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The Growth of Drumstick (*Moringa oleifera* Lam.) Seedling under Artificial Shade and their Early Growth after Transplanting

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Abstract Currently, *Moringa oleifera* multipurpose plant has become an important crop in the agro-industrial sector. In nursery propagation, suitable environmental conditions such irradiation is needed for the growth of seedlings. Modifying the sunlight intensity through setting the shade is an important thing must be considered. This study consisted of three experiments. The first and the second were carried out using black paranet shading, e.g. 90% shading (105.13 lux) using three layers of paranet; 65% shading (387.61 lux) using two layers of paranet; 35% shading (787.96 lux) using one layer of paranet, and without paranet shading (1,479.23 lux) for test the seed viability with five replications, and each replication consisted of 100 seeds, and test the seedlings growth with five replications, and each replication consisted of fifteen seedlings series. Third, an experiment to test the adaptability of seedlings from the second experiment to the production field, through the grid system planting method which was repeated three times and each replication consisted of 10 seedlings. The results showed that the level of shade had a significant effect on seed viability, seedling growth, and early adaptability of seedlings in the production field. The best quality *M. oleifera* seedlings could be obtained by application of artificial shade using one layer of black paranet with a shade level of 35% (787.96 lux).

Keywords adaptation, intensity, environment, light, paranet

1. Introduction

Moringa oleifera Lam (drumstick) is one of the cultivated species from the *Moringacae* family and it's a multipurpose tree. This tree is native to the Himalayan region in India which then spread widely in most tropical regions [1], including in Indonesia. This tree is a drought-resistant plant characterized by shedding its leaves when conditions very dry and then flourishing after the tree gets water or rains. This tree grows well in areas with annual rainfall ranging from 250-1,500 mm and temperatures in the range of 25-40 ^{O}C even up to 48 ^{O}C [2].

In relation to the many benefits and uses of *M. oleifera* trees, in the last few years this plant have come to the attention of researchers and growers or farmers. As a vegetable or herbal raw material, Moringa leaves contain great nutrients such as vitamine A, vitamine C, and calcium [3], important amino acids like methionine, tryptophan, and lysine, as well as a variety of phytochemicals that act as antioxidants [4]. The seeds can be used as water purifiers [5] [6], and also the seed oil possibly used as a cosmetic and health material due to have several medical properties, as well as an alternative source of raw materials to replace diesel fuel [7] [8] [9].

Although *M. oleifera* is a plant that is resistant to dry environmental conditions and will also be able to grow well in humid tropical areas and limited soil nutrient conditions [10], of course the proper cultivation technology is needed to get optimal products. It is necessary to develop its cultivation technology. The development of *M. oleifera* trees certainly requires the availability of quality seedlings. The use of quality seedlings can produce stands with a high level of leaf biomass productivity. The quality of seedlings in nurseries is strongly influenced by environmental factors besides genetic factors. Therefore, starting *M. oleifera* cultivation, which is a perenial plant, providing good and quality seeds to increase the growth of moringa in the production field needs intense attention.

In the process of plant propagation, the growing media and the size of the container for root growth and development are very important to note, because in this growing medium that the availability of water, nutrients and also oxygen supports the continuity of root growth and development to ensure the growth of the seedlings as a whole [11]. In the nursery period, environmental factors such as growth medium and light intensity are factors that determine the quality of growth of plant seedlings. It is well known, that different light conditions will certainly have an effect on the variation of plant morphology and physiology, and the degree of adaptation is also determined by the genetic characteristics that interact with the environment. Related to lighting, the light intensity factor plays a greater role in plant growth than the quality of light. Therefore, setting the level of shade by preparing artificial shade at the nursery stage is certainly very important to provide tolerable conditions for certain plant species, and then determines the growth and development of seedlings.

Then, Jahn et al. [12] reported that seeds germination and growth of *M. oleifera* seedlings were influenced by light conditions and it was recommended that half the seedling growth period be given screen. Mohamad [13] mentions that forest tree seedlings that grow at light intensities of 30% and 50% have tall stems and thin shoots with broad leaves that were dark green but lack the root system. Wardani and Latifah [14] reported that the height of *Dictyoneura acuminate* forest plant seedlings was influenced by light intensity, it was the less light intensity the longer the shoots. Whereas *M. oleifera* seedlings which were cultivated at a high level of shading produce weak and succulent seedlings [15]. Baru (*Dipteryx alata* Vog.) seedling emergence and emergence speed [16], have been found to be unaffected by 50% shading during seedling development. Moreover, de Sousa et al. [17] suggested that to produce good *Tachigali myrmecophila* seedlings, nurseries should be conditioned to have artificial shade levels ranging from 50-75% solar radiation.

In general, it can be said that from the marks of the previous studies above, there was no exact information on how much shade intensity is needed to produce *M. oleifera* seedlings which, after being transplanted in the production field, will provide good growth. Apart from that, high-quality seedlings with better development and early growth can be produced in seedling nurseries by using the proper artificial shading. It also in order to reduce seedling management, seedling mortality rate, and production costs, these seedlings can keep short and simple in seedling nurseries.

Therefore, there is a need to carry out studies to determine the appropriate shading levels for the production of *M. oleifera* seedlings. This article describes the results of our study that aims to determine the effect of shade on seed germination, seedling growth, and then its effect on the adaptability or growth of *M. oleifera* seedlings in the early period of growth in the production field.

2. Materials and Methods

2.1. Time and Location of Experiment

Series of experiments were carried out in July-December 2020. The germination and nursery experiments were conducted at the nursery location in the city of Mataram, West Nusa Tenggara (WNT), Indonesia with a geographical position at the coordinate point 8^{O}34'47.19"S 116^{O}05'47.91"E and altitude 16 m asl. The air conditions during three months of the seedling experiment were temperature 27.4-30.6 ^{O}C and humidity of 83-87%. Experiments in the production field was carried out in the Amor-Amor, Gumantar Village, North Lombok Regency, WNT with a geographical position at 8^{O}16'15.02"S 116^{O}17'34.02"E, altitude of 50-110 m asl with soil type of Entisol geluh sandstone composed of sand (69%), dust (25%), and clay (5%), with 1.8% organic carbon, 0.2% total nitrogen (N), pH around 5.9-6.3, and cation exchange capacity 7.2-10.4 cmol.kg^{-1}.

2.2. Plant Materials and Tools

M. oleifera seeds were used and obtained from adult moringa trees growing in homes yard in the Panggung Village, North Lombok Regency, WNT. Ripe fruit (brown) was collected from ten trees that appear to grow best and fertile. In connection with better seed viability, seeds which in the base and middle position of the fruit (pod) were selected [18]. A total of 50 pieces were taken from each plant, and the seeds were mixed then dried for 2 days. The selected seeds were then stored in a polypropylene plastic bag, and ready for applay in experiments. The instrument used to measure the intensity of light under the black paranet was Accu PAR/PAR-LAI CEPTOMETER LP-80, Decagon Devices, Inc

2.3. Treatment and Experiment Design

The shading material prepared for the experiments was black paranet. For shade of S1 (90% of shade =105.13 lux), three layers of paranet were used; for shade of S2 (65% of shade = 387.61 lux), two layers of paranet; for shade of S3 (35% of shade =787.96 lux), one layer of paranet was used; and without shading paranet for control, S4 (1,479.23 lux).

Paranet installed as a shade as high as 1.7 meters above the nursery beds measuring 2.0 m x 1.5 m.

The study consisted of three stages of the experiment, the first stage was aimed at knowing seed viability at various shading levels, and the second stage was aimed at knowing the growth of *M. oleifera* seedlings up to the age of two months from each shade level, and the third stage was an experiment aimed at knowing the adaptability of the seedlings *M. oleifera* originating from three levels of shade in the early period grew in the production field.

The experiments were arranged according to the Randomized Block Design, with four shading level treatments (described above). To find out the viability of seeds due to shade, a plastic box of 45 cm x 25 cm x 10 cm was prepared containing germination media in the form of a soil-sand-rice hull charcoal mixture (1:1:1 v/v) each made five replications, and each repetition consists of 100 seeds. Normal sprouts produced from each lot of seed viability testing were then planted as a second experiment on black polybags (measuring 15 cm x 25 cm) of five replications and each replication consisted of fifteen series of seed polybags. The nursery media in polybags was a mixtured of soil and bamboo leaf litter compost (1:1 v/v). In the third experiment, planting with a grid system in the field of seedlings that were 2 months old was carried out to determine the adaptability of the seeds obtained in the second experiment. Each row of each seedling from the four shade levels consists of 10 plant seeds and was repeated 3 rows alternating between the shade levels. Planting in the field was arranged with a spacing of 50 cm in rows and 75 cm between rows.

2.4. Seedling Maintenance

The study of seeds germination and seedling growth were carried out under the auspices of black paranet with manual watering every two days. After two weeks of transplanting seedlings to polybags, seedlings were fertilized with 5 g of NPK Phonska (15-15-15) each polybag. Control of pests and diseases was completed by spraying an insecticide of Lamda Sihalotrin and fungicides of Mancozeb. Seedlings were maintained for two months since transplanting. Into the planting hole buried cow manure as much as 2 kg per hole a day before transplanting. Watering was through every two weeks for 3 months of testing.

2.5. Data Observation and Analysis

A total of 10 samples of 100 seeds were weighed for each test. Weight measurements using sensitive electronic scales (0.01 mg) (OHAUS Precision Plus brand). From each unit of 100 seeds germinated in the germination container observed for 21 days of germination, germination rate, and number of normal seeds germinated. Seedling growth variables in the polybags were evaluated included seedling height, stem diameter, number of leaves, and dry weight per once a month. Adaptability of seedlings in the field was evaluated by calculating the percentage of seedlings survive (live), height, and number of leaves.

Data were analyzed by ANOVA at $P \leq 0.05$ confidence level and standard deviation of the average value of each variable of seed viability and seedling growth, as well as adaptability using the Minitab-14 software.

3. Results and Discussions

3.1. Results

Environmental factors that play an important role for seedling and plant growth and development are light, one of which is in the form of light intensity. The excessive lighting can be adjusting through the shade settings. In this study the data obtained that the air temperature at each shade level during the seedling nursery study which was observed every 12.30-13.00 during the day were recorded as follows; S1 (29.12±1.52 ^{O}C); S2 (30.03±1.83 ^{O}C); S3 (30.61±2.35 ^{O}C); and S4 (32.66±2.51 ^{O}C). And for air humidity data were recorded as follows; S1 (88.11±2.22%); S2 (86.78±2.05%); S3 (85.57±2.26%); and S4 (84.76±2.72%). Climatic conditions for the three months of the field experiment were showed in Table 1 below.

Table 1. Climatic conditions in the production field during the three months trial period

Month (2020)	Temperature (^{O}C)		Relative Humidity (%)		Rain	
	Max.	Min.	Max.	Min.	Raini days	Rainfall (mm)
October	36	24	98	66	2	4
November	34	24	98	73	10	82
December	31	23	99	80	12	244

Source: primary processed data

In relation to shading arrangements in the moringa plant nursery through this experiment, the fact that the shade effect was significantly on the seed vigor at $P \leq 0.05$ (Table 2), as well as the growth variable of seedlings during the two months nursery period (Table 3 and Table 4). The significantly effect of shade can also be seen on the initial adaptability of plants in production fields (Table 5).

Table 2. Seeds vigor of *M. oleifera* seeds at three levels of nursery shade

Shading level	Weight of 100 seeds (g)	Seed germinated (%)	Germination rate (days)	Normal Sprout (%)	Seedling Dry Weight * (g)
90 % (105.13 lux)	25.2	82.7 a	5.8 a	66.6 a	0.35 a
65 % (387.61 lux)	25.6	95.3 c	6.1 a	81.3 b	0.88 bc
35 % (787.96 lux)	24.9	96.7 c	8.7 b	95.8 c	0.93 c
No shading (1,479.23 lux)	24.7	89.3 b	11.5 c	93.5 c	0.76 b
HSD 5%	-	5.52	2.35	9.92	0.13

Note: * Seedling dry weight was measured 30 days after seeds sowing. The numbers in each column followed by the same letter were not significantly different according to the 5% HSD test

Table 3. Growth of *Moringa* seedling canopy components at nursery shade levels

Shading level	Seedling height (cm)		Number of leaves		Stem Diameter (cm)	
	first month	second month	first month	second month	first month	second month
90 % (105.13 lux)	42.8 c	81.4 c	8.1	11.9 a	0.19	0.33 a
65 % (387.61 lux)	34.7 b	63.6 b	8.6	13.5 b	0.22	0.51 b
35 % (787.96 lux)	30.5 b	58.2 ab	8.9	15.5c	0.31	0.69 c
No shading (1,479.23 lux)	25.3 a	52.8 a	8.5	13.6 b	0.24	0.53 b
HSD 5%	4.56	6.8	-	1.5	-	0.15

Note: The numbers in each column followed by the same letter were not significantly different according to the 5% HSD test

Table 4. Dry weight of seedling and T/R ratio of seedlings

Shading level	Dry weight of canopy (T) (g)		Dry weight of root (R) (g)		T/R ratio	
	first month	second month	first month	second month	first month	second month
90 % (105.13 lux)	0.53	2.97 a	0.22	1.71 a	2.41	1.74
65 % (387.61 lux)	0.88	3.69 ab	0.41	2.21 b	2.15	1.67
35 % (787.96 lux)	1.13	4.88 c	0.72	2.99 d	1.70	1.51
No shading (1,479.23 lux)	0.69	3.78 b	0.51	2.66 c	1.61	1.42
HSD 5%	-	0.63	-	0.31	-	-

Note: The numbers in each column followed by the same letter were not significantly different according to the 5% HSD test

Table 5. Plant height, number of plant leaves, and number of live seedlings after transplanting

Shading level	Plant height (cm)		Number of leaves		Number of live seedlings (%)	
	first month	second month	first month	second month	first month	second month
90 % (105.13 lux)	85.8 c	89.2 b	10.4 a	11.3 a	86.7a	63.3 a
65 % (387.61 lux)	69.3 b	79.3 a	13.2 b	14.5 b	96.7b	76.7 b
35 % (787.96 lux)	66.5 ab	78.9 a	17.6 c	19.4 c	100.0b	100.0d
No shading (1,479.23 lux)	62.6 a	78.5 a	16.6 c	18.5 c	93.3b	93.3 c
HSD 5%	5.7	6.2	2.53	3.57	7.62	6.45

Note: The numbers in each column followed by the same letter were not significantly different according to the 5% HSD test

In Table 2 it appears that the 35% shade level in *M. oleifera* seedlings was the best shading level conditions for obtaining viability of *M. oleifera* seedlings to then grow and develop. Meanwhile shade levels up to 90% was an uncondusive condition for germination and growth of *M. oleifera* seedlings. At this level of shading, seed germinated, seed germination rate, number of normal seed sprout, and seedling dry weight appear to be the lowest compared to other shade levels. The percentage of germination of *M. oleifera* seeds was obtained low under high shading levels may be due to the effect of low soil temperatures or low light intensity or both. In general, the experimental results shows that the percentage of moringa seed germination was quiet in the high category under all shade level to without shade. This means *M. oleifera* seeds can germinate at various temperatures and less light intensity, and also show that *M. oleifera* seed was quite hardy to high temperatures and open light.

The success of seedlings growing and developing into a quality seedling was also influenced by the level of shade (Table 3 and Table 4). Shading less to 35% appears as a shade intensity conducive to growth and then good quality *M. oleifera* seedlings. In the shade condition of 35%, the seedling height was neither too low nor too high. At the height of the seedlings there was found that the highest number of leaves and the largest stem diameter compared to seedlings at other shade levels (Table 3). The manifestation of the seedling growth component described in Table 3, was the weight of both canopy and root biomass, elaborated in Table 4, and shows that shade less to 35% was also found that the best shade level compared to other shade levels.

The findings of this study in general showed that seedling of *M. oleifera* in the low shade (35%) to without shade produces seedlings that were upright and sturdy but in the medium to high shade (65-90%) produce soft or soft seeds and easy to fall. This indicates that *M. oleifera* seedlings in conditions of receiving more light would be better used in photosynthesis and then a balanced carbohydrate partition between the above (canopy) and underground (root) parts.

Seedling transplanting in the production field was the initial stage of perennial crop cultivation such as *M. oleifera*, where moringa plants interact with the planting environment, both individually and in population. At the beginning of the growth after transplanting, various seeds obtained from different levels of shade showed a variety of adaptation levels (Table 5). The results showed that seedlings originating from shade 35% and without shade were the best adapted for up to 2 months of the initial growth period in the production field.

3.2. Discussion

Light is an abiotic factor that plays an important role in horticultural production, in relation to its importance for photosynthesis, biochemical and biophysical processes in terms of producing biomass. At the nursery stage, ensuring the right intensity of light is essential for the achievement of the photosynthesis process that supports the acquisition of large biomass and then forms an integral part of the plant [19]. However, the optimal light intensity for growth and development varies greatly between species and even plant eco-types. Therefore, redesigning photosynthesis for the seedling nursery of *M. oleifera* plants through shade manipulation may be useful to lessen the effects of excess or insufficient light scattering. In this study, observations and measurements were carried out ranging from seed germination to seedling planting on the production site. The experiment was conducted with the aim of determining the need for a more accurate light intensity of *M. oleifera* seedlings. The experiment's findings then demonstrated that the selection of the shadow level with a black paranet had a discernible impact on the level of light.

Plants grown from seeds initially grow slowly because growth during those periods was being primarily focused on root development, making plants extremely susceptible to the competing of growth factors. In this trial, it was discovered that it could take up to 11 days from the time the *M. oleifera* seeds were sown until they surfaced on the planting medium. During the experiment some seeds were found to germinate after the end of the observation period. According to [20], sowing seeds (seeds with a high fat content) result in a low proportion of germinated seeds and produces seedlings with slow growth. Success depends on a number of highly favorable circumstances, including the availability of enough soil moisture, the correct depth of hole, and the number (multiple seeds) per hole. According to reference of [21], sowing *M. oleifera* seeds directly is still possible as long as the seeds are of good quality and viability.

The survival of seedlings after transplantation is a complex process that could be influenced by many factors. One important factor if the conditions of the field of production are the same, of course, is the quality of seedlings to be transplanted. Good seed quality is determined by the propagation nursery environment in which it is carried out, including the lighting, which could be manipulated through the shading. In general, it could be said that a shade level of up to 35% was ideal for maintaining the seedlings of *M. oleifera* plants. In addition to being beneficial for seed vigor, it was also beneficial for seedling growth at the nursery and results in seedlings that are highly adaptable on the production field during the two-month growth phase following the transplant.

The findings of this research also indicate that *M. oleifera* seeds and seedlings grow without any difficulty in open space, despite the fact that the moringa plant's early development could be characterized as slow. While Zhang et al. [22] claimed that only a certain amount of shade can improve shade plant biomass, and reference of [23] claimed that complete exposure to sunlight can benefit plant biomass accumulation, particularly for sun plants. Additionally, the natural shade due to the shedding by leguminous trees could be a determining factor in the growth appearance of an Abaca banana which may be due to its influence on water and nutrient needs [24]. Therefore, based on the results of our experiments, it is possible to conclude that *M. oleifera* is a plant that prefers light (light-loving plant or sun plant type).

Different plants will grow at varying degrees of shade due to the altered environmental conditions brought about by artificial shading. According to reference of [25], greater shading levels will result in reduced air temperature, soil temperature, and light intensity, but higher moisture levels. In young plants at the nursery level, shading causes a distinctive morphological development and then causes a physiological reaction [26].

The best growth of *Jatropha* seedlings, according to [27], occurred in an environment with a shade level of approximately 330 mol $m^{-2}s^{-1}$ seconds of photon flow, or equal to 50% shadow. This environment was characterized by an increase of 140% in total seedling dry material. Additionally, references of [28] and [29] claimed that the biomass ratio between the seedling's shoot and root represents the distribution of photosynthate between the top and bottom of the plant. According to this research, *M. oleifera* seedlings from low-light environments would devote more biomass to their stems and leaves (shoot), increasing the shoot/root ratio.

The findings of this research supported by [30] viewpoint. According to a study by [21] on seed-derived *M. oleifera* seedlings, the seed has a high chance of adapting to the production field after seedling transplantation the smaller the value (near 1) of the shoot/root ratio. *Jatropha* seedlings from seeds with a shoot/root ratio value close to one or a smaller ration value were seedlings of higher quality, according to [31]. Similar to this, [32] claim that red pine seeds have a considerably higher total biomass in full light than in shade.

After seedlings are transplanted into a production field, the lower the shoot/root ratio, the better the plant and the greater the chance of plant survival [33], particularly in dry areas [26]. Additionally, *Parkia multijuga* Benth. seedlings with a lower T/R ratio have been shown to have higher seedling survival and better ability to survive after transplanting, as described by [34]. By lowering the T/R ratio, increased exposure to photosynthesis radiation raises the assimilation split into the root system. Moreover, according to [34], the loss of root weight in the shadow is caused by the restriction of plant water under full sunlight, which results in the accumulation of dry mass in the root system and lowers the build-up of assimilation on the top of seedlings.

Better *M. oleifera* seedlings were found in this research to be those which thus grow and develop under 35% or less sunlight. The findings of this research thus imply that the moringa plant is a sun-loving plant. The phenomenon would be that plants categorized as light-loving plants (sun) can increase their chlorophyll content when the light intensity is low, which makes them appear greener in nurseries and lowers the point of compensation and light saturation and increases light absorption and photosynthesis. The seedlings, on the other hand, look paler when they were exposed to higher shades (65% to 90%), or low light intensities. The accumulation of clear photosynthesis products and compounds required for regular growth will be reduced over extended times of low light intensity, which will result in a decrease in biomass [35] [36].

Thus, full light circumstances up to a shade level of about 35% can be used in a propagation environment to enhance the growth (biomass) of *M. oleifera* seedlings. Shading is a crucial cultivation approach for crop planting because it will produce high-quality seedlings, which will then produce a high percentage of adaptable seedlings on the production field after transplantation [37]. It was discovered in this research (see Table 4) that the shoot biomass and root biomass of the seedlings increased with increasing light intensity or decreasing shading levels arising in seedlings with a shoot/root (T/R) ratio of 1.51 thereafter. The nursery environment with a 35% shading level stored the greatest dry mass accumulation of *M. oleifera* seedlings. The seedlings did not achieve the point of light saturation in this environment. The environment facilitated faster initial seedling development because the energy from photosynthesis may have been used to build the dry mass of the shoot (shoots) and roots. These seedlings were found to be of high quality, which was determined by how adaptable they were after being transplanted in the production field (number of live seedlings in Table 5).

Therefore, although *M. oleifera* is an annual plant that can grow both in widespread environmental conditions, even in extreme climatic conditions [38], but in efforts to develop intensive farms or plantation in relation to the many benefits of this plant from as a medicinal material to human food and also as a feed for livestock [39], appropriate and efficient quality seedling preparation techniques are required. There is no good plantation without quality seedlings. Then the results of our research could be as a reference technique or method in multiplying planting material or *M. oleifera* seedlings

4. Conclusions

This study demonstrated how *M. oleifera* Lam. adaption to its environment in production fields is influenced by the amount of shade provided by black paranet. Raising *M. oleifera* seedlings under artificial shading using 35% black paranet (787.96 lux) will yield high-quality plants. Additionally, these high-quality seedlings offer the finest early development in fields of production under the same shade.

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