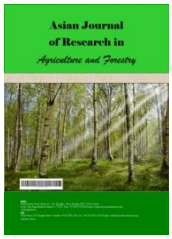

Asian Journal of Research in Agriculture and Forestry

7(4): 73-88, 2021; Article no.AJRAF.75871
ISSN: 2581-7418

Germination of Balsa Seedlings (*Ochroma lagopus* Swartz) under Different Sowing Media in East New Britain, Papua New Guinea

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Authors' contributions

Author BM carried out the study and collected data on germinations. Author KI contributed his technical knowledge to do all data analysis and statistics of the data. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRAF/2021/v7i430141
Editor(s):
(1) Dr. Sanjay Kumar Raina, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India.
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Reviewers:
(1) Luiz Rodrigues Freire, Universidade Federal Rural do Rio de, Brasil.
(2) Hari Om, Bihar Agricultural University Sabour, India.
(3) B. Kamatchi Kala, Sri Parasakthi College for Women, India.
Complete Peer review History, details of the editor(s), Reviewers and additional Reviewers are available here: https://www.sdiarticle5.com/review-history/75871

Original Research Article

Received 06 October 2021
Accepted 13 December 2021
Published 13 December 2021

ABSTRACT

A good sowing media ensures better anchorage of plants, provides a reservoir of nutrients and water, and enhance gaseous exchange with the atmosphere. Balsa (*Ochroma lagopus* Swartz); Vimmy variety, has proven its versatility in producing some of the best phenotypic characteristics such as higher jorquette height, less branching and high log volumes. This experiment was carried out using a combination of three different local materials; local garden soil, pumice soil and sawdust but in different combination ratios aimed to investigate the best combinations. Six treatments were tested: T1= Pure Garden soil, T2= Pumice, T3= Control (75% large coarse sawdust, 25% pure garden soil), T4= Pure Sawdust, T5= 50% medium coarse sawdust, 50% pure soil, and, T6= 33% medium coarse sawdust, 33% Pumice, 33% Pure garden Soil. The daily average germination count in Treatment 5 (50% medium coarse sawdust & 50% pure soil)

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produced constant germinations from day fifteen (15) to day twenty one (21). Treatments 1, 2, 3, 4 and 6 showed high variations in their daily average germination for the same period but did not produce a constant supply of germinations. Treatment 5 had the highest emergence rate index (ERI=71.76) followed by treatment 1 (ERI=66.59). Treatment 4 had the third highest seedling emergence (ERI=63.74) followed by treatment 3 (ERI=59.37), treatment 6 (ERI=57.22) and treatment 2 (ERI=53.81) at the lowest continuum. Substrates containing 50% soil and 50% medium coarse sawdust are regarded as better sowing media for *O. lagopus* seedlings.

Keywords: Sowing media; Ochroma lagopus Swartz; pumice; sawdust; garden soil; emergence rate.

1. INTRODUCTION

The demand for organic balsa products requires more innovative methods of rearing seeds coupled with more vigor balsa varieties to increase production. One of the technology that increases seedlings germination and rapid production is through careful selection of different combinations of sowing media. A good nursery management depends on the selection of a good sowing medium that produces plants with healthy root system [1,2]. A sowing media can be defined as a substance through which plants' roots grow and extract water and nutrients. The quality of seedlings depends mostly on the sowing media [3]. Selecting a right combination of growing medium is fundamental to healthy rooting system. Superior medias are usually produced from a mixture of various components that possess complementary physical and chemical properties [4]. Good media ensures better anchorage of plants, provides a reservoir of nutrients and water, and enhance gaseous exchange with the atmosphere [5]. Good sowing mediums are characterized by light weight, friability, easy blend ability, good water retention capacity, good drainage, good nutrient supply, must be porous, low bulk density and fungus free [6,7,8].

Balsa (*Ochroma lagopus* Swartz*);* Vimmy variety, is a surviving descendant of the initial *O. lagopus* which was introduced into Papua New Guinea in 1938 and later in 1946 [9] and has been thriving in East New Britain Province (ENBP) for the last 75 years. It has proven its versatility in producing some of the best phenotypic characteristics such as higher jorquette height, less branching and high log volumes. With increase in demand for growing balsa in ENBP in the last ten (20) years, the absence of a basic Standard Operation Procedure (SOP) has hindered the maximum potential of more field planting. The success of good and vigor seedlings begins with formulating the best combination of different sowing medium to trigger rapid growth and enable the full development of seedlings rooting system before field planting.

This experiment was carried out using a combination of three different local materials; local garden soil, pumice soil and sawdust but in different combination ratios aimed to investigate the best combinations. The soil in around the Gazelle Peninsula of East New Britain is volcanic in nature and is dominated by ash deposits from volcanic eruptions, has a humid climate with 2000mm-3500mm mean annual rainfall [10]. The soil is Andepts and is characterized by moderately weathered, freely drained soils formed from volcanic ash and contains appreciable amounts of allophane which usually contain significant organic matter. It has low bulk density of 0.85gcm^3 that has a high exchange capacity that lack characteristics associated with wetness [10]. Growing medium that has high Cation Exchange Capacity (CEC) produces heathy seedling growth [1].

Pumice (or pumicite in its powdered or dust form) on the other hand is formed from crushed lava rocks very common in volcanic areas. It forms the next layer below the top humus soil due to decomposition of dead organic matter over time. This crystal-like stone is formed when lava and water mix together as volcanic glass full of cavities and very low in density [11,12]. It enhances drainage, add bulk, improves aeration and keeps soils from getting mucky thus preventing root rots [4]. Pumice is an excellent sustainable inorganic component for any growing medium and significantly enhance the medium's physical and chemical characteristics by improving water retention, aeration, porosity, and fertility. Sawdust is also a common organic component used in sowing media. Sawdust has low bulk density, high porosity, moderate aeration, pH 3-6 and low CEC [1]. There are no global recommendations for growing media [13] and every manager needs to be able to experiment and find suitable, local, affordable ingredients to create good growing media. This is

true for balsa in East New Britain Province since there are no basic standard operating procedure (SOP) on how to prepare a good sowing media that has all the necessary physical and chemical properties to maximize seed germination and growth.

In this study a total of six (6) different media combinations were prepared from the three local materials at different combination ratios. Careful selections and preparations were carried out in order to fulfil the basic characteristics of sowing medium. The objective is to boost seedling production through the best combination of different media components. Vimmy Seeds were sown directly into these six (6) different media to test which sowing media would produce more germinated seedlings at a faster rate and to determine the consistency and average production of each sowing media overtime. The overall aim was to improve the nursery system in order to meet the demand for extensive field planting.

2. MATERIALS AND METHODS

2.1 Study Site

The study was done at Takubar nursery site which is located near Kokopo in East New Britain (ENB), Papua New Guinea (Fig. 1). With less than 13m above sea level, the study site is located approximately at 4°20' 40.91"S and 152°18' 19.52"S. The soil type is mostly sandy loam, well-drained, fertile, calcareous and volcanic in nature. The volcanic soil in ENB is young due to recent volcanic eruption in 1994 and has good binding traits for raising seedlings. There is no need for sterilization except if infection occurs. The climate is tropical where abundant rainfall is evident all year round even in the driest month. It is quite humid with an average rain fall of 2780 mm per annum and a brief dry season. Average annual humidity is 77-79% and temperature 27-29°C, respectively [14]. These abiotic conditions are highly suitable for crop cultivation as well as balsa cultivation.

2.2 Treatments

The six (6) Treatments tested were as follows: Treatment 1= Pure Garden soil, Treatment 2=Pumice, Treatment 3= Control (75% large coarse sawdust, 25% pure garden soil), Treatment 4= Pure Sawdust, Treatment 5= 50% medium coarse sawdust, 50% pure soil, and, Treatment 6= 33% medium coarse sawdust, 33% Pumice, 33% Pure garden Soil.

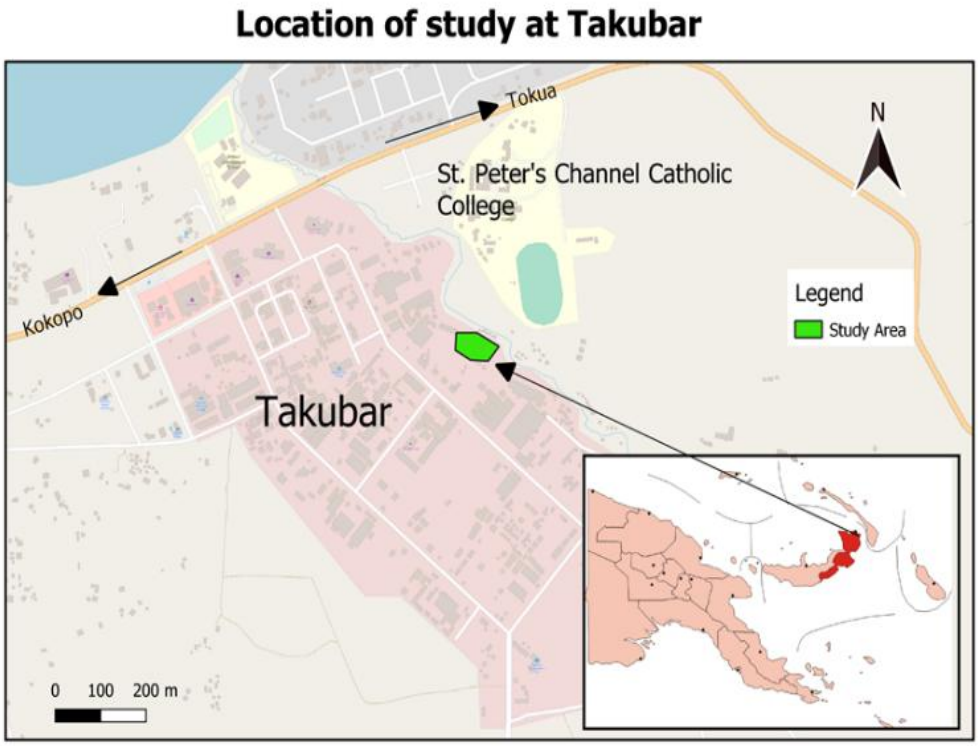

Fig. 1. Map of the study site at Takubar

2.2.1 Preparation of sowing media

(1). Pure Sawdust was obtained as a waste product from milled balsa logs and were bagged into sacks (Fig. 2). These sawdust was graded as medium coarse material since it had smaller pieces as coming straight from the mill (Fig. 3). The sacks were poured into a compost box of 1.5mx1.5mx1m and was watered down every day. Every five (5) days it was turned over using a spade and watered at the same time (Figs. 4,5 & 6). These steps were repeated weekly for a month (Fig. 7) until the sawdust structure was lose and forming crumbs when squeezed by the palm. Sawdust deprives seedlings off nitrogen [15], however for this study, no inorganic fertilizer was used in order to adhere to the protocols of Forest Stewardship Council [16] which promotes organic balsa products.

Fig. 2. Bags of fresh sawdust

Fig. 3. Grading sawdust material by straining

Fig. 4. Pure garden soil

(2). The second media was pure garden soil which was obtained directly from the top soil in the plantation using machinery. This media has been used as the main media for sowing balsa seeds. The soil was sieved using wire bench of 1cm x 1cm to remove debris and only pure soil was retrained in a wheelbarrow below the wire bench. The pure garden soil was stored away in a heap and covered with tarpaulin to keep it away from sun and rain to avoid evaporation of moisture and clogging with water respectively.

Fig. 5. Mixing of the soil and sawdust

Fig. 6. Mixing of the sowing medias

Fig. 7. Weekly media turning for 1 month

(3). Pumice soil media was obtained from the plantation in separate sacks. This was then strained using the bench sieve of mesh size 1cm x1cm. The sieved soil was stored away in a separate soil heap. It was also covered with tarpaulin to protect from rain and sun.

(4). Pure medium course sawdust was poured in another compost box of dimension 1.5m x 1.5m x 1m and mixed with pure soil at a ratio of 3 sawdust: 1 soil. This was watered every day, turned over and mixed every five (5) days for a month until there were no longer any sawdust but lose soil crumbs mixed with crumbs of sawdust.

(5). The control sowing media was the traditional formulation that has long been used for seed germination in the nursery and constituted of large coarse graded saw dust straight from the mill. This was mixed in the ratio of (3:1); 75% large coarse sawdust to 25% pure garden soil into a 1.5m x 1.5m x 1m compost box and watered down daily. It was turned over every fifth (5^{th}) day but watering continued daily for a period of one (1) month until they form a friable mixture.

2.3 Seeds Extraction

Flowering of balsa begins at the age of three years with distinct solitary white flowers which are usually pollinated by bats and insects. The seeds have long hairs which are encapsulated in a capsule and the feather-like hairs allow the seeds to be dispersed over long distances which is its natural way for colonization new areas. The dispersed seeds can remain in the soil for many years until germination triggered by burning of forest litter or creation of gap openings in the forest canopy due to dead or fallen trees. The seeds are very small, elongated and light [17] and thus careful extraction is required for commercial seedling rearing since these seeds are collected from selected seeds trees of best phenotypic characteristics.

Commercial production of balsa seeds required climbing the Seed Trees to harvest dried capsules with seeds in them. The seeds used in this experiment were Vimmy seeds, a local variety [9], widely used in field planting. The balsa seeds were extracted through mechanical means where the hairs containing the seeds are placed into a 240 litre hollow drum with a wire mesh welded to close off the hollow end and a removable collection tray below the mesh wire. Below the mesh is a cone shaped structure that enables the seeds to fall directly into the tray below. A rod attached to a motor above the drum was suspended into the middle of the drum which rotated on a circular motion while spinning the hairs with seeds thus allowing the seeds to drop directly into the collecting tray below. The seeds were collected and were further sieved to remove other debris before being weighed into 1 kilogram bags and stored away in a cooler between the range of 13 °C and 17°C until sowing time.

2.4 Seeds Preparation, Sowing and Monitoring

Six different trays each containing 100 plug trays each were filled with the six different treatments (Fig. 8). There were total of 600 tubes for all the six (6) treatments. Treatment A was placed into Tray 1, Treatment B into Tray 2, Treatment C into Tray 3, Treatment D into Tray 4, Treatment E into Tray 5 and Treatment F into Tray 6, respectively. These trays were placed on the nursery bench in preparation for seeds to be sown. Seeds were mechanically scarified by boiling in hotwater at 100°C and left overnight. Then water was changed every hour until one hour before the sowing time. Water was removed an hour before the sowing time to allow the seeds to dry on paper towels thus preventing them from sticking together.A dibbler was used to make hundred (100) holes (approximately 1 cm deep) for the seeds in each plug tray before sowing. After an hour the seeds were sown manually into each plug tray of different treatments. After sowing was completed, the trays were watered down using overhead mist sprayers and then daily watering followed for 21 days. Daily monitoring of the germination and growth of seeds began when the first seeds germinated on the fifth (5^{th}) day (Fig. 9) and continued for 21 days (Fig. 10).

Fig. 8. Seeds manually sown into each plug tray

Fig. 9. Seedlings after 5 days of sowing

Fig. 10. Seedlings after 2 weeks of transplanting

2.5 Data Analysis

2.5.1 Model testing and data representation

The data on germination count was negatively skewed (skewness= -0.806) and platykurtic (kurtosis= -0.288) implying a non-normal distribution as confirmed by Shapiro-Wilk test ($p<0.05$). We corrected the skewness in data distribution using the Generalized Linear Model (glm). Three (3) glm models were tested for their fit and relevance to the data: Gaussian linear, Poisson and Gamma distributions. Analysis of deviance was used as a measure of Goodness of Fit for the models. Gamma model had the lowest residual deviance (G^2=4.05) than Poisson (G^2=52.26) and Gaussian model (G^2=967.42). Residual deviance for Gamma model is $2\sum(\gamma - \mu)/\gamma - \ln(\gamma/\mu)$ where γ is observed data, $\bar{\gamma}$ the mean value of y, and μ are the fitted values of γ from the maximum likelihood model [18]. Due to the low deviance of Gamma, it was selected as the best model for the data. Data was fitted into this Gamma distribution, $g(\mu_i) = \eta_i = x_i\beta$, where g is the link function, $\beta = (\beta_0,...,\beta_p)$ is the vector of mean regression parameters, x_i is the i-th vector value of the explanatory variables, and $\eta_i$is a linear predictor [19]. All analysis were computed in RStudio (version 4.0.3) using the Gamma exponential family function (link = *log*). All graphs relating to germination counts were constructed with ggplot2 package. The Tukey HSD test was used to separate the treatment and time (days) means of germinations. Tukey HSD was also used in post hoc analysis to show level of significant differences between treatments. The subset function in R separated the temporal germinations of individual treatments and anova function produced the ANOVA of the model. All plots were iteratively executed with ggplot2 package and summary statistics in RStudio.

2.5.2 Germination indices

Six (6) germination indices were used to calculate the germinability of seeds under the different sowing media (treatments).

2.5.2.1 Median germination time (t_{50})

It is the time to reach 50% of final/maximum germination. With argument method specified as "coolbear", it is computed as follows.

$$t_{50} = T_i + \frac{(\frac{N+1}{2} - N_i)(T_j - T_i)}{N_i - N_i} \quad [20] \qquad (1)$$

Where, t_{50} is the median germination time, N is the final number of germinated seeds, and Ni and N_j are the total number of seeds germinated in adjacent counts at time $T_i$and $T_j$respectively, when $N_i<\frac{N+1}{2}<N_j$.

2.5.2.2 Mean germination time ($\bar{T}$)

It is the average length of time required for maximum germination of a seed lot and is estimated according to the following formula.

$$\bar{T} = \frac{\sum_{i=1}^{k} N_i T_i}{\sum_{i=1}^{k} N_i} \quad [21] \qquad (2)$$

Where, $T_i$is the time from the start of the experiment to the *i*th interval, N_i is the number of seeds germinated in the *i*th time interval (not the accumulated number, but the number corresponding to the *i*th interval), and *k* is the total number of time intervals.

2.5.2.3 Speed of germination or Germination rate Index (S)

It is the rate of germination in terms of the total number of seeds that germinate in a time interval. It is estimated as follows.

$$S = \sum_{i=1}^{k} \frac{N_i}{T_i} \quad [22] \qquad (3)$$

Where, T_i is the time from the start of the experiment to the *i*th interval, N_i is the number of seeds germinated in the *i*th time interval (not the accumulated number, but the number corresponding to the *i*th interval), and *k* is the total number of time intervals. Instead of germination counts, germination percentages may also be used for computation of speed of germination.

2.5.2.4 Mean germination rate ($\bar{V}$)

It is the mean number of germinations per day and is computed according to the following formula:

$$\bar{V} = \frac{\sum_{i=1}^{k} N_i}{\sum_{i=1}^{k} N_i T_i} \quad [23] \qquad (4)$$

Where, T_i is the time from the start of the experiment to the *i*th interval, $N_i$is the number of seeds germinated in the *i*th time interval (not the accumulated number, but the number corresponding to the *i*th interval), and *k* is the total number of time intervals.

2.5.2.5 Coefficient of velocity of germination (CVG)

It is the coefficient of rate or percentage of germination and it is estimated according to the following formula.

$$CVG = \bar{V}\mathbf{x}\,\mathbf{100} \quad [24] \qquad (5)$$

Where, $\bar{V}$ is mean number of germinations per day multiply by 100.

2.5.2.6 Emergence Rate Index (ERI)

It is estimated by dividing the total number of emerged seedlings (or germinated seeds) by the average length of time required for maximum germination.

$$ERI = \frac{\sum_{i=1}^{k} N_i}{\bar{T}} = \frac{N_g}{\bar{T}} \quad [25] \qquad (6)$$

Where, N_g is the total number of germinated seeds at the end of the test, N_i is the number of seeds germinated in the *i*th time interval (not the accumulated number, but the number corresponding to the *i*th interval), and $\bar{T}$ is the mean germination time or mean emergence time.

3. RESULTS

A total of 3954 germinations were recorded for a period of 21 days. Pertaining to each treatment, this is the order from highest to lowest germinations: T5 (752, 19.0%), T2 (727, 18.4%), T4 (676, 17.1%), T3 (628, 15.9%), T6 (606, 15.3%) and T2 (565, 14.3%). There are variations in the germination counts for both the treatments and days. Time is a factor to boost field planting and productivity of balsa. The sowing medium that produces more seedlings within a short time will meet the demand for extensive field planting.

3.1 Germinations as a Function of Time

The germination is significantly different between days (time) and T1 ($F=205$, $df = 1$, $p < 0.001$***). There was no significant difference between day 5 and day 6 under T1 ($p < 0.05$) (Table 1.). Statistical significance is expressed as mean±SE with level of significance set at $p=0.05$. Significant increase in germinations were detected at day 7 (4.50±0.96, $p< 0.05$), day 8 (6.50±1.26, $p< 0.05$), day 9 (8.75±0.85, $p< 0.05$) and day 10 (10.00±0.41, $p< 0.05$). Germination counts for day 11 to day 13 were not significantly

different from each other. The same was true for day 14 to day 20 having similar germination counts. However, day 21 had a significant increase in number of germinations (15.25±1.03, p< 0.05).

The germination is significantly different between days (time) and T2 (F=304, df = 1, p < 0.001***). There was significantly low germination counts at day 5 (0.00±0.00, p< 0.05) (Table 1.). Germination counts were statistically similar at day 6 and day 7. Significant increase in germinations were detected at day 8 (3.25±0.95, p< 0.05), day 9 (4.75±0.85, p< 0.05), day 10 (6.00±1.00, p< 0.05), day 11 (7.50±1.26bcde, p< 0.05), day 12 (9.50±1.55, p< 0.05) and day 13 (10.25±0.85, p< 0.05). There were no significant increases in the number of germinations from day 14 to day 19 (Table 1.).

The germination is significantly different between days (time) and T3 (F=137, df = 1, p < 0.001***). Significant increase in germinations were recorded at day 5 (1.75±0.48, p< 0.05), day 6 (3.50±1.19, p< 0.05) , day 7 (5.50±1.71, p< 0.05), and day 8 (7.50±1.26, p< 0.05). Day 9 and day 10 had similar germination counts (Table 1.). There were no significant difference in germinations from day 11 to day 14 (p> 0.05). With a slight increase, there were no significant difference observed from day 15 to day 19. There was a minute increase from day 20 to day 21 (p< 0.05).

The germination is significantly different between days (time) and T4 (F=134, df = 1, p < 0.001***). Significant increase in germinations were recorded at day 5 (2.75±0.48, p< 0.05), day 6 (3.50±0.87, p< 0.05) , day 7 (5.75±1.38, p< 0.05), day 8 (6.75±1.38, p< 0.05), day 9 (8.50±1.19, p< 0.05) and day 10 (9.00±1.29, p< 0.05). There were rarely a change in germination counts from day 11 to day 15 (Table 1.). Day 16 and 17 were significantly different from Day 18, 19 and 21 while a significant drop was recorded at day 20.

The germination is significantly different between days (time) and T5 (F=66, df = 1, p < 0.001***). There is a significant difference between day 5 (2.00±1.08, p< 0.05) and day 6 (4.25±1.49, p< 0.05) for T5. No significant difference was detected from day 7 to day 10 meaning they had similar germination counts (Table 1.). Days 11-14 were similar in terms of germination counts with no significant differences. Days 15-21 did not show any differences as germination counts were relatively constant.

The germination is significantly different between days (time) and T6 (F=103, df = 1, p < 0.001***). Germinations were significantly different for days 5-8 while similar for days 9-10. There was a significant increase on day 11 (9.00±0.71, p< 0.05) followed by further increase for days 12-17 although with non-significant difference. Day 18 recorded a significant hike in germination than its predecessor (11.50±1.26, p< 0.05). Although germination counts continued to increase, the counts for days 19-21 were not statistically significant.

Both the partial and cumulative germination counts were computed for each treatment as a function of time (days). Seeds planted under T5 media took less time to reach 50% of the maximum partial (t_{50}=10.37) and cumulative (t_{50}=3.20) germinations respectively (Table 2.). Treatment 5 also had the lowest mean germination time for partial ($\bar{T}$ =10.48) and cumulative counts ($\bar{T}$=5.25). The high cumulative (S=100.33) and partial germination rate indexes (S=20.87) hastened with high cumulative mean germination rate ($\bar{V}$ =0.19) and coefficient (CVG =19.03%), further confirms that T5 is a prime media. Treatment 3 showed some positive results for partial germination (t_{50}=10.44, $\bar{T}$ =10.57, S=91.43, $\bar{V}$ =0.09,CVG=9.56%) however cumulative germination were not promising (t_{50}=3.75, $\bar{T}$ =6.58, S=17.72, $\bar{V}$=0.15,CVG=15.19%). Treatment 2 took longer time to germinate partially (t_{50}=10.34, $\bar{T}$=11.49, S=58.41, $\bar{V}$=0.09,CVG=8.69%) and cumulatively (t_{50}=6.42, $\bar{T}$ =7.13, S=9.64, $\bar{V}$=0.14,CVG=14.02%). Treatment 1, treatment 4 and treatment 6 had rather moderate germination times and growth rates (Table 2.).

There was high significant difference between T1 and T2 (p=0.000***). This can be attributed to a big difference between the two treatments (d.=2.382) and confidential levels that excluded zero (LCL=1.221, UCL=3.544) (Table 3.). Confidential levels that includes zero produce significant differences. A significant difference was also detected between T1 and T3 (p=0.005**, d=1.46, LCL=0.294, UCL=2.617). No significant difference existed between T1 and T4 (p=0.434, ,d=0.750, LCL= -0.412, UCL=1.911), and, T1 and T5 (d= -0.368, LCL= -1.529, UCL= 0.794) (Table 3.). Following the same statistical procedure, further high significant differences were detected between T1-T6, T2-T4, T2-T5, T3-T5 and T5-T6. Further non-significant differences were detected between T2-T3, T2-T6, T3-T4, T3-T6, T4-T5 and T4-T6.

Table 1. Germination counts were done for each treatment for 21 days. Most of the seeds began germinating at day 5 and reaching their maximum at day 21. The temporal germinations varied between treatments as some showed early germination than others

Days to germination	Germination counts per treatment					
	T1 †mean±SE	T2 †mean±SE	T3 †mean±SE	T4 †mean±SE	T5 †mean±SE	T6 †mean±SE
5	0.50±0.50e	0.00±0.00g	1.75±0.48f	2.75±0.48f	2.00±1.08c	2.00±0.82e
6	1.50±0.87e	1.00±1.00fg	3.50±1.19ef	3.50±0.87ef	4.25±1.49bc	3.75±1.25de
7	4.50±0.96de	1.75±1.44fg	5.50±1.71def	5.75±1.38def	7.25±1.75abc	5.25±1.79cde
8	6.50±1.26cde	3.25±0.95efg	7.50±1.26cde	6.75±1.38cdef	8.50±1.94abc	5.75±2.02bcde
9	8.75±0.85bcd	4.75±0.85defg	8.00±1.00bcde	8.50±1.19bcdef	9.50±2.39abc	6.75±1.70abcde
10	10.00±0.41abcd	6.00±1.00cdef	8.00±1.00bcde	9.00±1.29abcde	10.00±2.27abc	7.75±1.03abcde
11	11.50±0.29abc	7.50±1.26bcde	9.00±0.91abcd	9.50±1.04abcd	11.00±1.78ab	9.00±0.71abcd
12	12.00±0.71abc	9.50±1.55abcd	9.75±1.11abcd	10.75±1.03abcd	11.75±1.97ab	10.25±0.85abc
13	12.50±0.87abc	10.25±0.85abc	10.00±0.91abcd	11.00±0.91abcd	12.00±1.91ab	10.25±0.85abc
14	13.25±1.03ab	11.25±0.48ab	10.75±0.85abcd	11.25±1.03abcd	12.75±1.65ab	10.25±0.85abc
15	13.75±1.03ab	11.5±0.29ab	11.00±0.91abc	11.25±1.03abcd	13.75±1.79a	10.50±1.04abc
16	14.25±0.75ab	11.75±0.25ab	11.00±0.91abc	11.75±1.31abc	14.00±1.58a	11.00±1.29abc
17	14.25±0.75ab	12.25±0.48ab	11.25±0.85abc	12.50±1.55abc	14.00±1.58a	11.00±1.29abc
18	14.25±0.75ab	12.25±0.48ab	11.25±0.85abc	12.75±1.49ab	14.00±1.58a	11.50±1.26 ab
19	14.25±0.75ab	12.25±0.48ab	12.00±0.71abc	13.75±1.31ab	14.00±1.58a	11.75±1.03a
20	14.75±0.85ab	13.00±0.41a	13.00±0.91ab	14.50±1.19a	14.50±1.32a	12.25±0.85a
21	15.25±1.03a	13.00±0.41a	13.75±1.25a	13.75±1.31ab	14.75±1.49a	12.50±0.87a

†Treatments with the same letter are not significantly different at α=0.05.
Separation of means by Tukey Honest Significant Difference (HSD).

Table 2. Partial germination refers to individual germination counts of each treatment. Both the partial and cumulative germination counts were compared to assess the response of germinability

Germination counts	Treatments	[1]50% germination (t_{50})	[2]Mean Germ. Time ($\overline{T}$,day)	[3]Germ. Speed Rate index (S, day^{-1})	[4]Mean Germ. Rate ($\overline{V}$, day^{-1})	[5]Coefficient velocity (CVG,%day^{-1})
Partial germination counts (PG)	T1	10.73	10.91	83.88	0.09	9.16
	T2	10.34	10.49	68.88	0.10	9.52
	T3	10.44	10.57	83.36	0.09	9.46
	T4	10.52	10.61	91.43	0.09	9.43
	T5	10.37	10.48	100.33	0.10	9.54
	T6	10.46	10.59	81.03	0.09	9.44
Cumulative germination counts (CG)	T1	4.56	6.08	14.85	0.16	16.44
	T2	5.42	6.13	13.52	0.16	16.30
	T3	3.75	6.58	17.72	0.15	15.19
	T4	4.14	5.71	20.10	0.18	17.52
	T5	3.20	5.25	20.87	0.19	19.03
	T6	4.63	5.88	17.46	0.17	17.01

[1]The time taken to reach 50% of the final/maximum germination (t_{50}).
[2]Average length of time required for maximum germination of a seed lot ($\overline{T}$).
[3]The speed of germination or germination rate expressed as index values (S).
[4]Mean germination rate ($\overline{V}$) for each treatment and [5]Coefficient of velocity of germination (CVG).

Table 3. The Post Hoc comparison of treatments was done by Tukey HSD test. Pairwise comparison took into consideration all possible differences between treatments and indicated their level of significance

Treatments	[1]Difference (d)	[2]LCL	[3]UCL	p-value	[4]Signif.
T1 - T2	2.382	1.221	3.544	0.0000	***
T1 - T3	1.456	0.294	2.617	0.0050	**
T1 - T4	0.750	-0.412	1.911	0.4341	
T1 - T5	-0.368	-1.529	0.794	0.9443	
T1 - T6	1.779	0.618	2.941	0.0002	***
T2 - T3	-0.926	-2.088	0.235	0.2023	
T2 - T4	-1.632	-2.794	-0.471	0.0010	***
T2 - T5	-2.750	-3.911	-1.589	0.0000	***
T2 - T6	-0.603	-1.764	0.559	0.6718	
T3 - T4	-0.706	-1.867	0.456	0.5045	
T3 - T5	-1.824	-2.985	-0.662	0.0001	***
T3 - T6	0.324	-0.838	1.485	0.9676	
T4 - T5	-1.118	-2.279	0.044	0.0669	
T4 - T6	1.029	-0.132	2.191	0.1154	
T5 - T6	2.147	0.986	3.309	0.0000	***

*[1]Difference between paired treatment data (d).; [2]Lower confidential limit (LCL) and [3]Upper confidential limit (UCL).; [4]Significance codes: *** p < 0.001, ** p < 0.01, * p < = 0.05.*

Ochroma lagopus seeds showed varied germination counts under the different sowing media. Treatment 5 produced more germination counts (44.24±3.63, p< 0.05) followed by treatment 1 (42.76±4.59, p< 0.05). The third highest germination counts came from treatment 4 (39.76±3.40, p< 0.05) and then treatment 3 (36.94±3.15, p< 0.05). Treatment 2 (35.31±4.19, p> 0.05) and treatment 6 (35.65±3.06, p> 0.05) did not differ significantly from each other with similar germination counts. As shown from the results, treatment 5 which contained 50% medium coarse sawdust and 50% pure soil produced more germination counts than the other treatments. The control treatment (T3) containing 75% large coarse sawdust and 25% pure garden soil was outperformed by treatment 5. Even treatment 1 (pure garden soil) and treatment 4 (Pure Sawdust) produced more germinations than treatment 3. However,

treatment 3 performed better than treatment 2 (pumice) and treatment 6 (33% medium coarse sawdust, 33% Pumice, 33% Pure garden Soil).

Emergence Rate Index (*ERI*) was used to assess the germination rate of seeds under different treatments. Fig. 2 illustrates the partial emergence rates of *Ochroma lagopus* seeds under each sowing media. Treatment 5 had the highest emergence rate for partial germination (*EFI*=71.76) followed by treatment 1 (*EFI*=66.59). Treatment 4 had the third highest seedling emergence (*EFI*=63.74) followed by treatment 3 (*EFI*=59.37), treatment 6 (*EFI*=57.22) and treatment 2 (*EFI*=53.81) (Fig. 2.). ERI values thus assess the suitability of the soil media that can trigger high number of germinations per day. And some of the media attributes can be explained by their physical structure as well as chemical composition. Treatment 5 produced more germinations from day 5 to day 8 than treatment 1 (Table 1). Treatment 1 started picking up at day 10 and steadily climbed to day 21. The other treatments showed weak temporal increase in number of germinations.

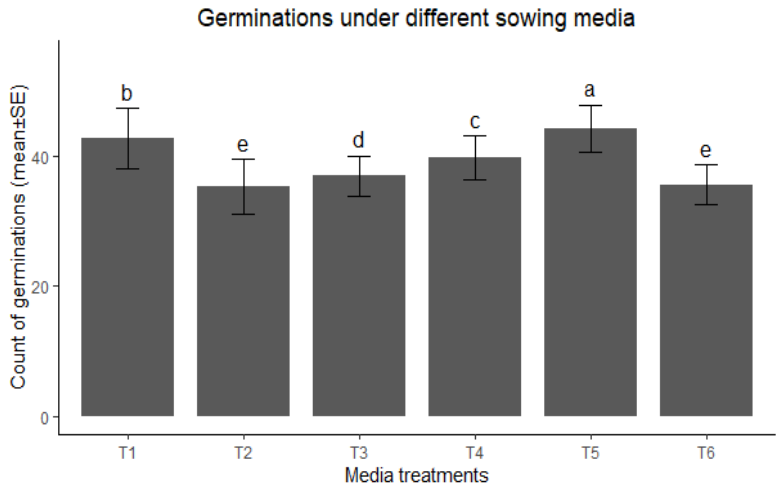

Fig. 11. Germination response of *Ochroma lagopus* seeds under different sowing media. Treatment 5 (T5) produced more germination counts followed by treatment 1 (T1). Both treatment 2 (T2) and treatment 6 (T6) produced low germinations. Treatments with the same letter are not significantly different at α=0.05

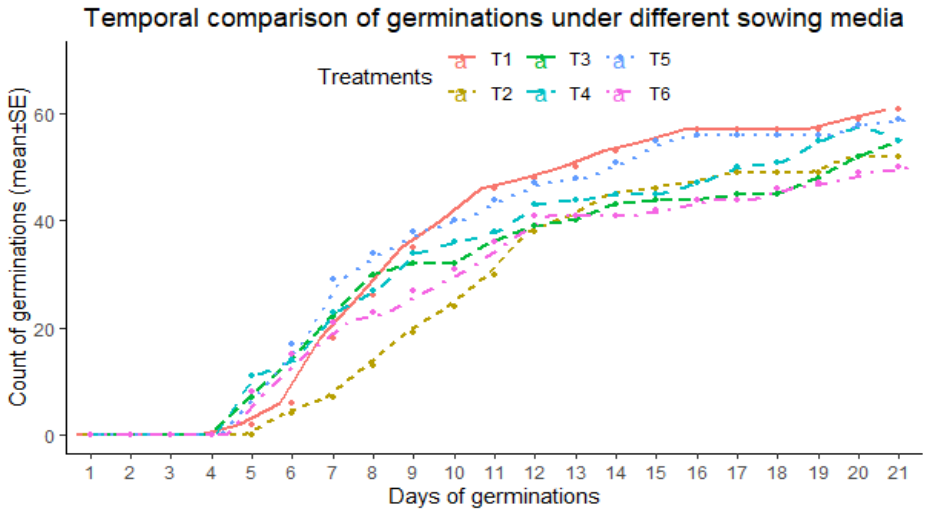

Fig. 12. The number of germinations for each treatment varied on a temporal scale (days). The distinction can be explained by Emergence Rate Index (ERI). Overall, treatment 5 and treatment 1 produced more germinations than the other treatments

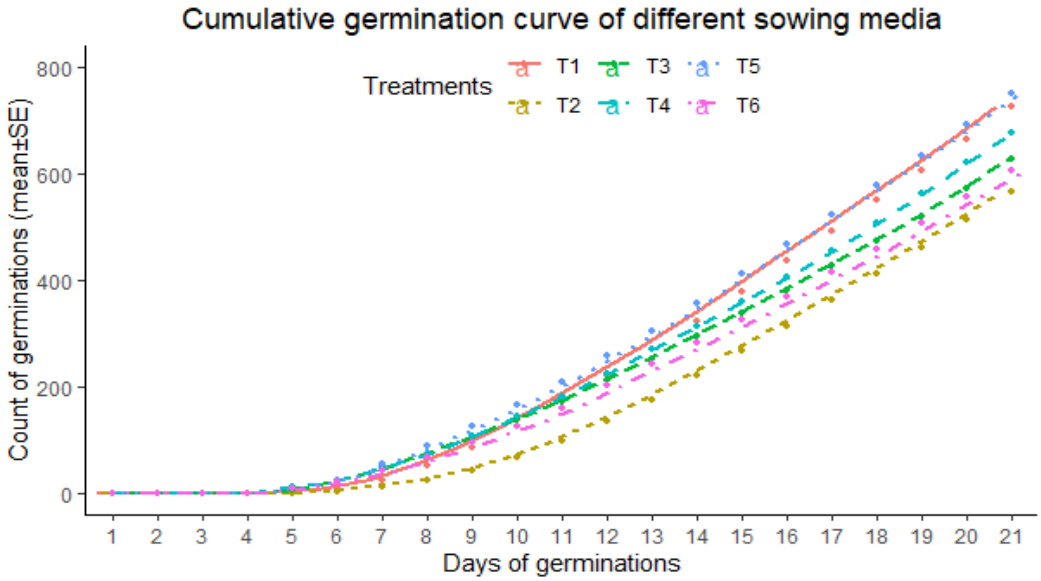

Fig. 13. The number of germinations were also interpreted in a cumulative manner. The variations were described using Emergence Rate Index (ERI). Both treatment 5 and treatment 1 produced more germinations than the other treatments

Emergence Rate Index (*ERI*) was also used to assess the cumulative germination rate of seeds under different treatments. Fig. 3 illustrates the cumulative emergence rates of *Ochroma lagopus* seeds under each sowing media. Treatment 5 still had the highest emergence rate for cumulative germination (*ERI*=51.93) followed by treatment 1 (*ERI*=48.73). Treatment 4 had the third highest seedling emergence (*ERI*=46.29) followed by treatment 3 (*ERI*=43.09), treatment 6 (*ERI*=41.53) and treatment 2 (*ERI*=36.45) (Fig. 2.). As aforementioned, ERI values thus assess the suitability of the soil media and its ability to trigger high number of germinations per day. Variations in media performance can be explained by their physical structure as well as chemical composition. Treatment 5 produced more cumulative germinations at day 5 (2.00±1.08, $p< 0.05$), day 10 (10±2.27, $p< 0.05$) and day 21 (14.75±1.49, $p< 0.05$). Treatment 1 produced similar germinations as treatment 5 on day 10 except day 5 and day 21 (0.50±0.50, $p< 0.05$; 10.00±0.41, $p< 0.05$; 15.25±1.03, $p< 0.05$).

4. DISCUSSION

Testing the germinability of *Ochroma lagopus* seeds under the six (6) sowing media isone of the simple yet effective plant bioassay tactic. A typical plant bioassay test involves the sowing of seeds into the media, and observing their germination performance over a few weeks [1]. Poor seedling emergence are related to soil water content [26], seed-soil contact [27], inaccurate seed placement [28], low and high soil temperatures [26], soil insects or soil-borne disease [28], soil compaction or smearing [29], surface crusting after sowing [28] and poor quality seeds [30]. The condition of sowing media and seedling emergence are affected by soil physical properties [31](24). Another important component of soil is organic matter which influences the soil's physical, chemical and biological properties [32,33].

The daily average germination count in Treatment 5 (50% medium coarse sawdust & 50% pure soil) produced constant germinations from day fifteen (15) to day twenty one (21). Treatments 1, 2, 3, 4 and 6 showed high variations in their daily average germination for the same period but did not produce a constant supply of germinations. The average germination in treatment 5 was predictable and constant even though treatment 1 scored the same average number for the same period. Sawdust provides additional carbon, supplies various nutrient needs of the plant and increases the porosity of the growth substrate [34]. There is less residue accumulation as it readily decomposes and it is economically beneficial due to its low cost than other conventional materials [35]. The incorporation of sawdust into T5 provided low bulk density, high porosity, moderate aeration, pH of 3-6 and low CEC [1]. The other component of T5 is pure garden soil which can also be

attributed to the success of T5 germinations. Treatment 1 which contained pure garden soil produced the second highest germination counts after treatment 5. Pure soil and sand+soil media produced significant germinations than sawdust substrate [28]. The volcanic soil around ENB is fertile, possess high Cation Exchange Capacity (CEC), has significant organic matter, low bulk-density, moderately weathered, freely drained and produces vigorous seedling growth [10,36].

Treatment 3 (75% large coarse sawdust, 25% pure garden soil) which is the control media presented a highly significant average between daily germination for the same period except on day 21 and therefore its average germination was unpredictable and not constant. The reduction of pure garden soil from 50% to 25% and incorporation of large coarse sawdust in T3 can be seen as limiting factors. Although sawdust has low bulk density, porosity to air is moderate while water holding capacity is low [1]. According to Marjenah et al. [34], a growing media containing 80% topsoil + 20% sawdust had 100% survival rate. Therefore increasing the ratio of top garden soil in the soil+sawdust media produces better germinations. In contrast, increasing the quantity of sawdust resulted in decreasing germination rate [28]. The improper combination of different components in a growth media is a major factor influencing plant quality [37]. The quality of sawdust used in sowing media depends on the wood species [2]. Results from proximate nutrients composition showed that hardwood (*Anogeissus leiocarpus*) sawdust was richer than softwood (*Daniellia oliveri*) sawdust [38]. Moreover, treatment 3 (75% large coarse sawdust: 25% pure garden soil) had a smaller ratio of sawdust surface area to its water retention ability as compared to Treatment 5 (50% medium coarse sawdust: 50% pure soil) which had a larger ratio of sawdust surface area thus increasing the ability for water vapour retention in the soil.

Treatment 2 (pumice) and treatment 6 (33% medium coarse sawdust, 33% Pumice & 33% Pure garden Soil) did not differ statistically from each other and had the lowest germination counts. The inclusion of pumice was presumed to be a critical factor that hindered germinations. During volcanic eruptions, rapid pressure is released leading to gas expansion and the formation of low-density pumice [11]. The light weighted pumice has a low bulk density of 0.4–0.8 g cm^{-3} with a total porosity of 70–85% however these physical properties depend on its origin and the sieving/grinding process [39,40,41]. Pumice has relatively low water-holding capacity compared with stone wool, perlite or organic substrates and may limit the uptake of water and nutrient by plants, especially in hot climates [41]. Due to its stable state and re-usability, it is considered a safe natural product that can be disposed without causing any environmental pollution [11]. Treatment 4 (Pure Sawdust) produced the third highest germination counts followed by Treatment 3 which was the control (75% large coarse sawdust, 25% pure garden soil). Although wood sawdust supplies additional carbon and increases the porosity of the growth substrate [34], it should be subjected to a period of composting in order to breakdown the lignin and cellulose to release the essential materials [42]. The ligno-cellulosic materials present in sawdust are protein deficient and thus insufficient therefore it requires supplement of nitrogen, phosphate and potassium [43]. The inclusion of large coarse sawdust in the growth substrates at higher ratio had less influence on germination.

Treatment 5 (50% medium coarse sawdust & 50% pure soil) had the highest germination rate or speed (100%) per day for 21 days followed by treatment 4 (Pure Sawdust) at 91.43%. According to a similar study, sawdust treatment had a constant and low germination rate (25%) after two weeks of sowing (WAS) while sawdust+soil mixture reached the maximum rate of 75% at 9 days after sowing (DAS) [28]. Treatment 1 (Pure garden soil) and treatment 3 (75% large coarse sawdust & 25% pure garden soil) had similar germination rate (~83%). Treatment 6 (33% medium coarse sawdust, 33% Pumice & 33% Pure garden Soil) followed with 81.03% while the lowest germination rate (68.88%) was produced by treatment 2 (Pumice). Treatment 5 also took less time (days) to produce 50 per cent (t_{50}) of the final germinations. Seed germination and seedling emergence are initiated by water imbibition and subsequent enzymatic reaction of stored nutrients [44]. These biological processes are regulated by the environment, the seed quality, suboptimal soil temperature and soil moisture thus any fluctuations may delay and reduce the germination rate and seedling emergence [45,46]. Any sowing media that contains optimum moisture and nutrient contents will increase the germination rate. An objective of intensive nursery and extensive field planting is to produce more germinations within a short period of time. As assessed by the Emergence Rate Index

(ERI), treatment 5 had the highest emergence rate for germination (ERI=71.76) followed by treatment 1 (ERI=66.59). This result supports the findings by Yerima et al. [28] that substrates containing soil in their composition produced better germination and emergence thereby were regarded as better media. Treatment 4 had the third highest seedling emergence (ERI=63.74) followed by treatment 3 (ERI=59.37), treatment 6 (ERI=57.22) and treatment 2 (ERI=53.81) at the lowest continuum. Treatment 2 (Pumice) recorded the lowest emergence rate which can be due to its low water-holding capacity [41], drainage [4], high porosity [1] and influence of water depth [47] on seedling roots.

5. CONCLUSION

A good sowing media ensures better anchorage of plants, provides a reservoir of nutrients and water, and enhance gaseous exchange with the atmosphere. Soil is an important component of any sowing media and its composition often determines the germination and emergence of seedlings [28]. The mixing of medium coarse sawdust and pure volcanic soil at 50:50% ratio in treatment 5 provided the combined benefits of additional nutrients (i.e. carbon), increased porosity, low bulk density, organic matter, high CEC capacity, and improved aeration [10,34,36]. The reduction of pure garden soil from 50% to 25% and incorporation of large coarse sawdust in T3 can be seen as limiting factors. Therefore increasing the ratio of top garden soil in soil+sawdust media is recommended to produce better germination and emergence. Exclusion of large coarse sawdust at higher ratio from growth media are also recommended due to its insignificant influence on germination. This study concludes that substrates containing 50% soil and 50% medium coarse sawdust are regarded as better sowing media that can produce sufficient *O. lagopus* seedlings to meet extensive field planting schedule.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENTS

A special thank you to the Takubar nursery staff who assisted in the experiment. Your hard work is highly appreciated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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