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RESEARCH ARTICLE

Comparative Study of Germination and Initial Growth in Nursery of Three Agroforestry Species at Ruhande Arboretum in Rwanda

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ABSTRACT

Agroforestry extension in Rwanda has economic, environmental benefits and its role in improving soil fertility among other numerous benefits. This research undertook a comparative germination and initial growth study of the three agroforestry species namely *Senna spectabilis*, *Leucaenna trichandra*, and *Calliandra calothyrsus* at Ruhande Alboretum when seeds are sown directly in pots and indirectly in seedbed. The germination period spanned from one to three weeks for three species. *Senna spectabilis* germinate at 8.0% in seedbed sowing method and 3.7% in pots. Germination rate of 49.7% was recorded for *Leucaena trichandra* in seedbed while 66.7% was recorded in pots. For *Calliandra calothyrus* a germination rate of 45.3% was recorded in seedbed while 50.3% was recorded in pots. For *Senna spectabilis* direct sowing in pots produced seedlings which are taller (16.1cn) and bigger (2.72 cm) than their counterparts in seedbed. Seedlings in pots showed a big variability (6.5) in height among themselves and a big deviation from the true mean (16.1± 5.408) compared to seedlings in seedbed both in mean height and coral diameter. For *Leucaena trichandra* direct sowing in pots produced seedlings which are taller (26.25) and bigger (3.28 cm) than their counterparts in seedbed. Seedlings in pots showed a low variability (4.857) in height among themselves and a low deviation from the true mean (26.25±1.34) compared to seedlings in seedbed which showed a bit high variability (4.929) and a big shift from the true mean (25.43±1.36) both in terms of mean height and coral diameter. The difference both in mean height and coral diameter was not significant at 5% level of probability for both *Senna spectabilis* and *Leucaena trichandra.* For *Calliandra calothyrus* direct sowing in pots produced seedlings which are taller (26.55cm) and bigger (3.02cm) than their counterparts in seedbed. Seedlings in pots showed a big variability (3.6) among themselves and a big deviation from the true mean (26.55±0.999) compared to seedlings in seedbed .Although there is no significance between means in terms of height, the difference in mean coral diameter is significant at 5% level of probability. Since direct seeding produce taller seedlings than seedbed method, it should be preferred when one has little time to prepare for plantation and not high quantity of seedlings is needed.

Keywords- Agroforestry, Calliandra calothyrsus, Leucaenna trichandra, Polythene, Senna spectabilis, Seedbed

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INTRODUCTION

The Republic of Rwanda is a land locked and densely populated country. The population of Rwanda is 10,515,973 residents, of which 52% are women and 48% men based on the 2012 Census. Since the 2002 Census, the population has increased by 2.4 million, which represents an average annual growth rate of 2.6% (MIDIMAR, 2015).The population of Rwanda is still largely rural, with 83% living in rural areas. It covers an area of 26,338km2 and located between 1004'and 2051'longitude South and between 28053' and 3005' latitudes East.

It borders with Tanzania to the East, the Democratic Republic of Congo in West, Uganda to the North and Burundi to the South. The altitude ranges between 900m in the Southwest in Bugarama and 4500m at the top of Kalisimbi Volcanoes in Northwest.

Rwanda shows a bimodal rainfall with an annual rainfall ranging from 700mm in lowland to 2000mm in highlands and the average temperature ranging between 16^0 C and 20^0C.The vegetation and soil type of Rwanda are variable and closely linked (Nduwayesu et al., 2009).

Agriculture in Rwanda accounts for a third of Rwanda's economy (GDP). It constitutes the main economic activity for the rural households (especially women) and remains their main source of income. Today, the agricultural population is estimated to be a little less than 80% of the total population. The sector meets 90% of the national food needs and generates more than 70% of the country's export revenues (RDB, 2016).

The country's Economic Development and Poverty Reduction Strategy (EDPRS) defines a large number of programs in the agriculture sector including the intensification of sustainable production systems in crop cultivation and animal husbandry; building the technical and organizational capacity of farmers; promoting commodity chains and agribusiness, and strengthening the institutional framework of the sector at central and local level (RDB, 2016).

In Rwanda, trees and shrubs provide many wood and non -wood products and other services of direct benefit to mankind. Rwandans use woods as sources of firewood, charcoal, timber, furniture, poles, beehives, tools and wood craft materials. The non- wood products are also important as they satisfy human basic needs including food (like honey and fruits), medicine, forage, and fodder for feeding livestock and wildlife animals (Nduwayesu et al.,2009).

Trees and shrubs are equally important as valuable resources because of their remarkable role in the improvement of our living environment and soil productivity, climatic amelioration, water sources protection, carbon sequestration, conservation of biodiversity and tourism promotion (ICRAF, 2006).

Land degradation is a serious national and worldwide socio-economic complex problem which is mainly caused by deforestation, over-exploitation and poor management of resources. Human settlement and agricultural expansion, commercial logging, overgrazing, fuel wood and charcoal production and wildfire are among major causal factors of uncontrolled deforestation and land degradation in Rwanda (Nduwayesu et al.,2009).In order to reverse the current situation, there is need for rehabilitation of degraded land through afforestation and reforestation scheme,

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extension of agroforestry practices, adaptation of soil conservation measures, establishment of rotational woodlots, and control of population growth and alleviation of rural poverty (Nduwayesu et al., 2009).

Identification of potential sources of rapid and sustainable growth within the agricultural sector is a key action in Rwanda (RDB, 2016). Conventionally *Senna spectabilis,Leucaena trichandra*, and *Calliandra callothyrsus* trees can be grown from seeds sown directly in containers or seedbeds and later pricked out into pots(ICRAF, 2006). The possibility of using these methods to produce seedlings may confuse people on which method is the best to produce high quality seedlings timely at low cost

Limited financial resources should be used efficiently to meet the intended objectives. The use of money in producing seedlings without clearly being aware of what sowing method is more economically efficient than others leads to wasteful use of financial resources.

Mature seedlings to be planted should be available on time. Direct seed sowing in containers or indirect seed sowing in seedbed followed by pricking out later result in producing mature seedlings to be planted at different times.

High quality seedlings produce strong and healthy trees. Both direct seed sowing in containers and indirect seed sowing in seedbed produce seedlings with differences in vigor at planting date. Paying little attention to quality of seedlings at planting date may result in inability of planted seedlings to resist harsh conditions which induce poor subsequent growth. This is a potential problem because poorly developed trees reduce intended agroforestry economic and environmental benefits.

Financial resources and time involved in nursery practice affect availability of seedlings to foster agroforestry extension. The quality of seedlings to be planted affect intended agroforestry benefits. Thus, a growing awareness of the environmental and economic benefits of maintaining agroforestry trees species in Rwanda's watersheds should go along side with a simple, economically viable and fast method of germinating seeds and growing strong and healthy seedlings in the nursery to produce viable trees and shrubs.

This research undertook a comparative germination and initial growth study of three common agroforestry species namely *Senna spectabilis, Leucaenna trichandra*, and *Calliandra calothyrsus* in order to determine which a sowing method which is most time efficient and economically viable to produce high quality seedlings. The best sowing method would be recommended in all forestry and agroforestry nurseries for best results and at low cost.

The general objective of this research was to carry out a comparative study of germination and initial growth in nursery of three agroforestry species (*Senna spectabilis, Leucaena trichandra,* and *Calliandra calothyrsus*) at Ruhande Arboretum when seeds are sown using both direct seed sowing in pots and seed sowing in seedbeds.

Finding out a method which is economically viable with little time lags for sowing, growing and producing high quality seedlings of *Senna spectabilis, Leucaena trichandra, and Calliandra calothyrsus* will be a very important breakthrough in agroforestry extension practices in Rwanda.

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MATERIALS AND METHOD

Study area

The research works were carried out mainly at Rwasave nursery site. The nursery is managed by Rwanda Agricultures Board of Ruhande station. This site is located down at the edge of Arboretum forest close to Rwasave fish ponds near the road heading to Gisagara. This site is located near the stream that accessibility to water is easy. The type of soil at this site is forest loamy soil.

Research and equipment

Seeds

Seeds used in the study are of *Senna spectabilis, Leucaena trichandra* and, *Calliandra calothyrsus.*

Electronic caliper and a ruler

Electronic caliper was used to measure diameter at coral level. Alongside, a ruler was used to measure seedling height.

Electric kettle

Since seeds pre-treatment were done using hot water, a kettle was used to heat water.

Petri dishes

Petri dishes were used to keep seeds when counting and treating the seeds with hot water.

Germination and growth medium.

According to the International Rules for Seed Testing (1976), papers, sand and soil are commonly used as media or substrate; each species has its own requirements (Wood et al., 1991). The principle function of the growth medium is to supply sufficient nutrients. The commonly used media for germination of seeds are mostly different from that recommended in germination test. As there are no rules yet regarding the use of media, the choice of media is left to individuals (Burley, 1991). To make a good medium for seeds germination and growth, a mixture of forest loamy sand soils with organic manure was used in the whole nursery during this study. Here five wheelbarrows of local forest loamy soil were mixed with one wheelbarrow of organic manure and one wheelbarrow of sand was added to make a good soil mixture that favors seeds germination and initial growth.

Polythene bags

Polythene bags of 15 cm height and 10-12 cm of diameter were used during the research. They were filled properly with mixed soil as described above. Polythene bags were covered using dry grass to limit direct exposure to the sun and water splash during watering and grass cover were removed after seeds have germinated.

Research approach and methods

Given the same soil type, same climatic conditions, and same physical conditions, to compare germination percentage and initial growth for seeds sown in polythene bags versus seeds sown in seedbed, activities proceeded as follows:

Site preparation

The site was cleared using hoe and hands to take away weeds. After construction, nursery was divided into small blocks to separate seedlings of different species, and each small block was labeled to identify seed species it hosts (Laurence Mathieu-Colas, 2009).

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Seed pre-sowing treatments

Seeds of the studied species were soaked in hot water (80-100o C) for 24 hours for pre-treatment. During the pre-treatment, all the seeds under treatment were stored in petri dishes. Thus a total of 18 petri dishes were used each containing 100 seeds.

Experimental design

Seeds sowing was done using randomized complete block design(RCBD).A total 100 seeds of each species was sown directly in polythene bags with 3 replications, and 100 of seeds of each species was sown in seedbeds with 3 replications as well (Wood et al., 1991). In seedbeds seeds were arranged in parallel uniformly spaced bands that run the lengths and breadths of the beds (JICA.et al, 2003). All plots where seeds were sown were tagged with papers for easy identification (Burley, 1991).

Sample size

A total of 1800 seeds were used during the experiment. This sample was taken to make easy management of nursery operation in order get better and accurate results.

Measurement parameters

Only 671 seedlings (37.2%) germinated and both germination rate and other parameters were assessed based on this number. Following systematic sampling, diameter at coral level and height were recorded on only 214 seedlings, almost a third of seedlings which germinated.

Watering

From planting date, seeds were watered two times a day (morning and evening) in both seedbeds and polythene bags to ensure enough moisture (Wood et al., 1991). The amount of water used to water seeds sown in both polythene bags and seedbeds were equal.

Shading and mulching

Seeds in both polythene bags and seedbeds were shaded by grasses (mulching) to prevent or reduce evaporation or splash when it rains or when watering (Laurence Mathieu-Colas, 2009).

The place where seeds are grown was shaded above and protected to ensure no damage or disturbance during the study (Laurence Mathieu-Colas, 2009).

Data collection

Follow up of the trial was done three times a week. After 3 weeks from the planting date, the researcher calculated the germination rate. Two weeks after planting, seedlings in seedbeds were pricked out and transplanted in polythene pots. After 3 months, the height of seedlings from seedbeds and the seeds sown directly and grown in polythene bags was taken. The selection of the seedlings to measure was done using a systematic sampling with random start where each third seedling was selected to be measured for both height and diameter at coral level. In this study data were collected on height and diameter at coral level only using a ruler and electronic caliper.

Processing and analysis

Different techniques and software were used for the analyses of the recorded data in this research. The recorded data was organized in tables by using Microsoft Excel and Word (version 2010). Measured parameters were analyzed using Genstat Discovery Edition 4 Software. Since the height and diameter at coral level are major growth indicators,

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mean height and mean diameter at coral level were analyzed to compare the growth of seedlings in seedbeds vis-à-vis in polythene bags. Both mean and standard deviation were used to help estimate growth and its variation among seedlings sown and grown in polythene bags versus seedlings originated from seeds sown in seedbeds.

RESULT AND DISCUSSION

Germination period

For all the three studied species, germination took place in two to three weeks from the sowing date. Germination process was progressive since all seedlings did not germinate the in the same week.

Germination rate

For three hundred seeds sown in seedbed method for *Senna spectabilis*, only twenty our germinated (8.0%).For three hundred seeds sown directly in pots, only eleven germinated (3.7%).

About one hundred fourth nine (49.7%) for *Leucaena trichandra* germinated from three hundred seeds sown in seedbed method. Direct sowing in pots produced two hundred (66.7%).This germinated from three hundred seed which were sown.

One hundred thirty six germinated seedlings (45.3%) were recorded for *Calliandra Calothyrus* sown in seedbed method out of three hundred seeds sown. With direct sowing in pots, one hundred fifty one seeds (50.3%) germinated out of three hundred sees sown.

For all the three studied species both *Leucaena trichandra* and *Calliandra Calothyrus* germinated at high percentage in in polythene pots. The opposite was observed for *Senna spectabilis* which showed a high germination rate in seedbed. For all studied species,the highest germination rate was recorded for *Leucaena trichandra* both seed bed(66.7%) and in polythene pots(66.7%).

Table 1.Ilustration of germination rate for studied species.

Tree species	Sowing method	Total number of seeds sown	Germinated seedlings	Percentage
Senna spectabilis	seedbed	300	24	8.0%
	Direct in polythene pots	300	11	3.7%
Leucaenna	seedbed	300	149	49.7%
	Direct in polythene pots	300	200	66.7%
Calliandra	seedbed	300	136	45.3%
	Direct in polythene pots	300	151	50.3%

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Height and coral diameter after three months

Senna spectabilis

For *Senna spectabilis* direct sowing in pots produced seedlings which are taller (16.1cn) and bigger (2.72 cm) than their counterparts in seedbed. In seedbed, low values for mean height (15.70 cm) and coral diameter (2.6 cm) were recorded. Seedlings in pots showed a big variability(6.5) in height among themselves and a big deviation from the true mean(16.1± 5.408) compared to seedlings in seedbed which showed a bit little variability(3.74) and a little shift from the true mean (15.70±2.156).The same trend was observed for coral diameter. However, calculated t-value for height (0.19) is less than tabulated t-value (1.697) at 5% level of probability which indicates no significance between means in terms of height. Moreover, calculated t-value for coral diameter (0.38) is less than tabulated t-value (1.697) at 5% level of probability meaning that there is no significance between means in terms of coral diameter.

Table 2.Descriptive statistics for *Senna spectabilis*

Parameters	Mean (X)	Standard. Deviation (Sd)	Standard error (SX)	Confidence interval (CI) at 5 %
Height of seedlings in seedbed method (cm)	15.70	3.74	1.1	15.70±2.156
Height of seedling in direct method (cm)	16.1	6.5	3.2	16.1± 5.408
Coral diameter in seedbed method (mm)	2.6	0.38	0.12	2.6± 0.23
Coral diameter in direct method (mm)	2.72	0.68	0.34	2±0.66

T-test results and interpretation

Calculated t-value (0.19) is less than tabulated t-value (1.697) at 5% level of probability. Therefore, there is no significance in difference between means in terms of height.

Calculated t-value (0.38) is less than tabulated t-value (1.697) at 5% level of probability. Therefore, there is no significance in difference between means in terms of coral diameter.

Leucaena trichandra

For *Leucaena trichandra* direct sowing in pots produced seedlings which are taller (26.25) and bigger (3.28 cm) than their counterparts in seedbed. In seedbed, low values for mean height (25.43cm) and coral diameter (3.03 cm) were recorded. Seedlings in pots showed a low variability (4.857) in height among themselves and a low deviation from the true mean (26.25±1.34) compared to seedlings in seedbed which showed a bit

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high variability (4.929) and a big shift from the true mean (25.43±1.36).The same trend was observed in coral diameter. However, calculated t-value (0.725) is less than tabulated t-value for height (1.660) at 5% level of probability. Therefore, there is no significance between means in terms of height. Moreover, calculated t-value for coral diameter (0.326) is less than tabulated t-value (1.660) at 5% level of probability which reflect no significance in difference between means in terms of coral diameter.

Table 3.Descriptive statistics for *Leucaenna trichandra*

Parameters	**Mean (X)**	**Standard. Deviation (Sd)**	**Standard error (SX)**	**Confidence interval (CI) at 5 %**
Height of seedlings in seedbed method (cm)	25.43	4.929	0.697	25.43±1.36
Height of seedling in direct method (cm)	26.25	4.857	0.687	26.25±1.34
Coral diameter in seedbed method (mm)	3.03	0.639	0.090	3.03±0.17
Coral diameter in direct method (mm)	3.28	0.796	0.113	3.28± 0.22

T-test results and interpretation for *Leucaenna trichandra*

Calculated t-value (0.725) is less than tabulated t-value (1.660) at 5% level of probability. Therefore, there is no significance between means in terms of height.

Calculated t-value (0.326) is less than tabulated t-value (1.660) at 5% level of probability. Therefore, there is no significance between means in terms of diameter.

Calliandra calothyrsus

For *Calliandra calothyrsus* direct sowing in pots produced seedlings which are taller (26.55cm) and bigger (3.02cm) than their counterparts in seedbed. In seedbed, low values for mean height (25.95cm) and coral diameter (2.9 cm) were recorded. Seedlings in pots showed a big variability (3.6) in height among themselves and a big deviation from the true mean (26.55±0.999) compared to seedlings in seedbed which showed a bit little variability (2.6) and a little shift from the true mean (25.95±0.735).The same trend was observed for coral diameter .However, calculated t-value (0.19) is less than tabulated t- value (1.697) at 5% level of probability. Therefore, there is no significance between means in terms of height. Moreover, calculated t-value (0.38) is less than

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tabulated t- value (1.697) at 5% level of probability for coral diameter. Therefore, there is no significance between means in terms of height. Calculated t-value (1.586) is less than tabulated t-value (1.660) at 5% level of probability. Therefore, there is no significance in difference between means in terms of height. However, calculated t-value for coral diameter (1.904) is greater than tabulated t-value (1.660) at 5% level of probability. Therefore, there is high significance between means in terms of coral diameter.

Table 4. Descriptive statistics for *Calliandra calothyrsus*

Parameters	Mean (X)	Standard deviation (Sd)	Standard error of the mean (SX)	Confidence interval (CI) at 5 %
Height of seedlings in seedbed method (cm)	25.95	2.648	0.375	25.95±0.735
Height of seedling in direct method (cm)	26.55	3.643	0.515	26.55±0.999
Coral diameter in seedbed method (mm)	2.9	0.518	0.073	2.9±0.14308
Coral diameter in direct method (mm)	3.02	0.566	0.080	3.02±0.1568

T-test results and interpretation for *Calliandra calothyrsus*

Calculated t-value for height (1.586) is less than tabulated t-value (1.660) at 5% level of probability. Therefore, there is no significance between means in terms of height. Calculated t-value for coral diameter (1.904) is greater than tabulated t-value (1.660) at 5% level of probability. Therefore, there is high significance between means in terms of diameter.

Germination period

Germination periods lasted for two to three weeks. This means the four principal environmental factors that affect seed germination which water; temperature; light and gases awoke embryos for all healthy seeds in soil to start growth during this period.

Germination rate

Low germination percentage noticed depicts that seeds may be were harvested when immature, were not stored in optimum conditions, or were damaged during harvesting or storage or seeds had some other defects which could prevent them from germinate at high percentage. This is supported by the fact that a germination rate of less than 60% had been recorded in laboratory.

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Height and coral diameter after three months

The difference in height and diameter at coral level is normal in such a kind of biological data where different parameters can affect growth. Seedlings which resulted from seed seedbeds sowing method were a bit shorter and smaller in size of diameter due to growth time lag which follows pricking out. Pricking out of seedlings from seedbed into pots sluggishes down growth before seedlings resume their initial growth rate in new growing medium and growing conditions.

Variability pertaining to height and diameter at coral level among seedlings is higher for direct seed sowing in pots than indirect seed sowing in seedbeds for all the three species because no time lag paused and resumed growth for direct seed sowing method in polythene bags. Seedlings which germinated first in polythene bags continued to grow bigger and taller than their counterparts which followed afterward as the growing medium and conditions did not change in polythene bags. Pricking out of seedlings from seedbed into polythene bags created a new growing medium and new condition which paused and resumed growth. Pausing and resuming growth reduced variability for seedlings which originated in seedbed.

Direct seed sowing in polythene bags shows a bit bigger range of deviation of value from the true mean at 5% level of probability than indirect seed sowing method in seedbed because high variability for direct seed sowing in polythene bags induced standard error of the mean to be high.

CONCLUSION

A low germination percentage resulted from defective seeds. After germination has occurred, pricking out of seedlings from seedbed into polythene bags creates a growth time lag which reduces variability among pricked out seedlings as newly created growing medium and conditions pause a bit before resuming growth. However, this time lag and new growing medium make pricked out seedlings grow slowly while initiating their roots systems to adapt in a new growing environment in early days. Seedlings originating from direct seed sowing in polythene bags are a bit taller and bigger in size than their counterparts pricked out since no time lag hindered their growth.

Although all three species grew well, *Calliandra calothyrsus* and *Leucaena trichandra* grew the fastest in direct seed sowing method. *Senna spectabilis* grew the least both in seedbed and pots. In terms of producing strong and healthy seedlings with noticeable vigor, indirect seed sowing in seedbed outperforms direct seed sowing in pots. To produce mature seedlings ready for planting in harsh conditions requires three to four months and indirect seed sowing method produces a big quantity of seedlings than direct seed sowing in polythene bags.

As recommendation, seeds should be harvested when are mature and handled with utmost care to reduce the odds of being defective. In tandem, they should be stored in optimum conditions to retain their viability. Indirect seed sowing in seed bed should be used. This seed sowing method produces, high germination percentage, strong and healthy seedlings. Since only strong and healthy seedlings are pricked out from seedbed into polythene bags, this method is associated with low and justified

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cost. Moreover, this method gives a desired number of seedlings in desired time as you can make several seedbeds at the same time at low cost.

Direct seed sowing in polythene bags should be the least alternative. Buying polythene bags and filling these containers with soil, followed by sowing is so much laborious. In case germination percentage become low sunk cost associated with labor and polythene bags cost will not be recovered. Moreover, there is high probability that seeds can be dropped too deep into the container during seed sowing, and compacted soil in polythene bags can likely hinder germination to reach its optimum level.

To get mature seedlings to plant in harsh conditions, sowing seeds in nursery should be done at least three months before the planting date. Since direct seeding produce taller seedlings than seedbed method, it should be preferred when one has little time to prepare for plantation and not high quantity of seedlings is needed. Direct method should also be recommended for big seeds and with high germination capacity.

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