Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 16, No. 5, p. 12-23, 2020
http://www.innspub.net

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RESEARCH PAPER OPEN ACCESS

Juvenile variations in forest genetic materials of seedlings of *Paraserianthes falcataria* (L.) Nielsen

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Article published on May 23, 2020

Key words: Tree families, Juvenile variations, Seedling growth, Provenance, *Paraserianthes falcataria*

Abstract

To prioritize genetic materials of *Paraserianthes falcataria* for laboratory analysis, this pot experiment was conducted, aimed to identify variations of families using seedling height, diameter, and biomass. Ten families from primary diffusion pathways (Bukidnon and Surigao del Sur) were used in the study. A nursery experiment laid out in completely randomized design was set up with four treatments: Treatment 1(acidic dry soil); Treatment 2(acidic wet soil); Treatment 3(alkaline dry soil); Treatment 4(alkaline wet soil). Ten seedlings in five replications were used for each treatment. Standardized protocol used pH of 4.2 acidic and 7.2 alkaline; every other day watering of 200ml/seedling for dry, and everyday watering of 200ml for wet. Analysis of variance and mean comparison of growth parameters were employed. Results showed that seedling growth was stunted due to strongly acidic and basic soil and poor drainage. Seedling height was significantly higher in acidic soil. The difference of three growth parameters among treatments was significant with acidic wet soil exhibited the highest height, diameter, and biomass. Variations between provenance and significant difference on seedling growth among families were evident with FM067 of Surigao obtained the highest height and biomass; FM001 of Bukidnon with largest diameter; FM024 of Bukidnon registered lowest height, diameter, and biomass. The genetic materials of FMO67 and FM064 of Surigao del Sur; and FM016, FM017, FM001, and FM020 of Bukidnon and families nearby will be priority in laboratory analysis. The study demonstrates that the protocols established are useful for tree geneticists in fast tracking analysis of genetic materials.

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Introduction

Paraserianthes falcataria (L.) Nielsen, is one of the most promising exotic, fast growing industrial tree plantation species in the Philippines. Its original population came from Papua New Guinea and Solomon Islands (Siladan, 2010). The species has been widely grown domestically by local people in Southern Philippines. Wood industries in the country heavily depend much on the availability of supply of good wood *of P. falcataria*. However, quantity and quality of wood of this species are oftentimes low and poor due to lack of knowledge, science and technology in raising the species (Bernaldez and Mangaoang, 2008). In 2015, the Department of Science and Technology of the Philippines launched a tree breeding research and development (R&D) program that will advance the required knowledge and techniques for optimizing the use of *P. falcataria* available genetic resources, as well as establishing the foundation of genetic materials for long-term breeding program for the species. With several hundreds of Forest Genetic Resources (FGR) materials collected and with the enormous funds needed, prioritizing the genetic analysis of the materials will fast-track the generation of knowledge and guide tree geneticists to analyze. Conducting pot experiment among selected FGR materials of falcata will identify which materials should be prioritized for genetic analysis.

Genetic variations in trees could be detected as early as seed germination and seedling growth and development. These various seed and seedling traits are essential for tree species to cope with variations in the amount and frequency of water, soil nutrient regimes, light quantity and quality, and other environmental factors (Swamy *et al.*, 2004). For instance, Ngulube (1989) documented genetic variations in seed germination and seedling growth of 24 *Gliricidia sepium* provenances in Mexico. Sudrajat (2015) observed a genetic variations of the fruit, seeds, and seedling morphophysiological characteristics of *Anthocephalus cadamba*.

The effect of soil media and water regimes to seedling growth of tree species had been widely documented. It was found out that too much soil acidity (less than pH 5.5) significantly reduced root length, leaf number and biomass of tree seedlings (Turner *et al.*, 1988; Pierce *et al.*, 1999). Wingrett (2005) observed a positive correlation between the lowered soil pH (below 7.0) of precipitation and the biomass of the seedlings of *Acer rubrum*. Tree species respond differently to soil media and water stress**.** Baraloto (2006) found out that seedlings of the nine tropical tree species investigated grew more slowly in sand than clay soil, and only *Eperua grandiflora* and *Eperua falcata* showed significant growth increases in the absence of water limitation. Drought stress dramatically decreased *Sophora davidii* seedlings height, basal diameter, leaf number, leaf area, root, length, and biomass production (Wu *et al.*, 2007). Seedlings of *Toona caliata var. pubescens* grew well under well-watered conditions (Sun *et al.*, 2014). Santosa (2014) opined that what matter most in soil medium is having adequate growing open space that allow soil aeration which favors root development as he found out that the best soil medium for *P. falcataria* was a mixture of 50% mud soil, 40% rice husk and 10% compost.

While various studies documented on the influence of soil and water to seedling growth, little is known on the effect of these factors to the juvenile variations of forest genetic materials among families of the tree species. Ngulube (1989) opined that while genetic variations can be traced at juvenile stage, a nursery pre-evaluation phase in provenance elimination trials of tree species is imperative. Hence, this pot experiment was conducted to fast-track genetic characterization of the forest genetic materials of *P. falcataria* in the tree breeding program. The study aimed to identify variations, if any, among the selected FGR materials of *P. falcataria* in the seedling stage as influenced by soil pH and water regimes, and prioritize materials that will be genetically characterized and analyzed in the laboratory.

Materials and methods

Study site

The study was conducted in February 2016 to January 2018. The nursery site was established in the Central Mindanao University (CMU), Maramag, Bukidnon, Southern Philippines (7.8649ºN, 125.0509ºE).

The nursery was laid-out towards north-south direction so as to control the effect of sunlight to the experimental plot. It had a dimension of 9m x 22m consisting of 20 beds. The dimension of the beds was about 1.3m x 5m. The height of the roof from the bed's flooring was 1.3m.

Research studies of FGR materials from the ten families of P. falcatari

Seed and seedling studies were conducted. The FGR seed materials collected from the ten (10) families of the species were utilized for the nursery experiment. These families were randomly chosen from the lists of the families from the two provenances (Bukidnon and Surigao del Sur, Philippines) which were in the primary diffusion pathways (Fig. 1) established in a previous study (Siladan, 2010).

The two original populations of *P. falcataria* from Papua New Guinea and Solomon Island were introduced respectively to Impalutao, Bukidnon and Bislig, Surigao del Sur, Philippines. However, due to its limited adaptability to the island of Mindanao, the species merely diffused to the Mindanao island provinces. The degree of genetic change and diversity of these populations is by and large unknown. Decades of regeneration could have contributed to these changes but likewise uncertain. To expedite the laboratory genetic analysis, seedling experiment to evaluate their juvenile characteristics was conducted. Samples from the original land races was used in the seedling experiment.

Fig. 1. Diffusion pathway of *Paraserianthes falcataria* from Papua New Guinea and Solomon Islands to the Philippines (Adapted from Siladan, 2010).

Standardization of the treatments

The soil acidity and water regime treatments were first standardized using protocols and pre-germination treatments. In soil pre-potting protocol, the soil pH was first determined to compute the lime requirement. The soil had a pH of 4.2. The lime had a 96% relative neutralizing power (RNP). Based on the computed lime requirement of the soil, 1kg of soil was mixed with 4.82g of lime to obtain a pH of 7.2 to 7.5. The soil medium was then sterilized. The potted soil was subjected to watering to determine the day when the basic pH of 7.0 to 7.5 was fully achieved. Soil samples were taken and analyzed every week until the pH of 7.2. was achieved in the 4^{th} week. This was the time when seed sowing commenced with acidic and basic soil treatments.

In establishing a water regime protocol, a total of 25 three-month old seedlings of *P. falcataria* in the existing nursery of the university were subjected to different water regimes for one month using 200ml water in a bed with plastic roofing. About five seedlings were subjected for each of the following watering treatments: daily; every other day; every two days; every three days; and every four days. Results showed that seedlings exhibited wilting in the second treatment and seedlings died in the third, fourth and fifth water treatments. Based on these results, the experiment used every other day watering of 200ml for each seedling for dry condition while every day watering of the 200ml for wet condition. The pre-germination treatment was conducted in which seeds were placed inside sock/cloth.

The water was boiled and once boiling, seeds were dipped for 3 to 5 seconds. The seeds were transferred into a container filled with tap water and were soaked for 24 hours. After which, seeds were spread into the wet white cloth and were covered with another white cloth. Seeds were sown as soon as radicle emerged.

Field lay-out and experiment

A simple experiment laid out in Completely Randomized Design (CRD) was set up in the nursery. Two soil treatments (acidic and alkaline) and two water regimes (dry and wet) were simulated in the nursery with the FGR materials of the 10 families. Ten seedlings in five replications were used for each of the four treatment combinations for a total of 2,000 seedlings. The treatments were as follows: Treatment 1 – acidic and dry soil; Treatment 2 – acidic and wet soil; Treatment 3 - alkaline and dry soil; and Treatment 4 – alkaline and wet soil.

The soil was first sterilized before it was mixed with sterilized fine sand with a ratio of 1:4 (sand-soil). A 1kg of soil was mixed with 4.82g of lime to obtain a pH of 7.2. During the whole observation period, sample of the soil medium was analyzed every month to determine if the pH had not been affected with the water application and through time. A 5" x 8" polyethylene bag was used for potting about 2,500 pots. This included a surplus of 500 pots for the replacement of pots where seeds did not germinate and for seedlings that died before the water regime treatment. The polyethylene bags were spaced 15cm apart. Seed sowing was done after 4th week from the time the potted soils had been placed in the experimental field area. This was the time when the effect of lime in the soil, achieving the pH of 7.2 had been observed. Sowing was completely done in one day so as to minimize error/bias. A roof net was installed to prevent the seedlings from wilting. When the seedlings were ready for water treatment (dry and wet), a plastic roofing was installed and the net was placed over the plastic to prevent it from tearing off.

Originally as proposed, after three months old, the seedlings would have been exposed to water regime treatment. However, after three months of growing in the nursery, the average height of the seedlings was only 4.67cm. This was way below the projected target average height of the seedlings of around 10cm. The stunted growth was attributed to poor aeration and drainage of the potting medium and possibly due to the strongly acidic and basic media used in this experiment. Consequently, water regime treatment was moved to another five months or eight months-old seedlings with an average height of more than 10cm.

Measurement and analysis

The following parameters were measured: seedling height (cm), diameter (mm) and biomass (g). Seedling height was measured at 8 months (245 days old) or day before water regime was employed to determine the main effect of soil pH to seedling growth. At 125 days after water treatments, seedling height, diameter and biomass were determined. Biomass measurement was done thru destructive method of the 50% of the total seedlings sampled randomly. The samples were oven-dried at 65 ^{o}C for three consecutive days. After oven drying, they were then placed in the styrobox to prevent them from absorbing moisture. This was followed by weighing the samples to determine the oven-dry weight. Statistical analysis using analysis of variance and pairwise mean comparison of the growth parameters was employed to determine the differential responses of the families FGRs to the soil pH and water regimes. The data were analyzed using Statistical Tool for Agricultural Research (STAR) software.

Results and discussion

Location and physical attributes of P. falcataria families

About seven families were from the province of Bukidnon located in four municipalities, and three families from the province of Surigao del Sur which were located in one municipality (Table 1). Except for FM001, all families were located in hilly terrain. The average DBH was 41.51cm with smallest and largest DBH of 23.5cm and 89.9cm, respectively. The average height was 24.27m and varied among provenance; the shortest and tallest were 19.3m and 38.5 m, respectively.

Data showed that generally in an elevation of lower than 260 meters above sea level (masl), the families exhibited good growth performance exemplified by high diameter and height. Growth and health performance of *P. falcataria* trees are substantially influenced by elevation (Lacandula *et al.,* 2017).

Table 1. Location, diameter at breast height (DBH), total height (TH), elevation (Elev.), and terrain of the families.

Family Tree No.	Family Tree Code	Location	DBH (cm)	TH (m)	Elev. (masl)	Terrain
1	FM001	Kitaotao, Bukidnon	38.6	19.3	316	gently hilly
2	FM016	Manolo Fortich, Bukidnon	23.5	23.0	400	hilly
3	FM017	Maramag, Bukidnon	35.0	22.3	277	hilly
4	FM020	Maramag, Bukidnon	45.0	28.1	258	hilly
5	FM024	Valencia, Bukidnon	28.0	15.7	335	hilly
6	FM030	Valencia, Bukidnon	36.0	21.7	334	hilly
7	FM123	Manolo Fortich, Bukidnon	23.5	23.0	401	hilly
8	FM042	Bislig, Surigao del Sur	59.6	38.5	45	hilly
9	FM064	Bislig, Surigao del Sur	36.0	25.8	108	hilly
10	FM067	Bislig, Surigao del Sur	89.9	25.3	140	hilly
		Average	41.51	24.27		

Height of P. falcataria seedlings as influenced by soil pH before water treatments

Results shown in Fig. 2 revealed that the seedlings exhibited stunted growth. For instance, the height of this 8 months old seedlings was way below the 3 months old *P. falcataria* seedlings in the nearby central nursery. The stunted growth was attributed to poor aeration and drainage of the potting medium which was 1:4 (sand-soil) and possibly due to the strongly acidic (pH 4.2) and strongly basic medium (pH 7.2) used in this experiment. The prescribed potting medium which was used in growing the seedlings in the central nursery was 7:2:1 (soil: rice hull: vermicast), which in contrast had better drainage and aeration and only slightly acidic medium. Soil pH favorable to tree seedling growth ranges from 5.5 to 6.5 (Turner *et al.*, 1988; Pierce *et al.*, 1999); and should be less than pH 7.0 to enhance seedling biomass production (Wingrett, 2005). Moreover, Santosa (2014) documented that the suitable soil medium for *P. falcataria* seedlings was with enough open space for root development that enhanced soil aeration and drainage.

Apparently not within the soil pH suitable for seedling growth, this study was in better position to explore the effect of too much acidic and extremely basic soil media to seedling growth parameters. Results showed that height growth of seedlings in acidic soil (13.63cm) is relatively higher than in alkaline soil (8.65cm) (Fig. 2a). Among families, variation in height was observed with FM067 exhibiting the tallest and FM024 the shortest with 14.59cm and 8.95cm, respectively (Fig. 2b).

Table 2 depicted that soil pH and families had a significant effect to the seedling heights of *P. falcataria*, both with Pr>F=0.0000; combination of these factors had no significant effect. The pair-wise mean comparison between acidic and alkaline soil (Table 3) revealed that *P. falcataria* seedlings significantly grow faster in acidic compared to alkaline soil. Soil pH affects the nutrients available for plant growth. In highly acidic soil, aluminum and manganese can become more available and more toxic to plant while calcium, phosphorus, and magnesium are less available to the plant. On the contrary, in the highly alkaline soil, phosphorus and most micronutrients become less available. However, since *P. falcataria* is a nitrogen-fixing species, this enabled the species to utilize nitrogen and made available despite the acidic conditions. *P. falcataria* does not require fertile soil and even grows well on dry soils, damp soils and even on salty to acid soils as long as drainage is sufficient (Soerianegara and Lemmens, 1993). This is supported by the finding of Dudhane *et al.* (2011) that tolerance of a fast growing species *Gmelina arborea* in arid and semi-arid soils is enhanced through an arbuscular mycorrhizal fungus *Glomus fasciculatum*. Similarly, Calvo-Albarado *et al.* (2007) reported a higher yield and dominant stand height of the exotic tree species in acidic soil with well-defined dry season than the selected native tree species. Meanwhile, the average seedling height of the families was 11.14cm, and differed significant among families (Table 4). While tallest seedling height was observed in FM067, it was not significantly different with FM064 and FM017. The shortest seedling observed in FM024 was not significantly different with FM001, FM016, FM020, FM030, FM123, FM042.

Table 2. Analysis of variance for seedling height with soil pH.

Source	DF	F-Value	Pr> F
Soil pH	1	164.39	0.0000**
Family	9	6.53	0.0000**
Soil pH x Family	9	1.19	0.3066^{ns}
CV%		24.65	

** = highly significant at 1% level; * = significant at 5% level; ^{ns} = not significant.

Table 3. Pair-wise comparison tests on the height (cm) of *P. falcataria* seedlings with soil pH before water regime treatment.

Soil pH	Means
Acidic	13.63^{a}
Alkaline	8.65^{b}

Means with the same letter are not significantly different.

Table 4. Comparison of average height (cm) of *P. falcataria* seedlings as influenced by soil pH

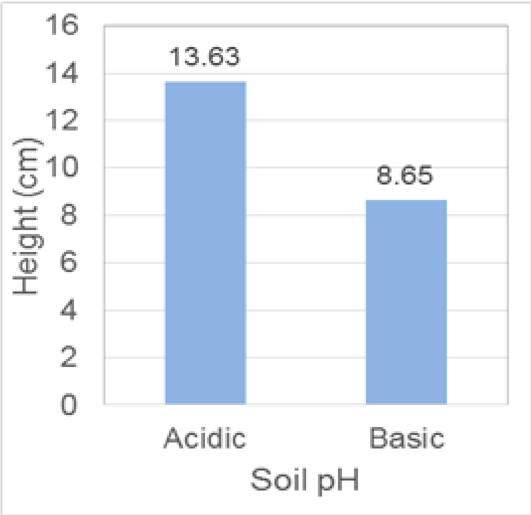
Family Tree No.	Family Tree Code	Location	Height
1	FM001	Kitaotao, Bukidnon	10.34^{bc}
2	FM016	Manolo Fortich, Bukidnon	11.68^{bc}
3	FM017	Maramag, Bukidnon	11.83^{ab}
4	FM020	Maramag, Bukidnon	10.62^{bc}
5	FM024	Valencia, Bukidnon	8.95^{c}
6	FM030	Valencia, Bukidnon	9.38^{bc}
7	FM123	Manolo Fortich, Bukidnon	11.22^{bc}
8	FM042	Bislig, Surigao del Sur	10.87^{bc}
9	FM064	Bislig, Surigao del Sur	11.93^{ab}
10	FM067	Bislig, Surigo del Sur	14.59^{a}
		Average	11.14

Means with the same letter are not significantly different

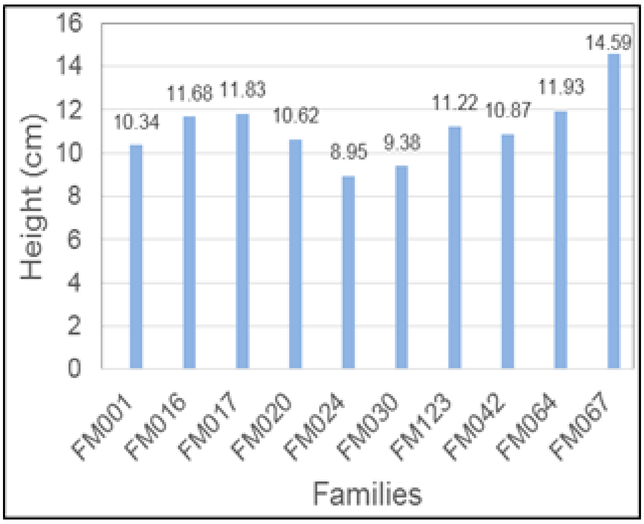
Table 5. Analysis of variance of height (cm), diameter (mm), and biomass (g) of *P. falcataria* seedlings with soil pH and water regimes.

Source	DF	Height		Diameter		Biomass	
		F-Value	Pr>F	F-Value	Pr> F	F-Value	Pr> F
Soil pH	1	756.74	0.0000**	455.920	0.0000**	487.73	0.0000**
Water Regime	1	2.74	0.0999^{ns}	6.660	0.0108*	33.60	0.0000**
Family	9	10.08	0.0000**	3.670	0.0003**	0.87	0.556^{ns}
Soil pH x Water Regime	1	5.38	0.0216*	13.690	0.0003**	20.55	0.0000**
Soil pH x Family	9	3.02	0.0023**	1.260	0.2627^{ns}	0.48	0.884^{ns}
Water Regime x Family	9	0.27	0.9814^{ns}	0.460	0.8989^{ns}	0.70	0.711^{ns}
Soil pH x Water Regime x Family	9	0.67	0.7391^{ns}	0.810	0.6102^{ns}	0.530	0.849^{ns}
CV (%)		20.87		13.88		34.81	

** = highly significant at 1% level; * = significant at 5% level; ^{ns} = not significant.



a



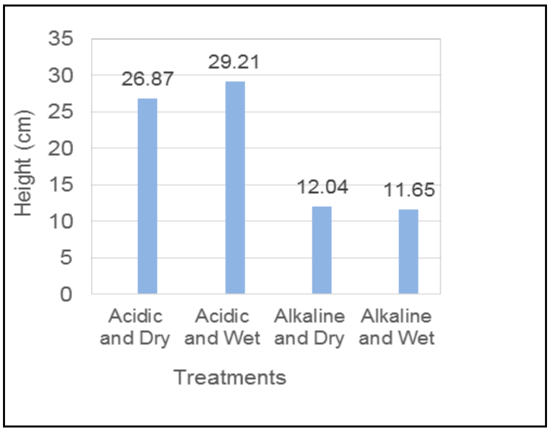
b

Fig. 2. Height of *P. falcataria* seedlings by soil pH (a) and by families (b) before water regime.

Height, diameter and biomass of P. falcataria seedlings as influenced by the soil pH and water regimes

Acidic wet soil exhibited the tallest height of 29.1cm while alkaline wet soil obtained the shortest height of 11.65 cm (Fig. 3a). Seedling height growth relatively favors acidic soil than alkaline soil even in dry condition (acidic dry 26.87cm; alkaline dry 12.04cm). This dominance of acidic soil over alkaline soil to seedling growth was also documented above during the early age (8 months) of the seedlings before water regime was employed. Similar results were observed in diameter growth (Fig. 3b), and biomass production (Fig. 3c). Acidic soil both for wet and dry treatments had large diameter growth of 7.41 mm and 6.69mm, respectively. Alkaline soil-water treatments obtained more or less the same diameter growth with alkaline wet soil having the smallest diameter (4.54mm). For biomass production, acidic soil in both dry and wet conditions produced higher biomass of 5.73g and 4.11g, respectively, compared to alkaline dry or wet conditions which biomass production was less than half of the acidic soil biomass. Alkaline dried soil had the lowest biomass production among treatments of 1.35g.

Analysis of variance showed that soil pH had a highly significant effect on the three growth parameters (height, diameter, and biomass) of *P. falcataria* seedlings, all with Pr>F =0.0000 (Table 5). Although it had a significant and highly significant effect on the biomass and diameter of the seedlings with Pr>F=0.0108 and Pr>F =0.0000, respectively, water regime had no significant effect on height growth. The effect of families to the height and dimeter growth of the seedlings was highly significant, Pr>F=0.0000 and Pr>F=0.0003, respectively, implying a significant variation of the FGR materials among families and between provenance. The soil pH and water regime interaction yielded significant effect to the height (Pr>F=0.0216), and highly significant effect to the diameter (Pr>F=0.0003) and biomass (Pr>F=0.0000) of the seedlings. These results are evidently illustrated on the difference of the seedling growth parameters among treatments as discussed above. On the interaction of soil pH and families, only height growth of the seedlings had been highly significantly influenced (Pr>F=0.0023).



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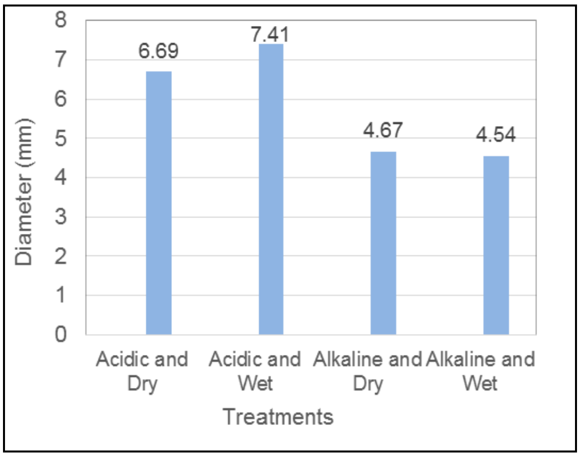

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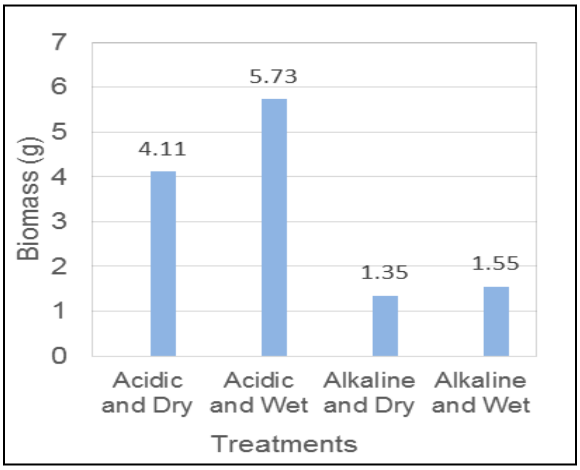


c

Fig. 3. Height (a), diameter (b), and biomass (c) of *P. falcataria* seedlings as influenced by soil pH and water regime.

Both the interaction of the water regime and families, and the interaction of the three sources of variation (soil pH x water regimes x families), had no significant effect to the three seedling growth parameters. It can be inferred that soil pH and water are essential to the growth and development of *P. falcataria* at juvenile stage regardless of the genetic traits and provenance of the FRG materials. This observation is a well-established fact since at seedling stage water is highly indispensable for seedling growth (Baraloto *et al.*, 2006) and soil medium fertility and drainage significantly influenced growth performance of tree seedlings (Baraloto *et al.*, 2006; Wang *et al.*, 2012; and Santosa, 2017).

Table 6. Pair-wise comparison tests on the height (cm), diameter (mm) and biomass (g) of *P. falcataria* seedlings for soil pH at each level of water.

Soil pH	Height		Diameter		Biomass	
	Dry	Wet	Dry	Wet	Dry	Wet
Acidic	26.87[a]	29.21[a]	6.69[a]	7.41[a]	4.11[a]	5.73[a]
Alkaline	12.04[b]	11.65[b]	4.67[b]	4.54[b]	1.35[b]	1.55[b]

Means with the same letter are not significantly different.

Pairwise comparison tests on the average height, diameter, and biomass of the seedlings for soil pH at each level of water showed a significant difference (Table 6). The results were the same in the three seedling growth parameters. There was a significant difference on the seedling height, diameter, and biomass between acidic and alkaline soil both in the dry and wet water regime, while no significant difference was observed between alkaline dry and alkaline wet soil. This indicates that seedling growth relatively favors both the dry and wet acidic soil compared to dry and wet alkaline soil. Considering water regime at each level of soil pH soil (Table 7), the difference of the average height, diameter, and biomass between acidic wet and acidic dry soil was significant, implying that *P. falcataria* seedlings grow faster in acidic wet soil than acidic dry. For obvious reasons, plants grow well on adequate water supply because water is a key component of all physiological processes in plants. This result was also observed by Zhang *et al.* (2005) on growth responses of *Populus davidiana* ecotypes to different soil water contents. Osonubi and Osundina (1987) observed that in soil drought seedlings of fast growing *Gmelina arborea* there was a decreased hydraulic conductivity from soil to plant as indicated by the shape of the slope of the water potential and transpiration relationship which resulted to decreased in root growth and root an shoot dry weight. Consistently, Wu *et al.* (2008) observed that drought stress dramatically decreased seedling heights, basal diameter, leaf number, leaf area, root, length, and biomass production of *Sophora davidii* seedlings. Likewise, Wang *et al.* (2012) documented a negative morphological effect of water stress and deficit to the seedling of *Medicago falcata* resulting in reduced biomass production.

Table 7. Pair-wise comparison tests on the height (cm), diameter (mm) and biomass (g) of *P. falcataria* seedlings for water regime at each level of soil pH.

Soil	Height		Diameter		Biomass	
pH	Acidic	Alkaline	Acidic	Alkaline	Acidic	Alkaline
Dry	26.87^{b}	12.04^{a}	6.69^{b}	4.67^{a}	4.11^{b}	1.35^{a}
Wet	29.21^{a}	11.65^{a}	7.41^{a}	4.54^{a}	5.73^{a}	1.55^{a}

Means with the same letter are not significantly different.

Table 8. Comparison of average height (cm) of seedlings of families with soil pH and water treatments.

Family Tree No.	Family Tree Code	Location	Height	Diameter	Biomass
1	FM001	Kitaotao, Bukidnon	17.76^{c}	6.33^{a}	3.32^{abc}
2	FM016	Manolo Fortich, Bukidnon	21.42^{b}	6.02^{ab}	3.45^{ab}
3	FM017	Maramag, Bukidnon	21.47^{b}	5.87^{abc}	3.18^{abc}
4	FM020	Maramag, Bukidnon	19.28^{bc}	5.94^{abc}	3.23^{abc}
5	FM024	Valencia, Bukidnon	15.63^{c}	5.15^{c}	2.89^{c}
6	FM030	Valencia, Bukidnon	16.68^{c}	5.68^{abc}	2.96^{abc}
7	FM123	Manolo Fortich, Bukidnon	19.97^{bc}	5.67^{abc}	3.03^{abc}
8	FM042	Bislig, Surigao del Sur	19.69^{bc}	5.46^{bc}	2.91^{bc}
9	FM064	Bislig, Surigao del Sur	21.52^{b}	5.95^{abc}	3.35^{abc}
10	FM067	Bislig, Surigao del Sur	25.88^{a}	6.18^{ab}	3.53^{a}
		Average	19.93	5.82	3.18

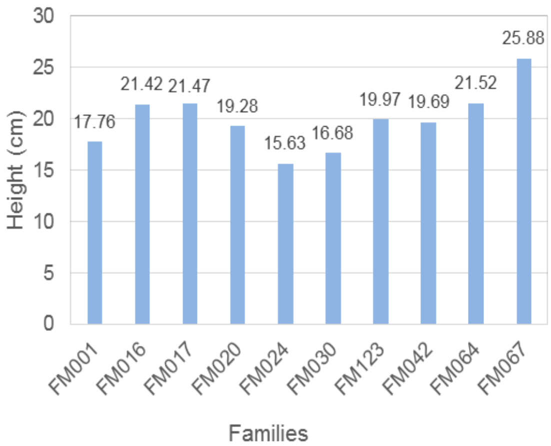
Means with the same letter are not significantly different.

Variations on the height, diameter, and biomass of P. falcataria seedlings by families

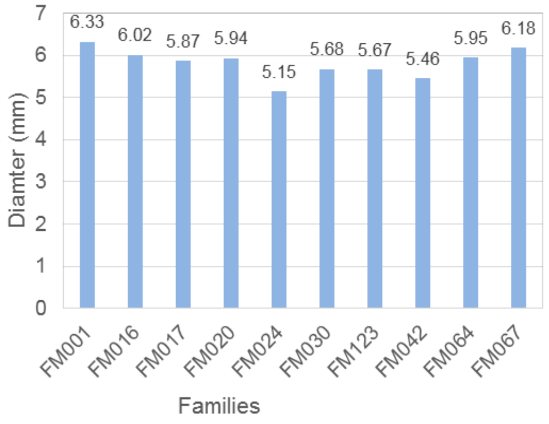
The significant effect of families, soil pH and water regime to the height, diameter, and biomass of *P. falcataria* seedlings was evidently expressed in the varied results of these growth parameters by individual family illustrated in Fig. 4. By growth parameter, Fig. 4a showed that FM067 exhibited the tallest height (25.88cm) and the shortest was observed in FM024 (15.63cm)). Other families with seedling height above average of 9.93cm (Table 8) were: FM064 (21.52cm), FM017 (21.47cm), and FM016 (21.42cm), FM123 (19.97cm). In terms of diameter growth, FM001 had the largest diameter (6.33mm) which was followed by FM067 (6.18mm), while the smallest diameter was exhibited in FM024 (5.15mm) (Fig. 4b). Families whose diameter growth was above average (5.82mm) were: FM016 (6.02mm), FM064 (5.95mm), FM020 (5.94mm), and FM017 (5.87mm).

Similar to height growth, the highest biomass production was exhibited by FM067 (3.53g) and the lowest was observed in FM024 (2.89g) (Fig. 4c). Families which obtained biomass above average (3.18g) were FM016 (3.45g), FM064 (3.35g), FM001 (3.32g), and FM020 (3.23g). It can be distilled from the results that family FM067 of Surigao del Sur had a superior seedling growth while family FM024 of Bukidnon had the poorest growth performance. Moreover, seedlings of families FM064 of Surigao del Sur and FM016 of Bukidnon showed a good growth performance as evidenced by their height, diameter and biomass which were consistently above average.

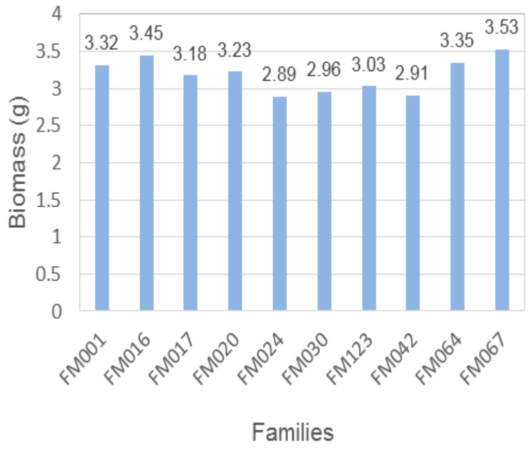
Pairwise mean comparison showed that the tallest seedling height of FM067 was significantly different from other families (Table 8). While seedling height of FM024 was the shortest, this was not significantly different with the following families: FM001, FM020, FM123, and FM042. Families with no significant difference on their seedling heights were FM016, FM017, FM020, FM123, FM042, and FM064. Meanwhile, the largest diameter exhibited by the family FM001 was not significantly different from other families except the families FM024 and FM042. On the other hand, seedling diameter of FM024 which was the smallest, was significantly different with families FM001, FM016, and FM067. In terms of biomass, FMO67 with the highest, significantly differed only with FM042 and FM024. The family FM024 with the lowest biomass significantly differ with FM016 and FM067. Other families were significantly different from each other.



a



b



c

Fig. 4. Height (a), diameter (b), and biomass of families with soil pH and water regime.

Findings above showed that in terms of growth performance, families FM067, FM064, and FM016 were performing well. Families FM017, FM001, and FM020 were growing fairly. Performing poorly were families FM123, FM030, FM042, and FM024. The variation on seedling growth among families indicates that certain genetic traits unique to its family had influenced the phenotypic traits of *P. facataria* at juvenile stage. This finds support from Sudrajat (2015) where a genetic variation patterns on the fruits, seeds, and seedling morphological characteristics of the 11 natural populations of *Anthocephalus cadamba* were observed and the genotype of species explained most of the variance for these characteristics. Moreover, results showed that seedling growth parameters between the two provenances of the families substantially differ, with Surigao del Sur exhibited superior performance. Ngulube (1989) reported the same finding on provenance of his study on genetic variations of *Gliricidia sepium* but none of the seedling traits assessed (height, diameter and dry-weight) was related with any of the seed-origin site characteristics. However, using the same species, Salazar (1986) found out that genetic variation between provenances for seedling variables was quite low, although differences of most of the seed and seedling traits assessed were statistically significant.

It is interesting to note that family FM067 with superior seedling growth had the biggest DBH and with superior total height while FMO64 with poor seedling growth performance had the smallest DBH and with only about 2/3 of the average total height among families. However, families FM016 and FM064 with smaller DBH and shroter total height performed well in seedling growth, and belonged to the top three families. Moreover, FM064 with bigger DBH and taller total height performed poorly in seedling growth. Whether the phenotypic parameters (diameter, height, health, and age) of families are correlated with juvenile variation performance of *P. falcataria* is an interesting topic for empirical investigation.

Conclusion

Variations among forest genetic materials of the families of *P. falcataria* from the two provenances in the primary pathways as influenced by soil and water treatments are evident at juvenile stage. This was exemplified by the significant differences of the height, diameter, and biomass among families. Acidic soil medium facilitates and enhances height and diameter growth performance and biomass production of *P. falcataria* seedlings. Likewise, water is a significant factor, hence, an acidic wet soil medium favors growth of *P. falcataria* seedlings. If water is a limiting factor, one may opt for acidic dry soil provided that a certain level of amount of water is maintained to prevent the seedlings from wilting and desiccation. Growth of *P. falcataria* seedlings in alkaline or fertile dry or wet soil media is relatively poor as manifested by a poor height and diameter growth and low production of biomass of the seedlings.

The top three most performing families combining height, diameter and biomass parameters with soil pH and water regime were families FM067, FM064 and FM016. It is suggested that FGR materials of these families and those which are located near to them can be prioritized in genetic analysis. However, to capture the genetic diversity of *P. falcataria*, it is imperative to consider the provenance of the species. Hence, the FGR materials of the families FMO67 and FM064 of Surigao del Sur; and FGR materials of FM016, FM017, FM001, and FM020 of Bukidnon and their neighboring families will be considered priority in genetic studies. Considering the time and budget elements in the genetic characterization, diversity and laboratory analysis, the following order of priority (from highest to lowest) will be as follows: families FM067, FM064, FM016, FM017, FM001 and FM020. The tree geneticists may differ genetic laboratory analysis of the families FM123, FM030, FM042, and FM024 owing to its poor growth performance at juvenile stage.

While genetic expressions of tree species are to a greater extent expressed phenotypically, the study demonstrates that pot experiment is highly relevant to expedite and cost effectively undertake tree genetic analysis. Evidently, the protocols established in this study are very much useful for tree geneticists in fast tracking genetic analysis given a number of FGR materials collected and the enormous cost needed in the laboratory analysis.

Acknowledgement

The authors would like to thank the Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development – Department of Science and Technology (PCAARRD-DOST), Los Baños, Philippines for the funding, and Central Mindanao University, University Town, Musuan, Bukidnon Philippines for the administrative support provided during the conduct of the study.

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