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Revegetation ex-Limestone Mining Soil with the Addition of Humic Acid and Limestone Waste

Dita Irwanti Pratiwi *[1], Mohammad Nurcholis [1], Rika Ernawati [1]
[1] Mining Engineering Department-Program Magister, UPN Veteran Yogyakarta, Indonesia
*e-mail: ditairwantipratiwi@gmail.com

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Abstract
PT Akarna Marindo is a limestone mining company located in West Bandung that will carry out revegetation activities with Arabica coffee plants on ex-mining land. PT Akarna Marindo did this by mixing a combination of <5 mm limestone waste from crusher activities and humic acid in Arabica coffee growing media. This research aims to analyze the response of Arabica coffee seedlings to the use of a combination of humic acid and limestone waste. The research used an experimental method with experimental polybags consisting of 5 treatments with 3 repetitions. The response of Arabica coffee seedlings includes seed height and seed diameter. Data processing uses the Analysis of Variance (ANOVA) test. The results of the analysis showed that the response of Arabica coffee seedlings to the combination of 15 mL humic acid and 4 kg limestone waste (A15L4) was an optimal combination of humic acid and limestone waste compared to other treatments in the response of Arabica coffee seedlings. There was an increase in the average height of seedlings from 19.23 cm to 24.90 cm and the diameter of seedling stems from 2.13 mm to 2.53 mm.

1. Introduction

Mining activities trigger problems of environmental degradation which start from the loss of vegetation cover and changes in topography (engineering impact), this is followed by the negative impact of decreasing water absorption capacity and high levels of erosion (cascading impact) which leads to degradation of soil fertility and hydrological systems [1]. Every mining business that has the aim of carrying out exploration activities and processing non-renewable natural resources is required to carry out reclamation activities. Reclamation is an activity carried out at all stages of a mining business, starting with structured activities, then restoring and then improving the quality of the environment and ecosystem so that it can function again according to its function. Revegetation activities are one of the activities carried out on ex-mining land during reclamation activities. Revegetation is an effort to repair and restore damaged vegetation through planting and maintenance activities on land used for forest areas [2]. PT Akarna Marindo plans to use Arabica coffee plants for reclamation activities. Damage to soil as a medium for plant growth by mining activities will make it difficult to revegetate reclaimed plants, especially Arabica coffee plants. Strategies that need to be applied to improve soil conditions include improving soil body space, providing topsoil and organic material as well as basic fertilization, and applying lime [3]. The addition of ameliorant can increase soil fertility. The ameliorants chosen were humic acid and limestone waste < 5 mm from crusher operations. Humic acid is part of a complex molecule consisting of various collections of organic materials originating from plant and animal residues. Most humic acids are obtained from the extraction of leonardite or lignite materials [4]. Several studies have been conducted showing the potential of humic acid to help improve soil health, especially increasing carbon storage in soils that are poor in organic C levels. [5]. This research aimed to determine the response of Arabica coffee plants to the addition of humic acid and limestone waste to ex-limestone mining soil.

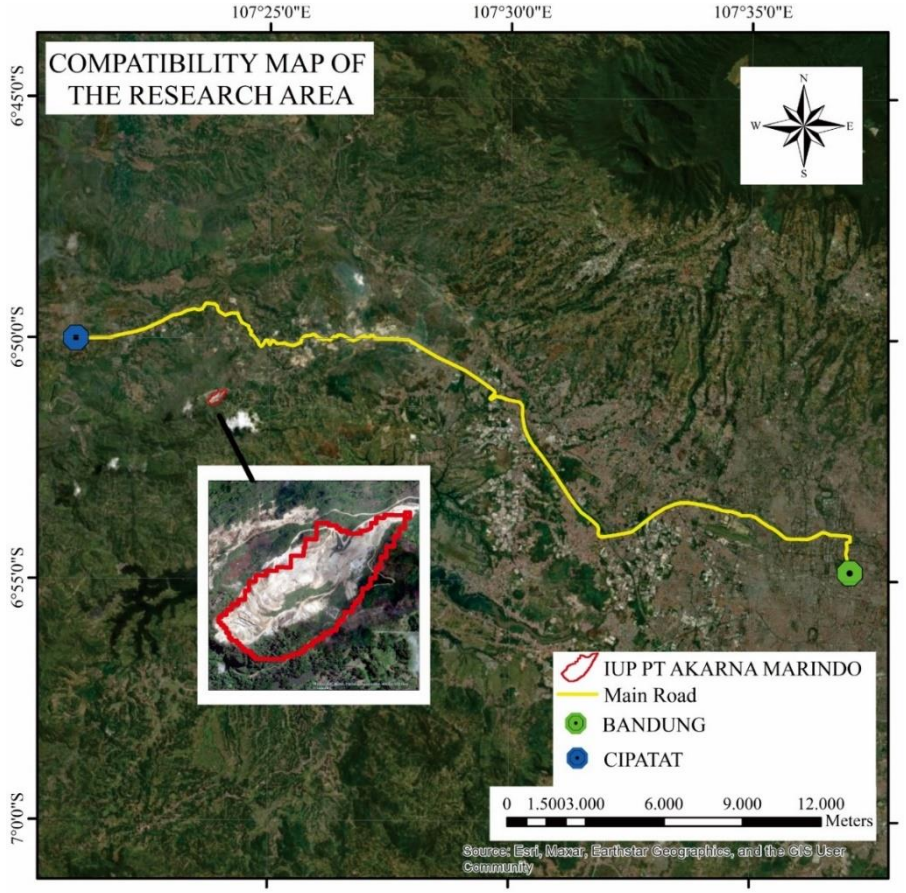

Figure 1. Compatibility map of the research area

2. Methodology

This research uses an experimental design method in soil with the addition of humic acid and limestone waste. Research activities include 4 parts of the design stage starting from the preparation stage then carrying out the experimental stage followed by the observation stage then the data processing stage.

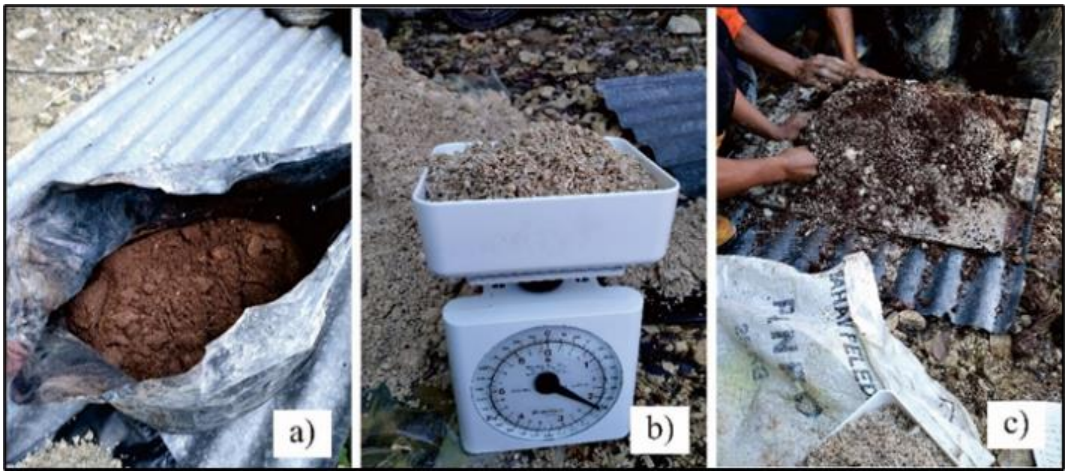

Figure 2. a) 10 kg soil in each polybag, b) Weighing the limestone waste according to the experimental plan (4 kg), c) Mixing the soil with the limestone waste

Figure 3. a) Humic Acid Powder, b) Humic Acid after dilution

2.1. Preparation Stages

This stage is carried out by preparing the tools and materials used for the experiment. The materials used are 2-month-old Arabica coffee seeds, 10 kg soil per polybag, 90% humic acid, limestone waste around the crusher area, and NPK 15-15-15 fertilizer while the tools needed are a hoe and shovel for taking samples of ex-mining soil. The polybags used were 25 x 25 cm in size as experimental planting media, parents were used as shade for Arabica coffee seedlings during the experiment so that they were not directly exposed to heat or rain, and scales were used to measure the weight of the planting media for each experimental polybag according to the treatment, stationery and cameras were used to recapitulating data and documentation during the research process, a ruler was used to measure the height of Arabica coffee seedlings and a caliper to measure the diameter of Arabica coffee seedlings. Apart from that, look for previous research literature, sources from books, journals, and company archives.

2.2. Experimental Stages

Soil samples were taken using the purposive sampling method, which is a way of taking soil samples at locations or points that could represent the research location. Soil samples were taken at a depth of 10 - 30 cm. The limestone waste samples used were leftover limestone resulting from crusher activities that did not meet marketing size criteria. The Arabica coffee seeds used in this research came from the PT Akarna Marindo nursery. The Arabica coffee used is Arabica coffee that has been grown previously and the seeds used are of the same age, which is around 2 months.

This research used a Completely Randomized Factorial Design. This stage was carried out on polybag soil weighing 10 kg each consisting of experiments on soil without mixture (A0L0), soil mixed with 4 kg of limestone waste (A0L4), soil mixed with 5 ml of humic acid and 4 kg of limestone waste. (A5L4), soil with a mixture of 10 ml of humic acid and 4 kg of limestone waste (A10L4) and soil with a mixture of 15 ml of humic acid and 4 kg of limestone waste (A15L4). Each treatment was carried out 3 times. Soil samples were taken around the reclamation area close to the crusher as much as 10 kg which was used as experimental media because it is soil that represents the reclamation area. The soil is taken using a hoe and then the soil is put into a polybag. Soil, limestone waste and humic acid were mixed according to the experimental combination plan then incubated for 2 weeks before being used as a growing medium for Arabica coffee seedlings. Preparation for planting activities is carried out by mixing all the soil planting media consisting of limestone waste and humic acid. Before inserting the planting media and seeds, the polybags are coded according to the treatment to be carried out, then the experimental polybags are placed in the PT. Akarna Marindo nursery area until harvest day.

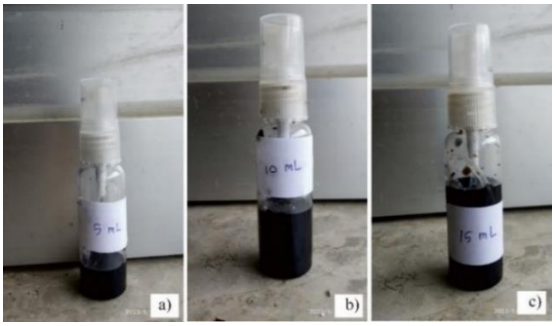

Figure 4. a) Humic Acid 5 ml, b) Humic Acid 10 ml, c) Humic Acid 15 ml

Figure 5. Application of Humic Acid to the treated soil mixture (left), Soil Incubation Activities (right)

2.3. Observation Stages

This stage makes observations and measurements of the height and diameter of the stem of the Arabica coffee plant. Measurements were taken on Arabica coffee seedlings on day 0, day 7, day 14, day 21, day 28, day 35 and day 42 to see changes in seed height and stem diameter of Arabica coffee plants. Height measurements use a ruler and calipers to measure stem diameter.

2.4. Data Processing Stages

The activities carried out at this stage are processing data on the height and diameter of Arabica coffee plants for analysis using Analysis of Variance (ANOVA) and the DMRT test with levels of 5% and 1%. This percentage aims to determine whether or not there is a real influence from the Arabica coffee plant. treatment.

3. Results and discussions

3.1. Time and Location of Research

The research was carried out at the location of the former mining area and nursery area of PT Akarna Marindo, Cipatat Village, West Bandung Regency, West Java Province. Observations and measurements of Arabica coffee seedlings were carried out in the nursery area. This research was conducted in May – July 2023. Astronomically, the research location is at 107° 23' 43.47" - 107° 23' 43.80" E and 6° 51' 18.04" - 6° 51' 18, 67" LS (see Figure 1). The distance traveled to the research location is around 40 km from the center of Bandung City by land using private transportation in the form of two-wheeled vehicles or four-wheeled vehicles. The Bandung City – Cimahi – West Bandung – Cipatat route has a travel time of 1 hour 6 minutes (see Table 1).

3.2. Soil Preparation

The soil used is first cleaned so that the soil is free from wild plants, rocks, and gravel to prevent the presence of lumps of soil which result in the composition of the treatment being inhomogeneous and producing uniform soil. Then the soil is weighed every 10 kg to be put into a polybag, after that the limestone waste is weighed according to the treatment to be mixed with the soil. The limestone waste used 4 kg according to the experimental plan.

Table 1. Experimental Design

No	Treatment	Humic Acid	Limestone Waste
1	A0L0	0 ml	4 kg
2	A0L4	0 ml	4 kg
3	A5L4	5 ml	4 kg
4	A10L4	10 ml	4 kg
5	A15L4	15 ml	4 kg

Table 2. Results of Observation of Height of Arabica Coffee Seedlings

No	Treatment	Average Height of Arabica Coffee Seedlings (cm) Days to-						
		0	7	14	21	28	35	42
1	A0L0	19,63	19,87	20,07	20,57	20,97	21,53	21,87
2	A0L4	19,80	20,43	21,10	22,37	23,37	23,97	24,67
3	A5L4	19,70	20,00	20,60	21,83	22,80	23,40	24,00
4	A10L4	19,23	19,63	20,53	21,60	22,57	23,10	23,60
5	A15L4	20,00	20,63	21,23	22,17	23,50	24,23	24,90

Soil that has been mixed with limestone waste is then added with humic acid according to the dosage. Humic acid is used in powder form where the humic acid needs to be diluted first. When diluting, the dose of humic acid used is 10 grams of humic acid per 1 liter of water. Then 5, 10 and 15 ml of humic acid are taken and poured into a combination of soil and limestone waste.

After being given humic acid, the mixture of soil and limestone waste was incubated with the aim that the soil could adapt to the mixture of humic acid and limestone waste. Soil incubation in a combination of humic acid and limestone waste was carried out for 2 weeks before the soil was used as a growing medium for Arabica coffee.

3.3. Experiment

This study had 5 treatments with 3 replications (Table 1) and there was 1 soil without treatment. The experiment was carried out for 42 days, on the 3rd day NPK fertilizer was added with the same dose of 8 grams and on the 20th day a second NPK fertilizer was added with the same dose of 17 grams. NPK fertilizer functions to provide nutrition for Arabica coffee seedlings, the NPK fertilizer used is NPK 15-15-15 fertilizer. NPK fertilization treatment increases the nutrients available to plants so that they are easily utilized by plants in metabolism which has an impact on increasing growth, in this case plant height [7]. Fertilizing with NPK functions to provide the nutrients needed by plants for growth and development. These three elements are essential macro elements that cannot be replaced by other elements [8]. Among the various nutrients, N is the element most needed because it stimulates cell elongation and vegetative growth [9]. The experiment was carried out on polybag media where changes in seed height and stem diameter of Arabica coffee seedlings were measured on days 0, 7, 14, 21, 28, 35, and 42 (see Table 1).

3.4. Results of Observation of Arabica Coffee Plant Height

The Arabica coffee seedling experiment for 42 days was evaluated in terms of the height of the Arabica coffee seedlings to determine whether there were any changes in the treatment of the soil samples. Observations were made on days 0, 7, 14, 21, 28, 35 and 42. Seedling height was measured using a ruler. There is a high increase every week. It can be seen in Table 2. The results of observing the height of Arabica coffee seedlings received an average value ranging from 19,23 – 24,90 (see Table 2).

Table 3. The effect of using a combination of humic acid and limestone waste on the height response of Arabica coffee seedlings (α level = 5%)

No	Treatment	Average Height of Arabica Coffee Seedlings (cm) Days to-						
		0	7	14	21	28	35	42
1	A0L0	19,63ab	19,87a	20,07a	20,57a	20,97a	21,53a	21,87a
2	A0L4	19,80ab	20,43a	21,10ab	22,37b	23,37b	23,97b	24,67b
3	A5L4	19,70ab	20,00a	20,60ab	21,83b	22,80b	23,40b	24,00b
4	A10L4	19,23a	19,63a	20,53ab	21,60ab	22,57b	23,10b	23,60b
5	A15L4	20,00ab	20,63a	21,23b	22,17b	23,50b	24,23b	24,90b

Table 4. The effect of using a combination of humic acid and limestone waste on the height response of Arabica coffee seedlings (α level = 1%)

No	Treatment	Average Height of Arabica Coffee Seedlings (cm) Days to-						
		0	7	14	21	28	35	42
1	A0L0	19,63a	19,87a	20,07a	20,57a	20,97a	21,53a	21,87a
2	A0L4	19,80a	20,43a	21,10a	22,37b	23,37b	23,97b	24,67ab
3	A5L4	19,70a	20,00a	20,60a	21,83ab	22,80b	23,40b	24,00b
4	A10L4	19,23a	19,63a	20,53a	21,60ab	22,57ab	23,10ab	23,60b
5	A15L4	20,00a	20,63a	21,23a	22,17ab	23,50b	24,23b	24,90b

Table 3 shows that the presence of humic acid and limestone waste has a significant effect on the height of Arabica coffee seedlings. In the DMRT test with a level of α= 5%, it can be seen that humic acid and limestone waste are significantly different on days 0, 14, 21, 28, 35, and 42, while on day 7 humic acid and limestone waste are not significantly different. Humic acid and limestone waste on day 0 of the A10L4 treatment were significantly different from the other treatments. On the 14th day, the highest significant difference was found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4), the A0L4, A5L4, and A10L4 treatments were not significantly different while the A0L0 treatment was significantly different from A15L4. On day 21, the highest significant difference was found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4), the A0L4, A5L4, and A15L4 treatments were not significantly different while the A0L0 and A10L4 treatments were significantly different. On day 28, the highest significant difference was found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4), the A0L4, A5L4, A10L4, A15L4 treatments were not significantly different, whereas the significant difference was in the A0L0 treatment. Meanwhile, on days 35 and 42, the highest difference was found in 15 mL humic acid and 4 kg limestone waste (A15L4), the A0L4, A5L4, A10L4, A15L4 treatments were not significantly different, whereas the A0L0 treatment had a significant difference.

In the DMRT test with a level of α= 1% (Table 4.) it can be seen that there are significant differences between humic acid and limestone waste on days 21, 28, 35, and 42, while on days 0, 7, 14 humic acid and limestone waste not significantly different. Regarding the high response of Arabica coffee seedlings. On the 21st day, the highest significant difference was found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4), the A5L4, A10L4, and A15L4 treatments were not significantly different while the A0L0 and A0L4 treatments were significantly different. On days 28 and 35, the highest significant differences were found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4), the A0L4, A5L4, and A15L4 treatments were not significantly different, while the significant differences were found in the A0L0 and A10L4 treatments. Meanwhile, on day 42, the highest difference was found in 15 mL humic acid and 4 kg limestone waste (A15L4), the A5L4, A10L4, and A15L4 treatments were not significantly different, while the significant differences were found in the A0L0 and A0L4 treatments. Several factors that can influence plant growth are soil pH value, nutrient availability, and growth-inhibiting factors [6].

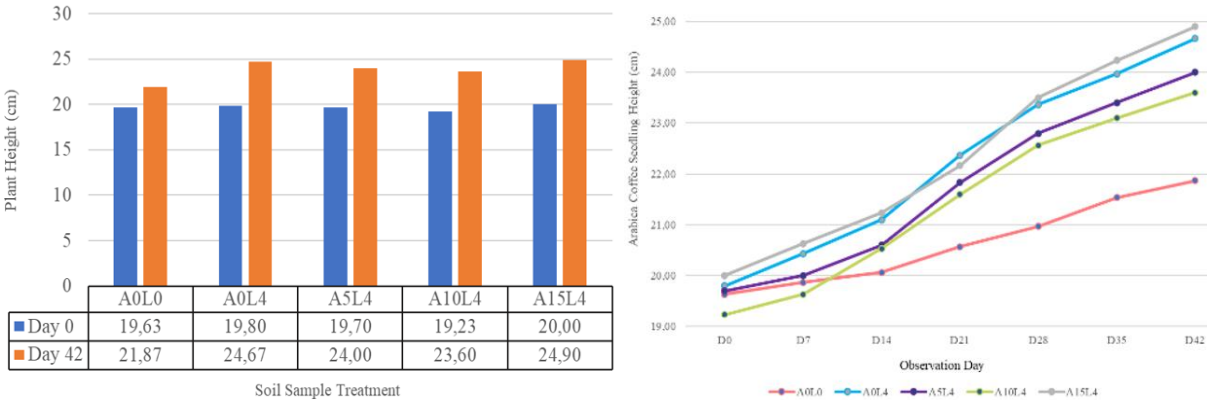

Figure 6. Arabica Coffee Height Bar Chart days 0 and 42 (left), Arabica Coffee Height Graph (right)

Table 5. Results of Observation of Diameter of Arabica Coffee Seedlings

No	Treatment	Average Diameter of Arabica Coffee Seedlings (cm) Days to-						
		0	7	14	21	28	35	42
1	A0L0	2,13	2,17	2,17	2,17	2,20	2,20	2,20
2	A0L4	2,20	2,30	2,33	2,40	2,50	2,50	2,50
3	A5L4	2,20	2,20	2,20	2,37	2,47	2,47	2,47
4	A10L4	2,17	2,33	2,33	2,40	2,50	2,50	2,50
5	A15L4	2,23	2,33	2,33	2,43	2,53	2,53	2,53

Figure 6 shows a graph of days of observation of Arabica coffee stem height. It can be seen that treatment A0L0 (without mixture) shows insignificant growth like other treatments which have a mixture of humic acid, limestone waste and both. The presence of a mixture of humic acid and limestone waste in the A0L4, A5L4, A10L4, A15L4 treatments resulted in stem height growth with a positive correlation, namely a fairly good increase. The highest growth in stem height was found in the A15L4 treatment. Plant growth and production will be high if there are balanced amounts of nutrients in the soil and the growth rate will decrease if the necessary nutrients are not available [10]. Plants will grow well if the nutrients provided are in balanced amounts and according to the plant's needs [11]. The height and low of plant stems is influenced by traits or characteristics that influence the yield of the variety [12]. Variations in plant height that occur between varieties are caused by each genotype having different genetic factors and characteristics [13]. Apart from that, the differences in genetic characters that appear in each genotype are caused by differences in the genes that regulate these characters. Each gene has its own task to be able to grow and regulate various types of characters in an organism's body [14]. Differences in genetic composition are one of the factors causing diversity in plant appearance, in this case plant height. Differences in plant height are determined more by genetic factors [15]. Plant height characteristics are greatly influenced by environmental factors [16]. Environmental conditions in all genotypes receive the same treatment, so that genetic factors play a greater role in differences in plant height. Plant growth and development are influenced by genetic and environmental factors [17].

3.5. Observation Results of Arabica Coffee Plant Diameter

The Arabica coffee seedling experiment for 42 days was evaluated on the aspect of the stem diameter of the Arabica coffee seedlings to determine whether there were any changes in the soil sample treatment. Observations were made on days 0, 7, 14, 21, 28, 35 and 42 (see Table 5). Stem diameter was measured using a caliper. There was an increase in stems every week but it was not significant. It can be seen in Table 5. The results of observing the stem diameter of Arabica coffee seedlings received an average value ranging from 2,07 – 2,60 mm.

Table 6. The effect of using a combination of humic acid and limestone waste on the diameter response of Arabica coffee seedlings (α level = 5%)

No	Treatment	Average Height of Arabica Coffee Seedlings (cm) Days to-						
		0	7	14	21	28	35	42
1	A0L0	2,13a	2,17a	2,17a	2,17a	2,20a	2,20a	2,20a
2	A0L4	2,20a	2,30ab	2,33abc	2,40b	2,50bc	2,50bc	2,50bc
3	A5L4	2,20a	2,20ab	2,20abc	2,37ab	2,47bc	2,47bc	2,47bc
4	A10L4	2,17a	2,33ab	2,33bc	2,40b	2,50bc	2,50bc	2,50bc
5	A15L4	2,23a	2,33ab	2,33c	2,43b	2,53bc	2,53bc	2,53bc

Table 6 shows that the presence of humic acid and limestone waste has a significant effect on the stem diameter of Arabica coffee seedlings. In the DMRT test with a level of α = 5%, it can be seen that there is a significant difference in humic acid on days 7, 14, 21, 28, 35 and 42, while on day 0 humic acid and limestone waste are not significantly different. Humic acid and limestone waste on day 7 had the highest significant difference in the treatment of 15 mL humic acid and 4 kg limestone waste (A15L4), treatments A0L4, A5L4, A10L4 and A15L4 were not significantly different. On the 14th day, the highest significant difference was found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4),

the A0L4 and A5L4 treatments had no significant difference while the A0L0, A10L4 and A15L4 treatments had a significant difference. On day 21, the highest significant difference was found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4), the A0L4, A10L4, A15L4 treatments were not significantly different while the A0L0 and A5L4 treatments were significantly different. On days 28, 35 and 42, the highest significant differences were found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4), the A0L4, A5L4, A10L4, A15L4 treatments were not significantly different, whereas the significant difference was in the A0L0 treatment.

Table 7. The effect of using a combination of humic acid and limestone waste on the diameter response of Arabica coffee seedlings (α level = 1%)

No	Treatment	Average Height of Arabica Coffee Seedlings (cm) Days to-						
		0	7	14	21	28	35	42
1	A0L0	2,13a	2,17a	2,17a	2,17a	2,20a	2,20a	2,20a
2	A0L4	2,20a	2,30a	2,33ab	2,40a	2,50ab	2,50ab	2,50ab
3	A5L4	2,20a	2,20a	2,20ab	2,37a	2,47ab	2,47ab	2,47ab
4	A10L4	2,17a	2,33a	2,33ab	2,40a	2,50ab	2,50ab	2,50ab
5	A15L4	2,23a	2,33a	2,33b	2,43a	2,53b	2,53b	2,53b

In the DMRT test with a level of α= 1% (Table 7) it can be seen that there is a significant difference between humic acid and limestone waste on days 14, 28, 35 and 42, while on days 0, 7 and 21, humic acid and limestone waste are not significantly different. on the response of stem diameter of Arabica coffee seedlings. On the 14th day, the highest significant difference was found in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4). Meanwhile, on days 28, 35, and 42, the highest significant difference was in the 15 mL humic acid treatment and 4 kg limestone waste (A15L4) on the stem diameter of Arabica coffee seedlings, the A0L4, A5L4, A10L4 treatments did not have a significant difference while the A0L0 and A15L4 treatments did. real.

Figure 7 shows a graph of days of observation of Arabica coffee stem diameter. It can be seen that the A0L0 treatment (without mixture) shows no significant growth compared to other treatments which contain a mixture of humic acid, limestone waste, and both. The presence of a mixture of humic acid and limestone waste in the A0L4, A5L4, A10L4, and A15L4 treatments resulted in stem diameter growth with a positive correlation, namely a fairly good increase. On days 28, 35, and 42, the stem diameter growth was relatively the same. The highest growth in stem diameter was found in the A15L4 treatment. One of the factors determining ideal diameter growth is planting distance. Diameter growth is faster in open areas than in shaded areas, which can be seen that plants planted in open areas tend to be short and stocky. has a positive effect on diameter growth [18]. Tight plant spacing allows for competition between plants, namely competition for growing space (canopy competition) for sunlight and competition for nutrients and generally often occurs in fast-growing plants [19].

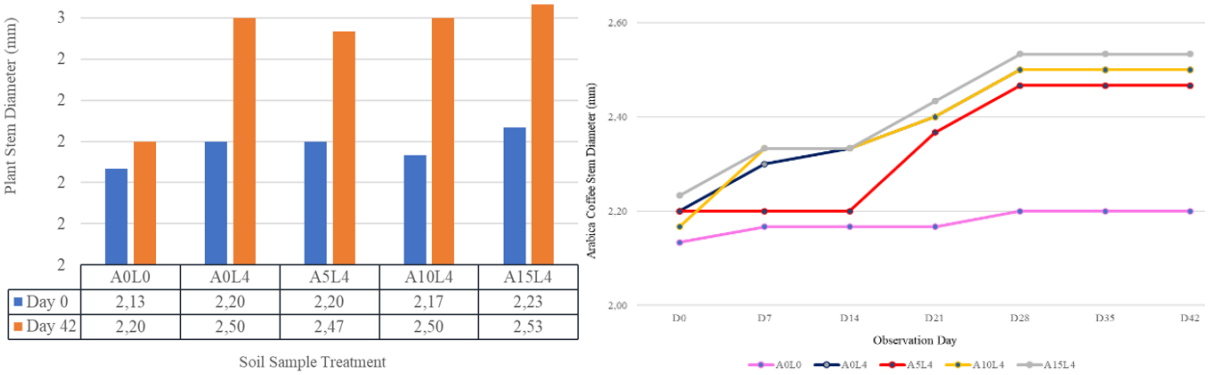

Figure 7. Arabica Coffee Height Bar Chart days 0 and 42 (left), Arabica Coffee Height Graph (right)

4. Conclusion

The results indicate that the treatment combination of 15 mL humic acid and 4 kg limestone waste (A15L4) is the most effective among the tested ratios for promoting the growth of Arabica coffee seedlings. This optimal blend led to notable enhancements in plant development, evidenced by an increase in the average height of the seedlings from 19.23 cm to 24.90 cm, and in the stem diameter from 2.13 mm to 2.53 mm. These findings suggest that A15L4 significantly improves the growth parameters of Arabica coffee seedlings compared to other humic acid and limestone waste mixtures.

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