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Response of Moluccan Sau (*Paraserianthes falcataria* (L.) I.C Nielsen) seedlings applied with biofertilizers and watering frequencies

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Abstract

The growth of Moluccan sau seedlings applied with biofertilizers and watering frequencies was evaluated in this study. Relative to the effect of biofertilizers, nonfertilized/control seedlings recorded the greatest number of root nodules & highest survival percentage; Bio-N recorded the greatest number of compound leaves, heaviest root & shoot dry weight, highest sturdiness quotient & seedling quality index; Mykoplus recorded the tallest height, largest diameter, & greatest number of compound leaves; and Mykovam recorded the highest root-shoot ratio. Relative to the effect of watering frequencies, daily watering recorded the tallest height, greatest number of compound leaves & root nodules, heaviest root & shoot dry weights, and highest seedling quality index; every other day watering recorded the tallest height, largest diameter, highest sturdiness quotient & survival percentage; and every three days watering recorded the highest root-shoot ratio. Significant difference of results was observed relative to watering frequencies, but not to biofertilizer application. Moreover, majority of the growth parameters of Moluccan sau seedlings exhibits significant relationship among others. Thus, it is relevant to consider the application of biofertilizers like Bio-N, Mykoplus, etc., as well as appropriate watering frequency for favorable growth of the plants.

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Introduction

Forest is a vital resource of a country for healthy nutrient and water, habitat to different macro and micro flora and fauna, and a wide resource for the life's necessities such as food, clothing, shelter, medicine and timber (Paquit & Rojo, 2018). However, the rapid growth and development of human civilization had caused primarily the increase of carbon dioxide (CO_2) concentration in the atmosphere and lead to deforestation and forest degradation. As forests are destroyed and wood becomes scarce, it remains to be the most economically important forest product with continues increase of demand. The planting of potential trees or tree plantation establishment is one of the best options to restore the forest lost hectares, reduce pressures on the remaining natural forests for the benefits of future generations (Nordahlia *et al.,* 2014; Paquit & Rojo, 2018), and achieve sustainable forest management which open up opportunities for incentive–based conservation programs like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) (Carandang *et al.,* 2015).

Moluccan sau (*Paraserianthes falcataria* (L.) I.C Nielsen) is one of the main timber tree species under Fabaceae family. It is characterized as high-yielding with short-rotation tree and widely planted throughout the tropics includes Bangladesh, India, Indonesia, Malaysia, Philippines, Mexico, Hawaii and Samoa (Cossalter & Pye-Smith, 2003). It is a fast-growing species that approximately attains a height of up to 40-45 m with 20 to 100cm dbh and maintains a clear bole for over 10 m that gained wide interest in the field of industrial wood processing (Nordahlia *et al.,* 2014). It is also one of the prime sources for pulp and paper, veneer, plywood, furniture, and light construction materials, and has been recognized for its multipurpose characteristics (Krisnawati *et al.,* 2011).

In the Philippines, Moluccan sau (also known as Falcata) is one of the most common cultivated tree plantation species other than *Gmelina* spp., & *Swietenia* spp. It is commercially grown in many parts of Mindanao, particularly in Caraga Region which is often found on river flood terraces, and sandy soils at 0-to-1,600 meter altitude in primary and secondary forests (Dela Cruz, 2011; Alipon *et al.,* 2016; Dacanay, 2018). Also, it is likely to grow better on slightly alkaline soils but tolerates wide range of soils from dry and damp soils even to saline and acid soils up to pH 4.5 as long as the drainage is sufficient (Varis, 2011). Moreover, Moluccan sau was first grown commercially at Bislig, Surigao del Sur, and it is the most usual species planted by farmers involved in the Philippine government's National Greening Program (NGP) in Northern Mindanao to enrich forest clearings and restoration, particularly in Region 10. This tree species attracts the populace in the community due to its suitability in the intercropping of cocoa, coffee, abaca, root crops, tea plantations, other short-term crops like corn, rice, sweet potatoes and cassava, and the stability of market for its wood/timber (ERDB, 2008; Beltran, 2013).

According to the Executive Order (EO) 23, Series of 2011, the cutting and harvesting of timber in the natural and residual forests in the country was suspended. However, Moluccan sau is among the Industrial Tree Plantation Species (ITPS) that are exempted from this policy. The propagation and plantation of Moluccan sau significantly contributes to the country's annual industrial timber requirements of 3 million m^3 (PWPA, 2012). From the total log production of local plantations having 1,102,365 m^3, Moluccan sau accounted for 743,687 m^3 where 649,590 m^3 (87.35%) came from Caraga Region (FMB-DENR, 2014), and from a total log production of 607,959m^3 in 2019, Moluccan sau logs accounted 91% (555,956 m^3) (FMB-DENR, 2019). Based on the cost analysis, harvesting of Moluccan sau with 16cm and above diameter with a price of Php. 2,000/m^3 is relatively profitable, yet 16cm and below diameter is not viable (Alipon *et al.,* 2016). In 2019, Moluccan sau logs' monthly FOB average price ranged from USD 46.77–95.88/m^3 (Php. 2,268.20–4,650.00/m^3) (FMB-DENR, 2019).

Ecologically, the pure stands of Moluccan sau give a good protective cover to prevent erosion on slopes. It is planted extensively for reforestation and afforestation of denuded and eroded land (Orwa *et al.,* 2009).

As cited by Rosario *et al.* (2013), the Ilocos Region has vast areas of denuded and barren uplands due to illegal logging, fuel wood gathering, kaingin making, and other destructive anthropogenic activities which resulted in wood shortage and numerous environmental problems. The reforestation of these areas is urgently needed to rehabilitate the ecosystem and meet the increasing demands for wood and other forest products. This reforestation effort had been inhibited by an inadequate supply of quality seeds/seedlings and other planting materials. Hence, the successful establishment of forest tree plantations depends largely on the quality of planting materials used, and appropriate cultural techniques must be considered to unleash the full potential of the seedlings from the nursery to the field conditions.

Furthermore, two of the nursery practices that affect the growth and development of seedlings are the application of favorable fertilizers and suitable watering frequencies. Fertilizers like biofertilizers were added/applied to plants to enhance its growth and ensure the seedling quality. It contain a wide range of natural plant nutrients and trace elements, carbohydrates, amino acids and other growth promoting substances. The application of biofertilizers exhibited several advantages like cost-effective, eco-friendly, and renewable resources of plant nutrients similar to organic fertilizers. It is a substance that contains living microorganisms that facilitate plants' uptake of nutrients by their interactions within the rhizosphere once applied (Ramasamy *et al.,* 2020). At present, among the common and widely utilized biofertilizers produced by the University of the Philippines-Los Baños National Institute of Molecular Biology and Biotechnology (UPLB- BIOTECH) include Bio-N, Mykovam, & Mykoplus (Masigal, 2016).

On the other hand, being one of the basic inputs in seedling propagation, proper and adequate watering must be considered to guarantee the quality growth of the plants. Too much and too little application of water could result to inferior plant growth. Further, proper watering is one of the most labor-intensive operations in the nursery that could enhance the quality of seedlings produced as well as reduce seedling production costs without sacrificing quality (Rosario *et al.,* 2013).

In order to assess the species' quality, suitability, and productivity in a given area to sufficiently meet the needed wood volume for the local wood-based industries, it is essential to conduct this study on Moluccan sau, particularly in La Union Province where this type of ITPS is quite unpopular or less regarded. This study evaluates the growth of Moluccan sau seedlings applied with biofertilizers and watering frequencies in terms of height, diameter, number of leaves (compound), root nodules, shoot dry weight, root dry weight, root-shoot ratio, sturdiness quotient, seedling quality index, and survival percentage; and determine the correlation of these seedlings' growth parameters.

Material and methods

Experimental Area and Sample Preparation

The study was laid out following a 4x4 factorial experiment in Completely Randomized Design (CRD) with three replications. The treatments used in the study were the different biofertilizers (Factor A) and the watering frequencies (Factor B). There were 16 plots used in the study. The experimental area was prepared by cleaning and taking away the unnecessary debris or wastes, followed by the potting of growing media. The growing media were prepared following the standard ratio composed of garden soil, compost (degraded forest litters), and carbonized rice hull (1:1:1). The garden soil was sterilized (dry-heat) at 100°C for 24 hours to remove soil-borne microorganisms. Prior to sowing activity, Moluccan sau seeds were subjected to a hot and cold treatment to fast-track the seed germination for 2 to 3 days in a basin contained with moist cloth. When the seeds sprouted or the radicles emerged to its seed coat, direct planting or sowing activity was conducted. There are 15 healthy Moluccan sau seedlings used per plot with a total of 720 seedlings for the whole study.

Application of Treatments

The application of treatments like biofertilizers and watering frequencies were done one week after

planting to give enough time for the samples to recover from the planting shock or stress. Based on the recommended rate, 2.5g per seedling of Mykovam and Mykoplus at about four centimeters deep and two centimeters away from the base of the seedlings was applied. For Bio-N, five grams dissolved in a 1 can of water was applied per seedlings. The biofertilizers were applied once. Watering was conducted early in the morning, applying 75 ml of water per seedling every watering schedule. Also, care and maintenance were done regularly such as cleaning/weeding and fungicide application.

Growth of Moluccan sau Seedlings

Height (cm)

The height was obtained by measuring the plants from the ground level up to the tip of the apical bud using a meter stick at 30, 60, 90, & 120 days after planting.

Diameter (cm)

The diameter was measured at 5cm above the ground using a vernier caliper at 60, 90, & 120 days after planting.

Number of Compound Leaves

The number of compound leaves was counted at 30, 60, 90, & 120 days after planting.

Number of Root Nodules

The number of root nodules was determined by counting the root nodules of Moluccan sau seedlings at the termination of the study.

Root and Shoot Dry Weight (g)

The root and shoot dry weights were measured by weighing the roots and shoots of Moluccan sau seedlings after oven drying for 48 hours at 65°C.

Root-Shoot Ratio

This was determined by dividing the measured root dry weight and shoot dry weight of the Moluccan sau seedlings.

Sturdiness Quotient

The sturdiness quotient was determined by dividing the height (cm) of the seedlings by the diameter (mm) taken at the root collar level following the procedure used by Takoutsing *et al.* (2013).

Seedling Quality Index (SQI)

This was determined following the Dickson's Quality Index (DQI) developed by Dickson *et al.* (1960) which was calculated as:

$$SQI = \frac{\text{Seedling Dry Weight (g)}}{\frac{\text{Height (cm)}}{\text{Root Collar Diameter (mm)}} + \frac{\text{Shoot Dry Weight (g)}}{\text{Root Dry Weight (g)}}}$$

Survival Percentage (%)

The survival percentage was determined by counting the total number of plants/seedlings that survived up to the termination of the study divided by the total number of plants planted multiplied by 100.

Statistical Analysis

All the data gathered were tabulated, summarized, and analyzed using the Factorial Analysis of Variance (ANOVA) in Completely Randomized Design (CRD). Also, Tukey's Honestly Significant Difference test was used to determine the significant differences between and among treatment means/percentages. Pearson's correlation analysis was used to determine the relationship among all growth parameters of Moluccan sau seedlings. All statistical analyses were generated using the RStudio v. 2022 (R Core Team, 2022).

Result and discussion

Growth of Moluccan Sau Seedlings

Height (cm)

The height growth of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 1. The result showed that the seedlings applied with Mykoplus recorded the tallest height from 30 to 120 DAP (9.24, 12.98, 16.13, & 20.29 (cm), respectively), while the nonfertilized (control) seedlings recorded the shortest height from 30 to 120 DAP (7.63, 11.41, 14.14, & 18.33 (cm), respectively). Despite showing no significant difference on height among biofertilizer treatments during the conduct of the study, the result still revealed better height growth performance for the inoculated seedlings. The present study relates to the findings of Ferraren *et al.* (2019) that the Arbuscular

Mycorhizal Fungi (AMF) inoculation may provide better and vigour seedlings to cope with transplantation stress considering also the types or fertility of potting medium used and the amount of AMF applied. Krisnawati *et al.* (2011) also stated that to accelerate the initial growth of Moluccan sau, fertilizer application is needed particularly in the marginal sites.

Table 1. Height of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Days After Planting (DAP)			
Biofertilizers	*30* ^{ns}	*60* ^{ns}	*90* ^{ns}	*120* ^{ns}
A_0 – Control	7.63	11.41	14.14	18.33
A_1 – Bio-N	7.72	11.77	14.78	19.63
A_2 – Mykovam	8.85	12.48	15.11	18.75
A_3 – Mykoplus	9.24	12.98	16.13	20.29
Watering Frequencies	*30* ^{ns}	*60* ^{ns}	*90* ^{ns}	*120* *
B_0 – Every day	8.79	11.41	15.20	24.09^{a}
B_1 – Every other day	9.20	14.66	17.67	21.21^{ab}
B_2 – Every other two days	8.31	11.81	14.68	17.71^{ab}
B_3 – Every other three days	7.13	10.77	12.60	13.98^{b}

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

On the other hand, the seedlings watered every other day recorded the tallest height at 30 (9.20cm), 60 (14.66cm), & 90 (17.67cm) DAP, while the seedlings watered everyday significantly obtained greater height growth at 120 (24.09cm) DAP. Moreover, the seedlings watered every other three days attained the shortest height at 30 (7.13cm), 60 (10.77cm), 90 (12.60cm), & 120 (13.98cm) DAP. Statistical analysis showed that the height of Moluccan sau seedlings varied significantly at 120 DAP as affected by watering frequencies, but a comparable effect relative to biofertilizer application. The result implies that watering at different frequencies affect significantly the height of Moluccan sau, particularly the everyday watering relative to every other three days of watering. Significantly greater height was also attained by *P. americana seedlings* treated with daily water application compared with longer intervals of watering as observed in the study of Mng'omba *et al.* (2011).

Diameter (mm)

The average diameter of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 2. The result revealed that the seedlings applied with Mykoplus recorded the largest diameter at 60, 90 and 120 DAP with 3.05, 3.52, and 3.87 (mm), respectively. However, the smallest diameter was obtained by the nonfertilized (control) seedlings at 60, 90 and 120 DAP with 2.85, 3.25, and 3.57 (mm), respectively. Moreover, the seedlings watered every other day recorded the largest diameter at 60, 90, and 120 DAP with 3.30, 3.74, and 4.06 (mm), respectively. While the seedlings watered every three days recorded the smallest diameter at 60 (2.56mm), 90 (3.01mm), and 120 (3.28mm) DAP.

Table 2. Diameter of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Days After Planting (DAP)		
Biofertilizers	*60* ^{ns}	*90* ^{ns}	*120* ^{ns}
A_0 – Control	2.85	3.25	3.57
A_1 – Bio-N	2.91	3.32	3.66
A_2 – Mykovam	2.98	3.36	3.70
A_3 – Mykoplus	3.05	3.52	3.87
Watering Frequencies	*60* *	*90* *	*120* *
B_0 – Every day	2.94^{ab}	3.28^{b}	3.71^{ab}
B_1 – Every other day	3.30^{a}	3.74^{a}	4.06^{a}
B_2 – Every other two days	3.00^{ab}	3.41^{ab}	3.75^{ab}
B_3 – Every other three days	2.56^{b}	3.01^{b}	3.28^{b}

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Statistical analysis showed no significant difference relative to biofertilizer application indicating a comparable response of Moluccan sau seedlings in terms of diameter. While significant difference at 60, 90, and 120 DAP relative to the watering frequencies was observed. This indicates that the frequency of watering relatively affects the diameter growth of Moluccan sau seedlings. Likewise, the seedling diameter at every other day watering significantly differed to every other three days watering at 60 and 120 DAP, while at 90 DAP, the every other day watering showed significant result to everyday and every other three days watering. The increase of stem diameter may be due to an increase of available soil water content, conversely, reduction of stem girth may be due to decreasing watering frequency and less uptake of nutrient (Dawid, 2020).

Number of Compound Leaves

The number of compound leaves of Moluccan sau seedlings as affected by biofertilizers and watering

frequencies was shown in Table 3. The result of the study showed that the seedlings applied with Mykoplus produced the greatest number of compound leaves at 30 DAP, while at 60, 90 and 120 DAP, the seedlings applied with Bio-N produced the greatest number of compound leaves with 6.09, 5.07, and 5.99, respectively. On the other hand, the nonfertilized (control) seedlings at 30 (7.08) & 90 (5.02) DAP, the seedlings applied with Mykovam at 60 (5.61) DAP, and the seedlings applied with Mykoplus at 120 (5.26) DAP produced the lowest number of compound leaves. Also, the result of the study showed that the seedlings watered everyday produced greater number of compound leaves at 30 (7.71), 60 (6.42), 90 (6.14), and 120 (7.48) DAP, followed by every other day, every other two days, and every other three days of watering, respectively.

Table 3. Number of Compound Leaves of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Days After Planting (DAP)			
Biofertilizers	*30* ^{ns}	*60* ^{ns}	*90* ^{ns}	*120* ^{ns}
A_0 – Control	7.08	5.75	5.02	5.69
A_1 – Bio-N	7.31	6.09	5.07	5.99
A_2 – Mykovam	7.24	5.61	4.74	5.30
A_3 – Mykoplus	7.41	5.95	5.05	5.26
Watering Frequencies	*30* *	*60* *	*90* *	*120* *
B_0 – Every day	7.71^{a}	6.42^{a}	6.14^{a}	7.48^{a}
B_1 – Every other day	7.59^{ab}	5.92^{ab}	4.93^{b}	6.05^{b}
B_2 – Every other two days	7.05^{bc}	5.65^{b}	4.65^{bc}	4.91^{c}
B_3 – Every other three days	6.70^{c}	5.41^{b}	4.16^{c}	3.79^{d}

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Statistical analysis showed no significant difference relative to biofertilizer application, although Bio-N application resulted to a more favorable compound leaves production. On the other hand, significant difference was observed on the number of compound leaves produced at 30, 60, 90, and 120 DAP relative to the watering frequencies. The result also showed that as the frequency of watering increases, the production of leaves also increases. Hence, there is a direct relationship between the watering frequency and the production of leaves of Moluccan sau seedling. The present study corroborates with the findings of Santosa *et al.* (2004) where they found greater number of leaves of *A. paeniifolius* seedlings that were watered daily compared to 3-,5-,7-, and 15-day watering intervals, as well as with the study of Mng'omba *et al.* (2011) where a more frequent watering resulted to greater number of leaves of *P. americana* seedlings. Furthermore, according to the DENR's Administrative Order 2010-11, seedlings with at least six leaves are considered favorable quality for seedling production (Gregorio *et al.,* 2016). Based on the result, everyday and every other day watering passed the standard at 120 DAP. However, the large number of leaves associated with low root volume may result to lower seedling survival, particularly to low soil moisture sites that is common characteristic of Philippine reforestation areas (Gregorio *et al.,* 2016).

Number of Root Nodules

The number of root nodules of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 4. The result of the study showed that the nonfertilized seedlings (control) recorded the greatest number of root nodules with a mean of 9.80, followed by the seedlings applied with Mykoplus (9.61), Bio-N (8.83), and Mykovam (8.33). Relative to watering frequency, the seedlings watered everyday produced greatest number of root nodules with a mean of 15.00, followed by every other day, every other two days, and every other three days of watering, respectively. Statistically, the result showed a significant difference on the number of root nodules developed relative to the watering frequencies, but not with biofertilizers. It is also observed that as the frequency of watering increases, the development of root nodules significantly increases. Hence, a direct relationship between watering frequency and root nodules development was observed. The result of the study supports the findings of Shrestha *et al.* (2021) wherein they found that water stress in *C. tetragonoloba*, a drought-tolerant legume, had a negative impact to nodule number, whereas the number increases when the rate of evapotranspiration replacement also increases. The negative effect of a decreasing water availability due to the development of the gap of watering frequency to Moluccan sau seedlings was generally found evident on its morphological characteristics such as on the number

of root nodules, along with the seedlings' height, diameter and number of compound leaves.

Table 4. Root Nodules of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Mean
Biofertilizers ns	
A_0 – Control	9.80
A_1 – Bio-N	8.83
A_2 – Mykovam	8.33
A_3 – Mykoplus	9.61
Watering Frequencies *	
B_0 – Everyday	15.00[a]
B_1 – Every other day	13.05[a]
B_2 – Every other two days	6.31[b]
B_3 – Every other three days	2.22[c]

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Root Dry Weight (g)

The root dry weight of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 5. The result showed that the seedlings applied with Bio-N records the heaviest root dry weight with a mean of 5.17g, followed by the seedlings applied with Mykovam (5.00g), nonfertilized (control) seedlings (4.92), and seedlings applied with Mykoplus (4.75). Relative to watering frequency, the seedlings watered everyday recorded the heaviest root dry weight with a mean of 6.92g, followed by every other day, every other two days, and every other three days of watering with the mean value of 6.67, 3.75, & 2.50 (g), respectively.

Statistical analysis showed a significant difference on the root dry weight relative to the watering frequencies, but not with biofertilizer application. The everyday watering exhibits significantly greater result towards every other two days and every other three days watering, but was revealed comparable with every other day. Further, the result showed an increasing trend of root dry weight as the frequency of watering increases. It depicts that Moluccan sau seedlings impose intolerance to longer watering intervals and may exemplify sensitivity to drought. Other studies also relate with the findings of the present study where *A. paeniifolius* and *D. tripetala* negatively responded to longer intervals of watering (Mng'omba *et al.,* 2011; Osaigbovo & Orhue, 2012).

Table 5. Root Dry Weight of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Mean
Biofertilizers ns	
A_0 – Control	4.92
A_1 – Bio-N	5.17
A_2 – Mykovam	5.00
A_3 – Mykoplus	4.75
Watering Frequencies *	
B_0 – Everyday	6.92[a]
B_1 – Every other day	6.67[a]
B_2 – Every other two days	3.75[b]
B_3 – Every other three days	2.50[b]

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Shoot Dry Weight (g)

The shoot dry weight of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 6. The result of the study showed that the seedlings applied with Bio-N recorded the heaviest shoot dry weight with a mean of 20.17g, followed by the control seedlings with 15.75g, seedlings applied with Mykoplus (14.25g), and seedlings applied with Mykovam (14.17g). Besides, the result of the study showed that the seedlings watered everyday achieved the heaviest shoot dry weight with a mean of 23.17g, followed by every other day, every other two days, and every other three days of watering with the mean value of 21.17, 13.50, & 6.50 (g), respectively.

Statistical analysis showed a significant difference on the shoot dry weight relative to the watering frequencies, but not with biofertilizers. The everyday watering exhibited significantly greater result towards every other two days and every other three days watering, but was found comparable with every other day. Likewise, a significant increasing trend of result was observed on the shoot dry weight as the frequency of watering increases. With likeness to the root dry weight of Moluccan sau seedlings, more frequent watering resulted to a heavier biomass of the shoot. As cited by Dawid (2020), the accumulation of dry matter in the stem and leaves were consistently reduced as the supply of water to the seedlings decreases. This finding also relates with various studies employing different watering frequencies to

species such as *A. cororima* and *D. tripetela* (Dawid, 2020; Osaigbovo & Orhue, 2012).

Table 6. Shoot Dry Weight of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Mean
Biofertilizers ns	
A_0 – Control	15.75
A_1 – Bio-N	20.17
A_2 – Mykovam	14.17
A_3 – Mykoplus	14.25
Watering Frequencies *	
B_0 – Everyday	23.17[a]
B_1 – Every other day	21.17[a]
B_2 – Every other two days	13.50[b]
B_3 – Every other three days	6.50[b]

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Root-Shoot Ratio

The root-shoot ratio of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 7. The result showed that the seedlings applied with Mykovam recorded the highest root-shoot ratio with a mean of 0.37, followed by the control seedlings and seedlings applied with Mykoplus having the same mean value of 0.35 g, then the seedlings applied with Bio-N (0.34). Basically, the root-shoot ratio is an important measure for seedling survival which it relates the transpiring area (shoot) to the water absorbing area (roots). Further, a seedling with balanced root and shoot biomass should have root-shoot ratio between one and two (Jaenicke, 1999), but none of the seedlings sampled attained the desired value. Relative to watering frequency, the seedlings watered every three days recorded the highest root-shoot ratio with a mean of 0.45 g, followed by every other day, everyday, and every other two days of watering with the mean value of 0.34, 0.31, & 0.30, respectively. Statistical analysis showed a significant difference on the root-shoot ratio relative to the watering frequencies, but not with biofertilizers. Particularly, every other two days watering has resulted the lowest ratio and was found statistically different with the treatment that gained the highest ratio. All the samples in this study obtained values less than 1 which means that shoot biomass is in poor proportion with root biomass.

Table 7. Root-Shoot Ratio of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Mean
Biofertilizers ns	
A_0 – Control	0.35
A_1 – Bio-N	0.34
A_2 – Mykovam	0.37
A_3 – Mykoplus	0.35
Watering Frequencies *	
B_0 – Everyday	0.31[ab]
B_1 – Every other day	0.34[ab]
B_2 – Every other two days	0.30[b]
B_3 – Every other three days	0.45[a]

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Sturdiness Quotient

The sturdiness quotient of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 8. The result of the study showed that the seedlings applied with Bio-N recorded the highest sturdiness quotient with a mean of 13.35, followed by the seedlings applied with Mykovam, Mykoplus, and control seedlings with the mean value of 12.83, 12.82, & 12.48, respectively. According to Chauhan & Sharma (2017), sturdiness quotient reflects the balanced growth of seedlings, comparatively taller seedlings may not withstand the wind pressure in the field, and additional balanced root collar diameter should support the seedling for quality. Basically, sturdiness quotient expresses the vigor and robustness of the seedlings wherein seedlings with a value of 6.00 or lower are considered sturdy (Jaenicke, 1999). Based on the sturdiness quotient result, Moluccan sau seedlings are relatively less sturdy and unlikely to withstand adverse conditions in the field. However, good hardening or conditioning of seedlings before field planting could enhance its sturdiness status.

Relative to watering frequency, the result showed that the seedlings watered every other day recorded the highest sturdiness quotient with a mean of 14.62, followed by everyday, every other two days, and every other three days of watering with the mean value of 14.31, 12.21, & 10.33, respectively. Statistical analysis showed a significant difference on the sturdiness quotient relative to the watering frequencies, but not

with biofertilizers. Specifically, it is observed that everyday watering treatment exhibited a significantly higher seedlings' sturdiness quotient compared to watering every other three days, but was found comparable with every other day and every other two days of watering. Further, the result of the study exceeds the standard value of sturdiness quotient indicating less desirable quality seedlings or less sturdy.

Table 8. Sturdiness Quotient of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Mean
Biofertilizers ns	
A_0 – Control	12.48
A_1 – Bio-N	13.35
A_2 – Mykovam	12.83
A_3 – Mykoplus	12.82
Watering Frequencies *	
B_0 – Everyday	14.31^a
B_1 – Every other day	14.62^a
B_2 – Every other two days	12.21^{ab}
B_3 – Every other three days	10.33^b

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Seedling Quality Index

The seedling quality index of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 9. The result of the study showed that the seedlings applied with Bio-N recorded the highest seedling quality index with a mean of 1.39, followed by the control seedlings with 1.30, seedlings applied with Mykovam (1.21), and Mykoplus (1.17).

According to the findings, Bio-N application may improve seedling quality because by integrating the seedling's morphological traits and biomass distribution, a higher seedling quality index indicates a promising seedling to be planted. Generally, all the results of the study surpassed the minimum seedling quality index that is 0.2 (Burcer *et al.,* 2021).

Besides, Herbohn *et al.*(2001) specified that the lack of availability and low quality of planting stock appear to be the major impediments to both planting and selection of species by small-scale farmers in the Philippines. On the other hand, the seedlings watered everyday recorded the highest seedling quality index with a mean of 1.73, followed by every other day, every other two days, and every other three days of watering with the mean value of 1.54, 1.07, & 0.73, respectively.

Table 9. Seedling Quality Index of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Mean
Biofertilizers ns	
A_0 – Control	1.30
A_1 – Bio-N	1.39
A_2 – Mykovam	1.21
A_3 – Mykoplus	1.17
Watering Frequencies *	
B_0 – Everyday	1.73^a
B_1 – Every other day	1.54^a
B_2 – Every other two days	1.07^b
B_3 – Every other three days	0.73^b

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Statistically, a significant difference was observed on the seedling quality index relative to the watering frequencies, but not with biofertilizers. It is also observed that as the frequency of watering increases, the seedling quality index relatively increases. The result showed that everyday watering varied significantly with every other two days & three days, but did not vary significantly with every other day watering. Nevertheless, the result indicates a better seedling quality based on the seedling index. Based on the annual audit reports (1998–2006) by the Commission on Audit (COA), the use of seedlings with substandard height and quality was one of the shortcomings of the Department of Environment and Natural Resources (DENR) reforestation programs. Thus, determining the health or quality of seedlings before planting, would most likely increase the success rate of projects (Burcer *et al.,* 2021).

Survival Percentage (%)

The survival percentage of Moluccan sau seedlings as affected by biofertilizers and watering frequencies was shown in Table 10. The result of the study showed that the nonfertilized (control) seedlings recorded the highest survival percentage with a mean of 95.00%, followed by the seedlings applied with Mykovam, Mykoplus, and Bio-N with the mean value of 93.33%, 90.56%, & 89.44%, respectively.

Further, Orwa *et al.* (2009) noted that Moluccan sau species can grow on comparatively poor sites and survive without fertilizer, however, inoculation with mycorrhizal fungi is suggested to promote the growth of young trees, particularly in a phosphorous-deficient soil.

Table 10. Survival Percentage (%) of Moluccan Sau Seedlings as Affected by Biofertilizers and Watering Frequencies.

Treatments	Mean
Biofertilizers ns	
A_0 – Control	95.00
A_1 – Bio-N	89.44
A_2 – Mykovam	93.33
A_3 – Mykoplus	90.56
Watering Frequencies *	
B_0 – Everyday	95.00[a]
B_1 – Every other day	95.56[a]
B_2 – Every other two days	88.89[b]
B_3 – Every other three days	88.89[b]

*All means followed by different letters are significantly different at 0.05 level (HSD); ns – not significant

Also, the result of the study showed that the seedlings watered every other day recorded the highest survival percentage with a mean of 95.56%, followed by everyday (95.00%), while every other two days and every other three days watering both attained 88.89% survival rate. Statistical analysis showed a significant difference on the survival percentage relative to the watering frequencies where every other day watering exhibits a significantly higher result towards every other two days and every other three days of watering. However, no significant difference was observed on the result relative to biofertilizers application. This indicates that the biofertilizers applied in this study have a comparable effect on the survival percentage of Moluccan sau seedlings.

Correlation of Moluccan Sau Growth Parameters

Table 11 shows the result of the correlation of Moluccan sau growth parameters. The results of the study showed that the growth parameters of Moluccan sau seedlings were found significantly correlated among others. Particularly, the height was positively correlated with the diameter, number of leaves, number of root nodules, root dry weight, shoot dry weight, sturdiness quotient, and seedling quality index. The correlation between seedling height and shoot dry weight is an element to consider, due to their relative contribution toward the seedling quality pattern (Binotto *et al.,* 2010).

The diameter was positively with the number of root nodules, root dry weight, shoot dry weight, sturdiness quotient, and seedling quality index. The number of leaves was positively correlated with the number of root nodules, root dry weight, shoot dry weight, sturdiness quotient, and seedling quality index.

The number of root nodules was positively correlated with the root dry weight, shoot dry weight, sturdiness quotient, seedling quality index, and survival percentage. The root dry weight was positively correlated with the shoot dry weight, sturdiness quotient, seedling quality index, and survival percentage. The shoot dry weight was positively correlated with the sturdiness quotient and seedling quality index, but negatively correlated with the root-shoot ratio.

The root-shoot ratio was negatively correlated with the sturdiness quotient. The sturdiness quotient was positively correlated with the seedling quality index and survival percentage. Lastly, the seedling quality index was positively correlated with the survival percentage.

Thus, the majority of the growth parameters of Moluccan sau seedlings exhibited significant relationship among others that maybe due to treatments applied in the study. Krisnawati *et al.* (2011) also recorded a significant height-diameter relationship on the Moluccan sau plants. The correlation result of the study corroborates the findings of Burcer *et al.* (2021) that showed a significant correlation on the morphological parameters of the three Philippine native tree species such as Bignay, Kamagong, and Molave. Further, the study of Binotto *et al.* (2010) on the correlations between growth variables and SQI in forest seedlings also posted positive and significant results as also observed in the present study.

Table 11. The Correlation of Moluccan Sau Growth Parameters.

Parameters	H	D	L	RN	RDW	SDW	RSR	SQ	SQI
D	0.75***								
L	0.82***	0.42^{ns}							
RN	0.88***	0.62*	0.89***						
RDW	0.85***	0.62*	0.89***	0.95***					
SDW	0.81***	0.60*	0.87***	0.84***	0.88***				
R-S-R	-0.44^{ns}	-0.47^{ns}	-0.42^{ns}	-0.38^{ns}	-0.32^{ns}	-0.63**			
SQ	0.74***	0.67**	0.79***	0.79***	0.80***	0.86***	-0.65**		
SQI	0.84***	0.57*	0.90***	0.91***	0.96***	0.95***	-0.46^{ns}	0.76***	
SP	0.39^{ns}	0.22^{ns}	0.49^{ns}	0.66**	0.61*	0.43^{ns}	-0.11^{ns}	0.53*	0.51*

H – height; D – diameter; L – leaves; RN – root nodules; RDW – root dry weight; SDW – shoot dry weight; RSR – root-shoot ratio; SQ – sturdiness quotient; SQI – seedling quality index; SP – survival percentage; ns - not significant ($p \geq 0.05$); * - significant at $p < 0.05$; ** - significant at $p < 0.01$; and *** - significant at $p < 0.001$

Conclusions

The growth of Moluccan sau seedlings applied with biofertilizers and watering frequencies was evaluated in this study. Also, the relationship among all growth parameters were assessed. Relative to the effect of biofertilizers, the tallest height & largest diameter were recorded by the seedlings applied with Mykoplus, the greatest number of compound leaves was recorded by the seedlings applied by Mykoplus & Bio-N, the greatest number of root nodules & the highest survival percentage were recorded by nonfertilized (control) seedlings, the heaviest root dry weight & shoot dry weight, and the highest sturdiness quotient & seedling quality index were observed in the seedlings applied with Bio-N, and the highest root-shoot ratio was observed in the seedlings applied with Mykovam. Relative to watering frequencies, the tallest height was recorded by the seedlings watered everyday & every other day, the largest diameter, the highest sturdiness quotient & the survival percentage were observed in the seedlings watered every other day, the greatest number of compound leaves & root nodules, the heaviest root dry weight & shoot dry weight and the highest seedling quality index were observed in the seedlings watered everyday, and the highest root-shoot ratio by the seedlings watered every three days. On the other hand, the results of the study showed that the applied biofertilizers provided no significant difference in all growth parameters of Moluccan sau seedlings, while significant difference was observed relative to the watering frequencies. Moreover, majority of the growth parameters exhibited significant relationship among each other.

Recommendations

Despite the ability of Moluccan sau to thrive at different land area and condition, enhancement of the planting materials or seedlings should be considered. Thus, based on the findings derived in the study, some recommendations may be considered such as the application of biofertilizer like Bio-N that may result to a more favorable seedling quality index which is a good indicator for seedlings quality; application of Mykoplus to promote height and diameter growth; and water the seedlings every other day to promote height and diameter, as well as to have a favorable seedling quality index and survival percentage.

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