1994), a good agroforestry tree is characterised by a fast growth rate, ability to coppice quickly after pollarding, ability to improve soil nutrients and compatibility with crops on the field. Since growth rate is very significant as far as the quality of agroforestry tree component is concerned (Barrios et al., 2019), determining the indigenous tree species with a considerable fast growth rate is still a problem in the Nigeria agroforestry system. This culminates from the fact that most indigenous tree growth studies end up in the nursery, and as such, the early growth on the field, where little or no external resources are supplied, is not known (Verinumbe, 2017). This has undoubtedly limited the expanded use of indigenous species for afforestation, reforestation and agroforestry purposes.

Soils of tropical regions, such as in Nigeria, where there are problems of degradation of habitat and loss of biological diversity following shifting cultivation and logging practices, are nutrient-deficient (Mukul, Herbohn, 2016). The poor-nutrient soils have hitherto aggravated the low yield obtained in many arable crops produce like maize, which are cultivated solely in an exposed field without a complementary impact of the tree (Amujoyegbe, Elemo, 2011). Consequently, rural communities are still battling with the problem of food insecurity. Therefore, in the face of the decreased agricultural production capacity triggered by land degradation in Nigeria,

incorporating *R. heudelotii* into agricultural cropland such as maize would be one of the means for food security to the local farmers as well as the entire populace in the country. If well designed and adopted by the local farmers, it is capable of diversifying the production output, which would have been single-crop-output under agricultural management practice alone. This study therefore aimed at determining the agroforestry potential of *R. heudelotii* to provide the information required for the diversification of agriculture and forest productivity.

RESEARCH METHODS AND CONDITIONS

This study was sited at the Teaching and Research Farm, University of Ibadan, Nigeria, and it lasted for the period of 15 months (from April 2017 to July 2018). The University of Ibadan is located on latitudes 7°46'20.27" N and 7°43'28.33" N, longitude 3°88'27.93" E and 3°90'78" E, on the edge of the derived savannah ecosystem. It has a humid tropical wet and dry climate and a relatively cool environment with an average rainfall of 1420.06 mm and relative humidity of 74.55%. The agroforestry practice used for this study is alley cropping and the method of Keerthisena and Gunawardana (1996) was adopted with little modifications. Alley cropping involves the simultaneous cultivation of the arable crop in between the rows (alleys) of trees. Maize was utilized as the test crop because it is one of the most important sources of food for human and animal nutrition and raw materials for industrial processing (Krasauskas, 2018).

Due to fair uniformity observed on the topography of the plot used, the study utilized a completely randomized design with three replications. Before and after the experiment, soil samples were collected systematically from the experimental plot to a depth of 15 cm using a soil auger and air-dried for onward analysis of organic carbon, total nitrogen, pH, available phosphorus, Fe³⁺ and exchangeable cations (K⁺, Ca²⁺, Na⁺, Mg²⁺) (Falade, Bada, 2009; Akinbisoye et al., 2014). A total number of 120 *R. heudelotii* seedlings raised at the Nursery Unit of the Department of Forest Production and Products, University of Ibadan, were used for this study. The experiment involved two alley widths of 3 and 6 m planted at 1 m spacing with control (15 × 10 m) having

no tree. The total dimension of the alley plot was 30 × 10 m containing a total of 7 rows of trees. Trees were allowed to stabilize for six months before the incorporation of maize as a test plant. During this period, silvicultural practices such as weeding and beating-up were carried out using a cutlass and a hoe. Maize seeds were sown in the alleys of *R. heudelotii* and in the control plot at a row espacement of 60 cm. Each of the 6 and 3 m alleys contained 7 and 2 rows of maize, respectively (Reynolds et al., 2007). Four maize distances to the trees were used according to Keerthisena, Gunawardana (1996). These include 120, 180, 240 and 300 cm. The sowing of maize was carried out both in the dry and the wet season, but the dry season maize failed to survive due to the problem of pests such as *Thryonomys swinderianus*, which burrowed into the soil and consumed most of the seeds before germination. The height, collar diameter and number of leaves of the survived during the wet season maize plants were taken every two weeks for the period of three months while the height, collar diameter and number of leaves of the trees were determined every month using a meter tape, Vernier calliper and visual counting for twelve months to document the early growth of the tree species on-site. Pollarding of the trees was done once at the twelfth month of tree planting to determine the coppicing ability of the trees, while the leaves were used as mulch on the plot. The coppices lengths and number of leaves of the pollarded trees were assessed for three months before the termination of the experiment.

The data were analysed for descriptive statistics, analysis of variance (ANOVA), *t*-test, Kruskal Wallis and Mann–Whitney U test using Statistica

Version 7, IBM SPSS version 20 and Microsoft Excel 2016. Mann–Whitney U was used to compare the significant difference in the number of *R. heudelotii* leaves produced from the two alley widths, while Kruskal Wallis was used to determining the effect of distance to the tree on the number of leaves produced by the maize crop. *T*-test was used to analyse the significant difference in the height and collar diameter of trees between the two alley widths. ANOVA was used to determine the significant effect of distance to the tree on the maize collar diameter and height.

RESULTS AND DISCUSSION

At the end of the one-year growth assessment, *Ricnodendron heudelotii* (Baill.) Pierre ex Pax planted at a 6 m alley width had better growth than those in a 3 m alley in terms of height, collar diameter and number of leaves (Table 1). The statistics show that the effect of alley width was significant ($p < 0.05$) on the height, collar diameter and the number of leaves produced by the trees (Table 1).

The growth characteristics of *Ricnodendron heudelotii* observed in this study is a good indication that it has the potential for agroforestry purpose. One of the most important qualities of a good agroforestry tree is the fast growth rate, which has been undoubtedly demonstrated by the one-year early growth of this tree species. The average height of *R. heudelotii* recorded in this study superseded the average height of 4-year old *Gmelina arborea* that was reported by Aleksandrowicz-Trzcinska et al. (2017). Over the years, it has been mentioned and believed that exotic tree species grow faster than the indigenous tree species of which one of the exotic tree species with the so-

Table 1. Growth characteristics of a year old *Ricnodendron heudelotii*

Alley width	Height ± SD, mm	Collar diameter ± SD, mm	Number of leaves	Mann–Whitney U value
3 m	1705.0 ± 73.6	201.2 ± 12.1	24	262.500
6 m	2557.1 ± 66.5	381.0 ± 12.0	31	
<i>t</i> -value	4.972	6.054		
df	66	66		
<i>p</i> -value	0.000*	0.000*	0.000*	

* = significant at 5% probability level.

SD = standard deviation.

called fast growth rate happened to be *G. arborea*, but this was recently disproved by Onefeli, Adesoye (2014), with on-site pragmatic study by comparing the exotic species growth with the indigenous species. These authors concluded that some of our indigenous tree species grow faster than the exotic species. Although this study may not have been conducted under the same environmental condition with that of Aleksandrowicz-Trzcinska et al. (2017), the present finding and the previous report (Onefeli, Adesoye, 2014) have further strengthened the fact that some indigenous tree species like *R. heudelotii* possess a faster growth rate than the exotic counterpart.

The results (Table 2) show that the average height of maize in the 6 m alley, 3 m alley and control were 1187.0, 1051.2 and 743.1 mm, respectively. The average collar diameter of maize in the 6 m alley was 121.4 mm, for the 3 m alley it was 124.3 mm while the control maize had an average collar diameter of 97.1 mm. Maize in both alley widths had the same number of leaves of 7 while the control maize had 6. The statistics show that the effect of alley treatments on maize growth characteristics was significant ($p < 0.05$). The significant effect of alley widths on the maize growth characteristics observed in this study is in agreement with the study by Reyn-

olds et al. (2007). However, the average height of maize for the present study is higher than what was reported by Reynolds et al. (2007) and this may be due to the differences in the study site, maintenance practices utilized and maize variety. The better performance of maize grown in between alleys than the control plot can be linked to the fact that the *R. heudelotii* used as the alleys contributed significantly to the nutrients utilized by the maize. This finding, however, contradicted the report of Elton (2013), which indicated that maize sown in an open field had better growth and yield compared to the maize intercropped with trees. This difference may be due to the fact that the growth of some trees retards the growth of other plants that are found around them through allelopathic inhibition (Aleem et al., 2014).

The effect of maize planting distance on the trees was not significant ($p > 0.05$) on the maize growth characteristics (Table 3). However, maize sown at 300 cm to the trees was the highest (1098.4 mm). This was closely followed by those sown at 240, 180 and 120 cm to the trees with an average height of 1033.1, 1031.0 and 906.2 mm, respectively. Maize sown at 300 and 120 cm to the trees had an equal number of leaves, which was 7, while those that were at 180 and 240 cm produced 8 leaves each.

Table 2. Growth characteristics of maize grown within different alley widths

Treatments	Height, mm	Collar diameter, mm	Number of leaves
6 m	1187.0 ± 13.8a	121.4 ± 4.0ab	7
3 m	1051.2 ± 29.2a	124.3 ± 3.2a	7
Control	743.1 ± 19.1b	97.1 ± 3.1b	6
<i>p</i> -value	0.015*	0.000*	0.006*

* = significant at 5% probability level.

SD = standard deviation.

Note. Means with a similar alphabet along the same column are not significantly different.

Table 3. Growth characteristics of maize with different planting distance to the tree

Distance to the tree	Height, mm	Collar diameter, mm	Number of leaves
120 cm	906.2 ± 26.5	111.0 ± 3.1	7
180 cm	1031.0 ± 29.2	125.4 ± 3.2	8
240 cm	1033.1 ± 32.5	122.0 ± 3.2	8
300 cm	1098.4 ± 30.8	124.1 ± 4.1	7
<i>p</i> -value	0.153ns	0.399ns	0.102ns

ns = not significant at 5% probability level.

SD = standard deviation.

Although the distance of maize to the tree did not significantly influence the growth characteristics of maize, maize that were farther to the trees performed better than the maize located very close to the alleys. This implies that the shade created by the branches of the trees may have interrupted the amount of light that reaches the maize.

The average coppiced length of *R. heudelotii* in the 3 m alley (672.3 mm) was insignificantly ($p > 0.05$) higher than that of the 6 m alley (645.1 mm) after three months (Fig. 1). A significant ($p < 0.05$) difference was observed between the number of leaves produced by 3 m alley trees (15) and 6 m alley trees (20) (Fig. 2). Tree species with the ability to withstand repeated pruning or pollarding with the pruned components, also be-

ing useful for other purposes such as a folder for animals or as mulch for soil fertility enhancer, were categorized as a unique candidate for agroforestry tree by Tengnas (1994). The average coppiced height recorded in this study has given a clear fact that *R. heudelotii* possesses such attributes. The significant higher quantity of leaves produced by the 6 m alleys than those of the 3 m alleys may be ascribed to the wider row planting distance between the trees in the 6 m alleys, which would have necessitated the production of many branches that brought about the increased number of leaves. This agrees to the existing findings (Briggs et al., 2007; Glencross et al., 2012), which emphasised that aside genetic constitution, planting density and artificial pruning are the main measures regulating

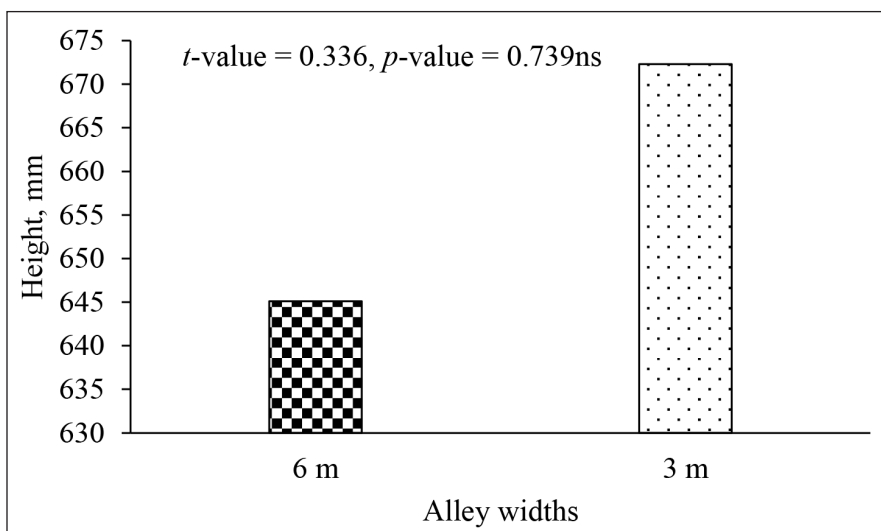


Fig. 1. Length of *Ricinodendron heudelotii* coppices after three months of pollarding

ns = not significant at 5% probability level.

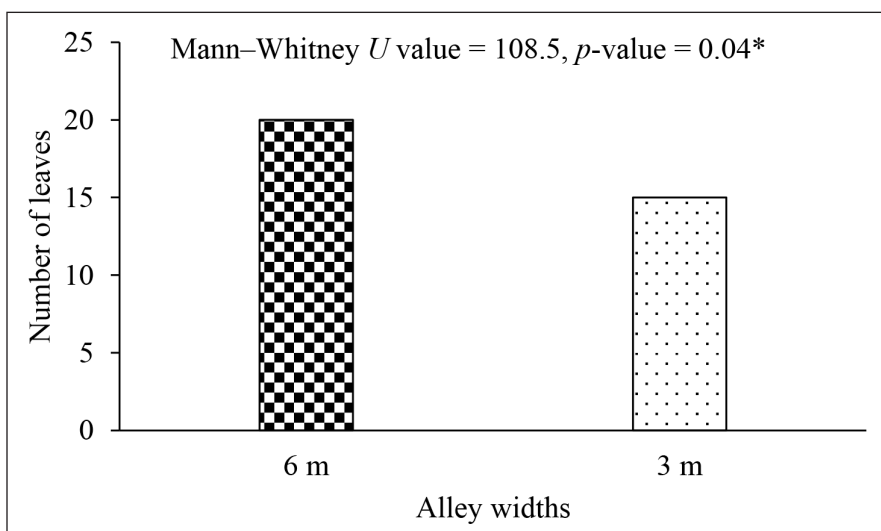


Fig. 2. Number of leaves of *Ricinodendron heudelotii* coppices after three months of pollarding

* = significant at 5% probability level.

the branch development in trees. However, planting density may have no full control over the early formation of buds, but it does significantly influence the subsequent growth and persistent of branches that obstruct branch occlusion (Mäkinen, Hein, 2006; Hein et al., 2007; Wang et al., 2017).

Considering the soil properties of the agroforestry plot, organic carbon (0.95%), nitrogen (0.10%), pH (6.14) and available phosphorus (19.75 mg kg⁻¹) before the experiment were lower compared to 1.23%, 0.13%, 6.36 and 23.91 mg/kg, respectively, after the experiment (Table 4). Pre-experiment exchangeable cations/bases (Ca 0.95, Mg 0.41, K 0.85 and Na 0.34 cmol kg⁻¹) were also lower when compared with the post-experiment (Ca 1.27,

Mg 0.49, K 0.88 and Na 0.39 cmol kg⁻¹). Likewise, the iron (Fe) concentration of the soil was higher in the post-experimental period (187.44 mg kg⁻¹) than in the pre-experimental period (131.80 mg kg⁻¹). The *t*-test result (Table 4) shows that the impact of the agroforestry on the soil pH, available phosphorus, magnesium and sodium was significant ($p < 0.05$), while the agroforestry effect was not significant ($p > 0.05$) on carbon, nitrogen, calcium, potassium and iron. The effect of the agroforestry treatments was significant ($p < 0.05$) on all the analysed soil properties except for organic carbon, nitrogen and micronutrient Fe (Table 5) with the control plot having the least values. The highest values were estimated in the 3 m

Table 4. Nutrient composition of the soil before and after the agroforestry experiment, *Ricinodendron heudelotii*

Analysis period	pH ± SD	C ± SD, %	N ± SD, %	P ± SD, mg kg ⁻¹	Ca ± SD, cmol kg ⁻¹	Mg ± SD, cmol kg ⁻¹	K ± SD, cmol kg ⁻¹	Na ± SD, cmol kg ⁻¹	Fe ± SD, mg kg ⁻¹
Before experiment	6.14 ± 0.25	0.95 ± 0.30	0.10 ± 0.02	19.75 ± 5.25	0.95 ± 0.24	0.41 ± 0.05	0.85 ± 0.09	0.34 ± 0.05	131.80 ± 18.9
After experiment	6.36 ± 0.16	1.23 ± 0.47	0.13 ± 0.05	23.91 ± 1.98	1.27 ± 0.37	0.49 ± 0.08	0.88 ± 0.06	0.39 ± 0.01	187.44 ± 57.6
<i>p</i> -value	0.013*	0.230ns	0.209ns	0.014*	0.098ns	0.039*	0.362ns	0.006*	0.050ns

* = significant at 5% probability level.

ns = not significant at 5% probability level.

SD = standard deviation.

Table 5. Soil nutrient composition of the different treatments

Treatments	pH ± SD	O.C ± SD, %	N ± SD, %	P ± SD, mg kg ⁻¹	Ca ± SD, cmol kg ⁻¹	Mg ± SD, cmol kg ⁻¹	K ± SD, cmol kg ⁻¹	Na ± SD, cmol kg ⁻¹	Fe ± SD, mg kg ⁻¹
3 m	6.35 ± 0.18a	1.27 ± 0.46	0.14 ± 0.05	23.39 ± 1.23a	1.26 ± 0.38a	0.51 ± 0.08a	0.88 ± 0.06a	0.38 ± 0.01a	174.25 ± 40.11
6 m	6.34 ± 0.12a	1.11 ± 0.43	0.12 ± 0.04	24.61 ± 2.69a	1.22 ± 0.31a	0.45 ± 0.03ab	0.89 ± 0.07a	0.39 ± 0.01a	191.29 ± 77.54
Control	6.00 ± 0.00b	0.70 ± 0.00	0.08 ± 0.00	14.2 ± 0.00b	0.71 ± 0.00b	0.35 ± 0.00b	0.76 ± 0.00b	0.29 ± 0.00b	114.00 ± 0.00
<i>p</i> -value	0.036*	0.236ns	0.220ns	0.000*	0.044*	0.015*	0.044*	0.000*	0.238ns

* = significant at 5% probability level.

O.C = organic carbon.

SD = standard deviation.

ns = not significant at 5% probability level.

Note. Means with a similar alphabet along the same column are not significantly different.

alley width for pH (6.35), organic carbon (1.27%), nitrogen (0.14%), calcium (1.26 cmol kg⁻¹) and magnesium (0.51 cmol kg⁻¹). Whereas the 6 m alley width had the highest value for phosphorus (24.61 mg kg⁻¹), potassium (0.89 cmol kg⁻¹), sodium (0.39 cmol kg⁻¹) and iron (191.29 mg kg⁻¹).

The positive impact of this agroforestry trial on the soil properties disagrees with Anikwe et al. (2015) in which drastic depletion of soil nutrients was reported in the post-experiment soil analysis result. This improvement in soil nutrients of the agroforestry plot after the trial may be ascribed to the pruning materials that were utilized as mulch on the soil. There are replete of findings (Jodaugienė et al., 2006; Kar, Kumar, 2007; Singh et al., 2007; Sinkevičienė et al., 2009), where the application of organic mulch improved the properties of depleted soil, which indirectly increased crop yields. According to Sinkevičienė et al. (2009), the use of organic mulches as a soil cover is efficiently effective in improving the quality of soil and increasing crop yield, especially in organic farming. Hence, the notable coppicing property of *R. heudelotii* vis-à-vis its ability to withstand pruning put it at a great advantage for agroforestry purpose.

CONCLUSIONS

This study has shown that *Ricinodendron heudelotii* (Baill.) Pierre ex Pax, being a non-leguminous multipurpose tree, has the potential for agroforestry purpose. This emanated from the fact that the tree is a fast-growing species, which attained the height and collar diameter of about 2557 and 381 mm, respectively, in one year. This growth rate is higher than what has been reported for *Gmelina arborea* that is one of the fastest-growing exotic tree species in Nigeria. Hence, this finding has disapproved the fact that exotic trees grow faster than the indigenous trees in Nigeria, however, there is a need for repetition of the study in different parts of the country for further confirmation. It was discovered that this agroforestry practice improved the nutrient qualities of the soil. This study revealed that the maize plant can be intercropped with the alleys of *Ricinodendron heudelotii* (Baill.) Pierre ex Pax to achieve a complimentary and better output than the monoculture system of only crop or tree with some precautions. On the aver-

age, a 6 m alley can be preferred as a better width for the selected tree species and maize crop. Therefore, agroforestry systems have the capacity to promote the transition to multifunctional agriculture that successfully ameliorates the problems of increasing the products of the crop in tandem with the provision of other ecosystem services.

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***Ricinodendron heudelotii* (Baill.) PIERRE EX PAX
POTENCIALAS AGROMIŠKININKYSTEI
NIGERIJOJE**

S a n t r a u k a

Dėl Nigerijos gyventojų skaičiaus didėjimo ir išekvotų dirvožemio maistinių medžiagų šalyje sumažėjo žemės ūkio produkcijos. Tikslinga įvertinti svarbius vietinius agromiškininkystės medžius, kurie tame pačiame žemės sklype derėtų su žemės ūkio augalais. Šiame tyrime buvo siekiama nustatyti *Ricinodendron heudelotii* potencialą agromiškininkystei, daugiausia dėmesio skiriant medžio augimo tempui *ex-situ*, suderinamumui su kukurūzais, gebėjimu atželti ir jo poveikiui dirvožemio maistinėms medžiagoms.

Eksperimentas buvo įrengtas Ibadano universiteto Mokymo ir tyrimų ūkyje (Nigerija). Naudoti du alėjos pločiai (3 ir 6 m) ir kontrolė (15 ir 10 m). Kukurūzai su medžiais buvo auginami sausuoju ir lietinguoju sezonais. Tyrimai atlikti praėjus šešiams mėnesiams po medžių sodinimo, tolimesni tyrimai vykdyti su kukurūzais, kurie išliko tik lietingojo sezono metu. Surinkti duomenys apie medžių ir kukurūzų aukštį, stiebo skersmenį ir lapų skaičių. Dirvožemio analizės atliktos prieš ir po eksperimento. Duomenys buvo išanalizuoti statistiškai, atlikti ANOVA, t-testas, *Kruskal Wallis* ir *Mann-Whitney U* testai.

Rezultatai parodė, kad alėjos pločio poveikis medžių ir kukurūzų augimui buvo esminis ($p < 0,05$), o 6 m alėja turėjo didžiausią poveikį. Sodinimo atstumo įtaka kukurūzų augimui nebuvo reikšminga. Alėjos agromiškininkystės praktika iš esmės ($p < 0,05$) pagerino vietovės dirvožemio savybes, ypač pH, fosforo, magnio ir natrio kiekius.

Šio tyrimo rezultatai parodė, kad kukurūzus galima įtraukti į *Ricinodendron heudelotii* alėjos daugiafunkcinį produktyvumą.

Raktažodžiai: agromiškininkystė, alėjos auginimas, *Ricinodendron heudelotii*, kukurūzai, dirvožemio maistinės medžiagos