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Coconut Coir Net Integrated with Tropical Kudzu (*Pueraria phaseoloides*) Seeds for Slope Protection

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ABSTRACT

This study describes the development of tropical kudzu seeds incorporated in the coconut coir net (coconet) twines as a potential improvement in the installation of geonets for slope protection. The performance of the system was determined by installing the net (2x3m) in a sloping (40-45%) plot using a 32 factorial experiment. The three factors are fertilizer (with and without), seed spacing (152x152mm and 305x305mm), and seeding (direct seeding and integrated into the net) with three replications. Response variables were germination rate, vegetation index, and the volume of soil collected. Results showed that the average germination rate ranged from 51% to 84%. The highest germination rate yielded from the treatment with no fertilizer and integrated into the net. The average vegetation index for all treatments was more than 92% for the 12-week duration. Unfortunately, no soil particles were collected due to the low rainfall during the conduct of the study. In the long run, the coconet incorporated with tropical kudzu is found to be a more economical slope protection solution as it will not require regular re-installation as compared to a regular coconet. Furthermore, it is recommended to further study the establishment of tropical kudzu considering a longer period of time and actual slope protection setup.

Keywords: *coconut coir net, tropical kudzu, vegetation index*

INTRODUCTION

Natural fibers and geotextiles were being used in various geotechnical applications such as drainage, reinforcement, slope protection, and heavy metal containment. The Department of Public Works and Highways (DPWH) is turning to cheap, natural solutions to prevent soil erosion that perennially damages roads, drainage systems, bridges, and mountainsides in the upland region, said Edilberto Carabbacan, DPWH Cordillera Director (Caluza, 2012). He said that this simple solution means growing plants and vegetables, hydroseeding, and using coconut fiber nets to hold the slopes. The technology has been tested along the Benguet-Nueva Vizcaya Road in Bokod, Benguet, and the DPWH is replicating it in other provinces (Caluza, 2012). The process starts by spreading coconut fiber nets held in place by bamboo pegs on a specific area where plants will grow. Then, organic mixture and seeds (hydroseeding) are spread in the area to allow plant growth and to act as erosion control (Caluza, 2012). Hydroseeding is being done to establish vegetation to control soil erosion after geotextile degradation. Geotextiles, depending on the material and field conditions, degrade from 6 months to 3 years. In a study by Bhattacharyya et. al, 2010, the life of Borassus mats used as geotextiles was □2 years against only 1 year for Buriti mats. Hence, the use of Borassus mats is highly effective for rain splash erosion control in the UK. Durability studies were carried out on simple Panama weave-type coir geotextiles with an area density of 1390 g/m2 and short-term tensile strength of 22 ± 5 kN/m (machine direction) (Sumia et al, 2018). The biological degradation of the geotextiles was examined by conducting a soil burial test as per IS 1623, 1992. The test soil was prepared by mixing garden soil, cow dung, and sand in a 2:1:1 ratio. The geotextiles were buried in the prepared soil (pH 6.75–6.85) at depths of 25 cm (top layer), 50 cm (middle layer), and 75 cm (bottom layer) inside fiber-reinforced plastic tanks (1.5m×1m×1 m) that were open at the top. The tanks were kept in a field and were subjected to natural weather conditions. The natural geotextile placed in the top layer (up to a depth of 25 cm) of the specially prepared soil suffered a faster rate of biodegradation with a strength loss of nearly 88% after four months. Beyond 4 months, the strength of natural geotextile in the top layer was too low and hence not measurable (Sumia et al, 2018).

Among the various lignocellulosic fibers, coconut coir has the highest lignin content (Rajan et al., 2005). This accounts for the high rigidity, strength retention, and resistance to microbial degradation of coconut coir geotextiles in comparison with other natural geotextiles. Specific characteristics such as drapability and the ability to withstand sudden shock make coconut coir geotextiles a better choice over other natural geotextiles in erosion control and slope protection applications (Pritchard et al., 2000). Coconut coir has a tendency to absorb moisture due to its rough texture with numerous fine pores on the surface. The moisture absorption capacity of coconut coir further increases with the further degradation of geotextile (Vishnudas et al., 2012). Moisture penetrates through the fine pores and cracks on the fiber surface and causes the fiber to swell. This weakens the cell wall and allows microbial attack under ambient pH, temperature, and nutrient conditions. Based on earlier reports of various field studies carried out across the world, natural geotextiles including coir geotextiles have been found to lose tensile strength over time. The tensile strength of coconut coir geotextiles has been reported to drop by nearly 80% of its original value in the first year of installation under tropical climatic conditions (Lekha, 2004; Marques et al., 2014). Coco fiber may be used as a medium for plants to grow, while the soil is gradually restoring the nutrients for the plants – thereby, preventing nutrient deficiency which may lead to the poor growth and low-rate survival of plants most especially in eroded soil.

Tropical kudzu has a biomass generation of 4 to 5 tons per Ha per annum. It is a cover crop predominantly used in coffee, oil palm, citrus, and rubber plantations. In addition, it is a vigorous twine and creeper that can be marketed as seeds and cuttings (Heuzé et al, 2016). Tropical kudzu (Pueraria phaseoloides) is a fast-growing, very popular leguminous creeper and climber that has shallow roots with plenty of root nodules and fixes over 100 kg of Nitrogen per Ha per annum. It grows around 3 to 4 months. It lies in its quick growth and in its ability to cover land areas in the first year of sowing. Since it's a fast-growing crop, tropical kudzu was used primarily because its roots can move up to 2 meters and can cover the soil. It may be grown in areas with either hot or cold weather conditions and is also typically resistant to diseases. Tropical kudzu can also be used as forage material. A study conducted in Trinidad and Tobago concluded that open un-utilized grasslands produced a significant amount of P. phaseoloides herbage year -round to support ruminant livestock production (Leon, et al, 2023). However, the nutritive value, herbage mass, and crude protein yield of P. phaseoloides herbage were highest during the late wet and early dry seasons (Leon, et al, 2023).

However, hydroseeding after geotextile (like coconet) installation entails additional costs for slope protection setup. Also, in case the plants used during hydroseeding did not grow and the coconet decayed (degraded) after around two (2) years, re-installation of the coconet will be needed. Thus, this study aimed to determine the viability of incorporating tropical kudzu seeds into the coconet twines for slope protection. The proposed study may reduce the cost of the installation of the coconet by removing the hydroseeding process as well as reinstallation after coconet decay.

METHODOLOGY

Experimental Setup

The performance of the coconet incorporated with tropical kudzu seeds was tested using a 32 complete factorial design experiment as indicated in **Table 1.** The three (3) factors considered in the factorial design experiment were fertilizer (A), seed spacing (B), and seeding (C) with two (2) levels and three (3) replications. The levels include: a) seeds with and without fertilizer; b) seeds spacing of 152x152mm (247 seeds) and 305x305mm (123 seeds); and c) direct seed to soil and seed integrated into the net mesh. The fertilizer used in the experiment was NitroPlus, a seed inoculant for legumes composed of bacteria called rhizobia in a solid-based carrier of soil and charcoal. It was obtained from BIOTECH-UPLB. Its properties are equal to 30 kg N/ha that can substitute chemical nitrogen fertilizer at a reduced cost. Meanwhile, the tropical kudzu seeds were obtained from Magpantay Cover Crop Buyer, Maharlika Highway, Sipocot, Camarines Sur. The tropical kudzu seed has dimensions of 3-5 mm length x 2-3 mm width x 1-2mm thickness. The seeds were coated with fertilizer by approximately 1-2 mm in thickness. The coconet used in this study was manually produced by the Bonaobra Family of Barangay Villa Bota, Gumaca, Quezon. The ropes were interlaced at a right angle with 50.8mm apart to complete the total length of 3,048mm and width of 2,032mm. A two-ply rope with tropical kudzu seeds was established from manual twining. **Figure 1** shows the schematic diagram to produce coconet with tropical kudzu.

Table 1. The eight (8) treatments used in the experimental design.

TREATMENT NUMBER	TREATMENT DESCRIPTIONS
1	no fertilizer, seeds spacing 152x152mm, seeds were directly planted to soil
2	seeds coated w/ fertilizer, seeds spacing 152x152mm, seeds were directly planted to soil
3	no fertilizer, seeds spacing 305x305mm, seeds were directly planted to soil
4	seeds coated w/ fertilizer, seeds spacing 305x305mm, seeds were directly planted to soil
5	no fertilizer, seeds spacing 152x152mm, seeds were integrated to net mesh
6	seeds coated w/ fertilizer, seeds spacing 152x152mm, seeds were integrated to net mesh
7	no fertilizer, seeds spacing 305x305mm, seeds were integrated to net mesh
8	seeds coated w/ fertilizer, seeds spacing 305x305mm, seeds were integrated to net mesh

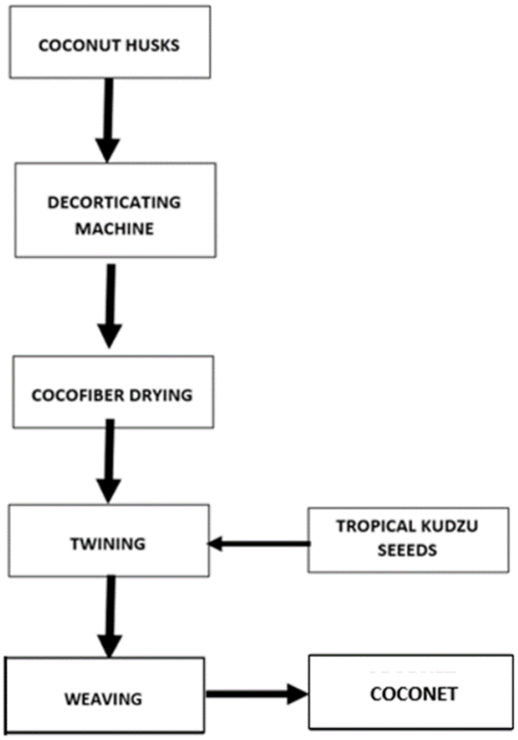


Figure 1. Coconut Coir Net Plus production process

Experimental Site

The Irrigation Side of Barangay Cahabaan, Talisay, Camarines Norte, which is part of the Main Canal of the Daet-Talisay River Irrigation System, was selected as the site for the conduct of the experiment (**Figure 2**). The site has a 40 to 45% slope and 3.8 to 5.3 meters slope length which was a suitable site for the experiment based on the guidelines from the Department of Public Works and Highways (DPWH, DO no. 29 series of 2008). It specified that the coconet should be in an area with less than 60% slope. Coconet was not advised for use in areas with more than 60% slope as it would require a permanent structure to hold the soil against erosion. The study site was only 6 kilometers away from the PAGASA Agrometeorology Station of Daet, Camarines Norte.

Installation of Coconet with Tropical Kudzu

The coconet experimental treatments (24 sets) were randomly installed in the experimental site (**Figure 3**). The dimension of the coconet was 2x3 m, with a 2.5x2.5 cm net eye and 5mm twine diameter. Sharp materials in the study site were first removed from the surface of the slope. This was to maintain primary slope stabilization measures and to avoid instances of tearing. Then, the first coconet roll was anchored at a distance of 1m from the top edge of the slope through a live stake (e.g. bamboo, other wood variety, etc). After that, it was rolled down through the slope and adjusted to the desired alignment on the slope face. The nets were laid loosely, not stretched. The stakes, with a dimension of 5 to 15 cm in diameter and 50 to 100 cm in length, were then fastened to the slope face. About three pegs were required per square meter of coconet to ensure its proper installation to the slope face. The nets were anchored in a perpendicular position to the slope face. Finally, the next roll was

Figure 2. Selected experimental site for coconut coir net plus testing
Photo taken from Google Map, 4/15/2020

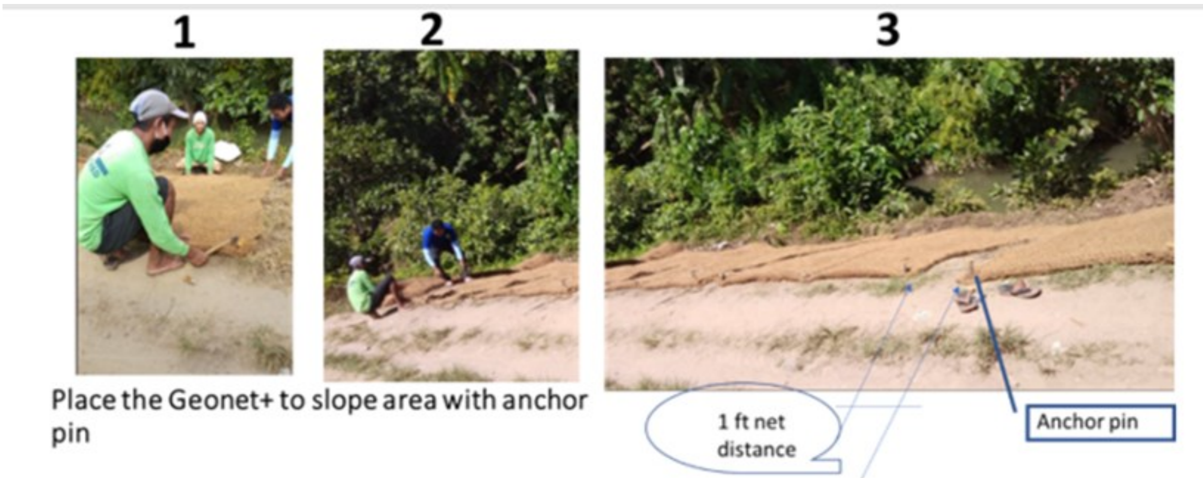


Figure 3. Installation of the Coconut Coir Net Plus

Figure 4. Experimental setup of the Coconut Coir Net Plus

anchored at the top of the slope with sufficient overlap. Two adjacent nets were then sewn using coco coir rope. The whole experimental setup is presented in **Figure 4.**

Data Collection and Analysis

The germination rate, vegetation index, and soil loss were measured weekly on each of the 24 experimental plots. The experiments lasted for twelve (12) weeks from June to September 2020. The germination rate was computed as the number of seeds germinated over the number of seeds planted multiplied by 100 (expressed in percentage, %). The Canopeo app as shown in **Figure 5** was used to determine the quantity of vegetation index (canopy cover) for the live vegetation of the crop. With just a photograph, the app can assist in tracking the progress of the vegetation index. It can also determine the intensity of crop destruction that may occur from unfavorable weather conditions. Each image was carefully tagged for proper documentation.

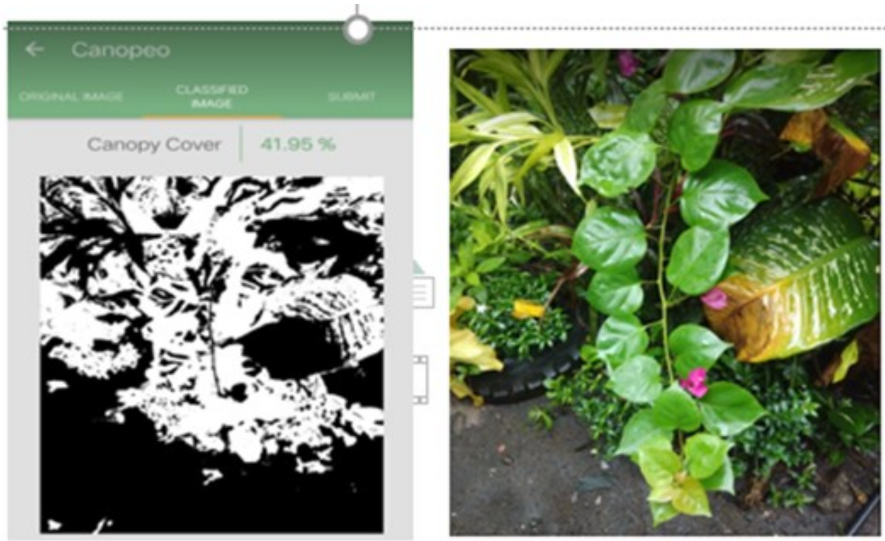


Figure 5. Canopeo Apps interface trial

Analysis of Variance (ANOVA) was carried out using Statistical Tools for Agricultural Research (STAR, Trial version design expert v 8.0.6) to determine the significant effects of the three factors on the germination and vegetative index of the tropical kudzu at a 95% level of significance. The mean comparison was done using Tukey's Honest Significant Difference (HSD). A simple cost computation from the utilization of coconet was made to gauge how it would turn out for possible end users in financial terms.

RESULTS AND DISCUSSION

Germination Rate of Tropical Kudzu

The average germination rate of the eight (8) treatments is shown in **Figure 6.** The lowest average germination rate observed was about 51% with the treatment: no fertilizer, seeds spacing 305x305mm, and seeds were directly planted into the soil. The highest average germination rate observed was about 84% with the treatment: with fertilizer, seeds spacing 305x305mm, seeds were integrated into a net mesh. The differences in germination rate were expected since the exposure of seeds to the environment where the hydration occurs that triggers the emergence is not constant. It is important to note that the highest germination rate was observed on the setup with no fertilizer.

On the other hand, the treatments with the seeds integrated into the net mesh (Nos. 5 to 8, **Figure 6**) have relatively higher average germination rates. The average germination rates were within the average obtained during the preliminary controlled trial, which is 70%. The higher germination rate of the treatments with the seeds integrated into the net mesh was due to the capacity of coconut coir to absorb moisture. As presented in **Figure 7**, rainfall was almost distributed from the 2nd week to the 4th week of June 2021. Moreover, due to low rainfall amount and intensity, no soil particles were observed in the soil collector during the whole duration of the experiment. Only four (4) high rainfall events could be observed during the conduct of the study (**Figure 7**).

Using the software STAR, only fertilizer application is affected by the germination rate (**Table 2**). Using Tukey's HSD, the mean differences among fertilizer treatments were also significant (**Table 3**). Although

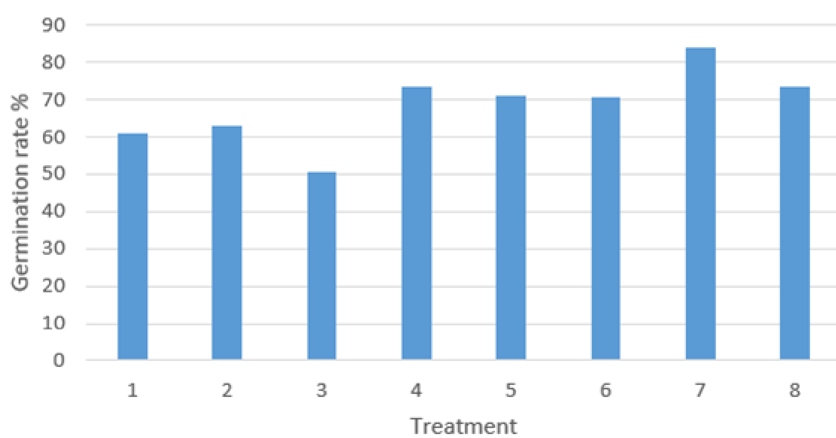
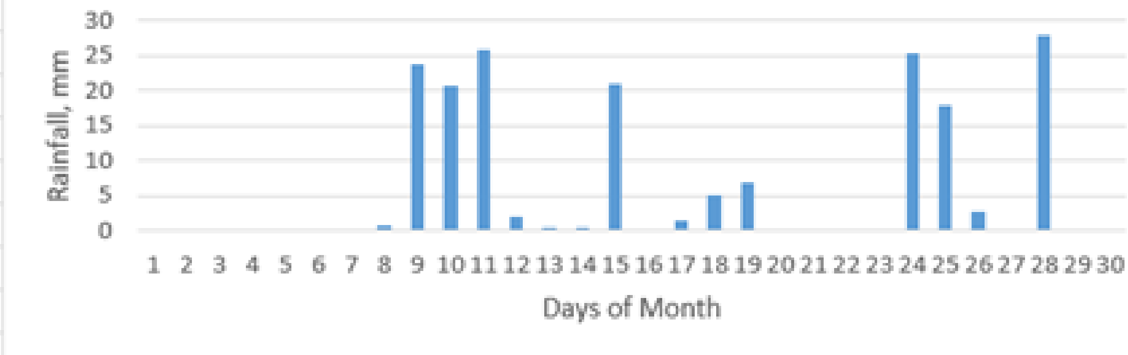
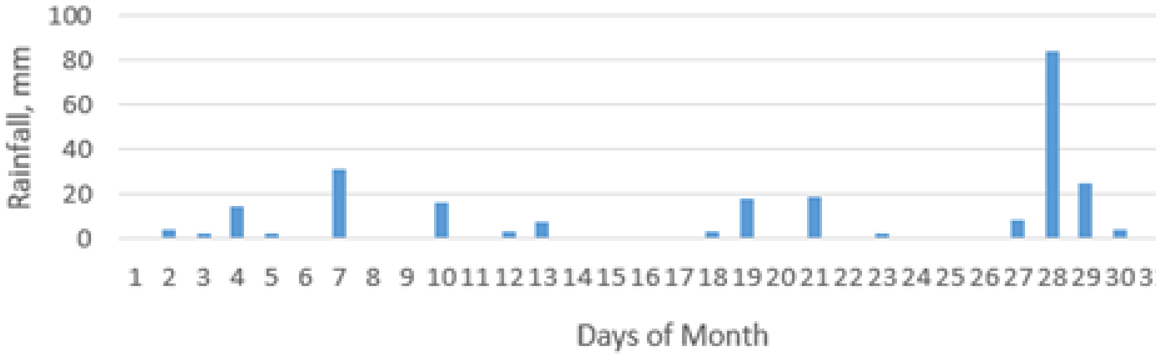


Figure 6. Average germination rate of Tropical Kudzu seeds in Coconut Wire Coir Net

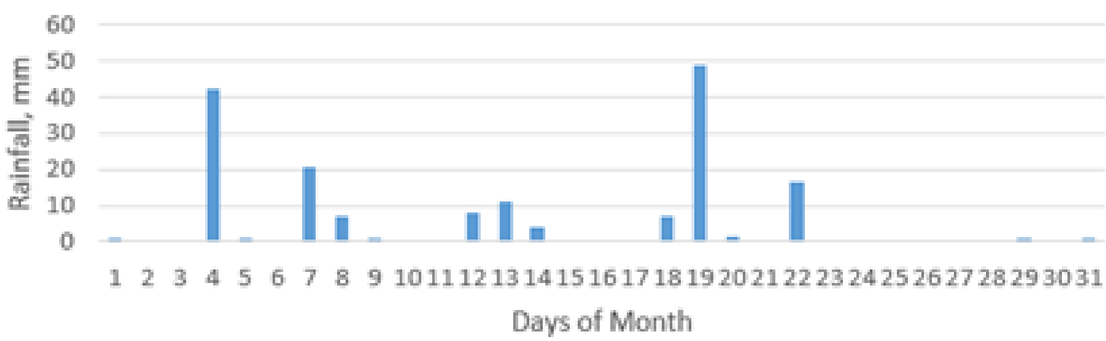
(a) June 2020
ave:6.05mm;
total:181.6mm



(b) July 2020
ave:8.0mm;
total:250mm



(c) August 2020
ave:5.73mm;
total:172.1mm



(d) September 2020
ave:5.19mm;
total: 155.7mm

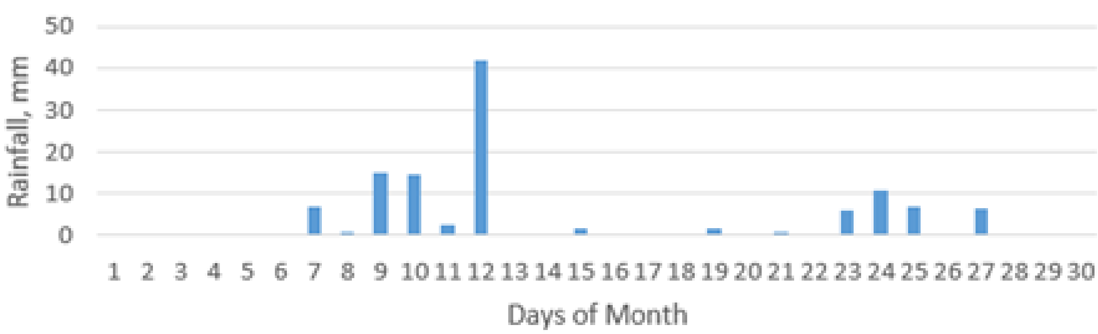


Figure 7. Rainfall data in Camarines Norte from June 2020 to September 2020

fertilizer (nutrient content) directly affects germination rate, the addition of fertilizer is very important in soil erosion control. Soil erosion control system is usually installed in locations wherein the nutrient-laden topsoil is eroded.

Vegetation Index

It can be observed in **Figure 8** that the average vegetation index of tropical kudzu was around 92% at the end of the 12-week duration. Sample progress images from each treatment are shown in **Figures 9 to 16.** Also, relatively higher vegetation index was observed even with treatments at lower than 70% germination rate (**Figure 8**). All of the vegetation index with seeds integrated into the mesh started peaking at Week 6. This could be due to the moisture absorbed by the net mesh during the rainfall events from Weeks 2 to 5.

It can be observed in **Figure 8** that the average vegetation index of tropical kudzu was around 92% at the end of the 12-week duration. Sample progress images from each treatment are shown in Figures 9 to 16. Also, a relatively higher vegetation index was observed even with treatments at a lower than 70% germination rate (**Figure 8**). All of the vegetation index with seeds integrated into the mesh started peaking at Week 6. This could be due to the moisture absorbed by the net mesh during the rainfall events from Weeks 2 to 5.

Table 2. Results of ANOVA for germination rate.

SOURCE	DF	SS	MS	F-value	Pr (>F)
Fertilizer	1	11283.1393	11283.1393	259.66	0.00
Seeds Integrated	1	45.4851	45.4851	1.05	0.3215
Seed Spacings	1	0.0171	0.0171	0.00	0.9844
Fertilizer x Seeds Integrated	1	506.1853	506.1853	11.65	0.0036
Fertilizer x Seed Spacings	1	1.8407	1.8404	0.04	0.8383
Seeds Integrated x Seed Spacings	1	0.7350	0.7350	0.02	0.8981
Fertilizer x Seeds Integrated x Seed Spacings	1	21.4704	21.4704	0.49	0.9242
Error	16	695.2627	43.4539		
Total	23	12554.1653			

Table 3. Results of ANOVA for germination rate.

Response Variable: Germination
Comparison of Fertilizer at each level of Seeds Integrated
Tukey's Honest Significant Difference (HSD) Test

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	43.4539
Critical Value	2.9980
Test Statistics	8.0681

Summary

Fertilizer	N	Seeds. Integrated = S1 group	Seeds. Integrated = S2 group
A1	6	41.9750 b	35.5433 b
A2	6	76.1550 a	88.0933 a

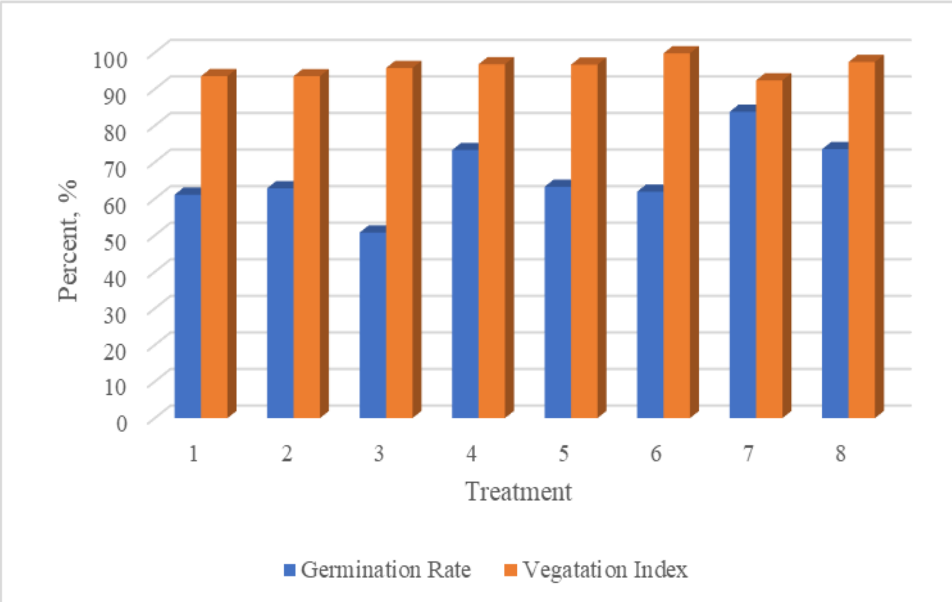


Figure 8. Average germination rate and vegetation index of Tropical Kudzu seeds in Coconut Wire Coir Net

Even though the germination rate observed ranges from 51% to 84% (**Tables 7 and 8**), tropical kudzu provides additional cover (more than 92% vegetation index) for the coconet installed. This has proven the fast-growing and creeper characteristics of tropical kudzu. Furthermore, this could provide the possible soil erosion control properties of tropical kudzu as soil cover. Vegetation acts as a protective layer or buffer between the atmosphere and the soil. The aboveground components, such as leaves and stems, absorb some of the energy of falling raindrops, running water, and wind, so that less is directed at the soil, while the below-ground components, comprising the root system, contribute to the mechanical strength of the soil (Morgan, 2005).

The STAR software showed that only the fertilizer application affects the vegetation index as presented in Table 4. Using Tukey's HSD, the mean differences among fertilizer treatments were also significant (**Table 5**). It is common knowledge that fertilizer (nutrient content) directly affects the vegetation index.

Simple Cost Analysis

Simple cost analysis was done for the two systems: coconet and coconet with tropical kudzu. The project cost estimate for the installation of the coconet is about Php 750,000 per hectare (**Table 6**). Additional PhP 32,900.00 in the total cost (**Table 7**) of each system includes the expenditures on the seeds, fertilizer, and additional labor for incorporating the seeds into the twine. Treatment no. 5 (152x152mm spacing, seeds coated with fertilizer and integrated to net) was used in the computations. According to Engr. Dave Rieza of Barangay Malacbang, Paracale, Camarines Norte (personal communication, July 28, 2020), a new set of coconets shall be installed again after two (2) years. This puts the possible users of coconet with tropical kudzu in a long-term economic advantage as it does not require reinstallation after 2 years as compared to a regular coconet. A stability of about three (3) years was observed for geotextile products, which were based on uncoated coir fibers and exposed to UK highland conditions (Ghosh et al., 2009). On the other hand, comparing the cost of hydroseeding, the incorporation of tropical kudzu would be way much cheaper. In a DPWH program of works in Zamboanga del Sur, the estimated cost of hydroseeding was around PHP 271.49 (DPWH, 2017). In a one (1) hectare hydroseeding activity, this would cost around PHP 2,714,900.

CONCLUSION AND RECOMMENDATION

Even though the germination rate observed ranges from 51% to 84%, tropical kudzu provides additional cover (more than 92% vegetation index) for the coconet installed. This has proven the fast-growing and creeper characteristics of tropical kudzu. Furthermore, this could provide the possible soil erosion control properties of tropical kudzu as soil cover (vegetative cover). Soil erosion protection would still be possible after coconet decay. Comparing the cost of hydroseeding with the incorporation of tropical kudzu, the latter would be

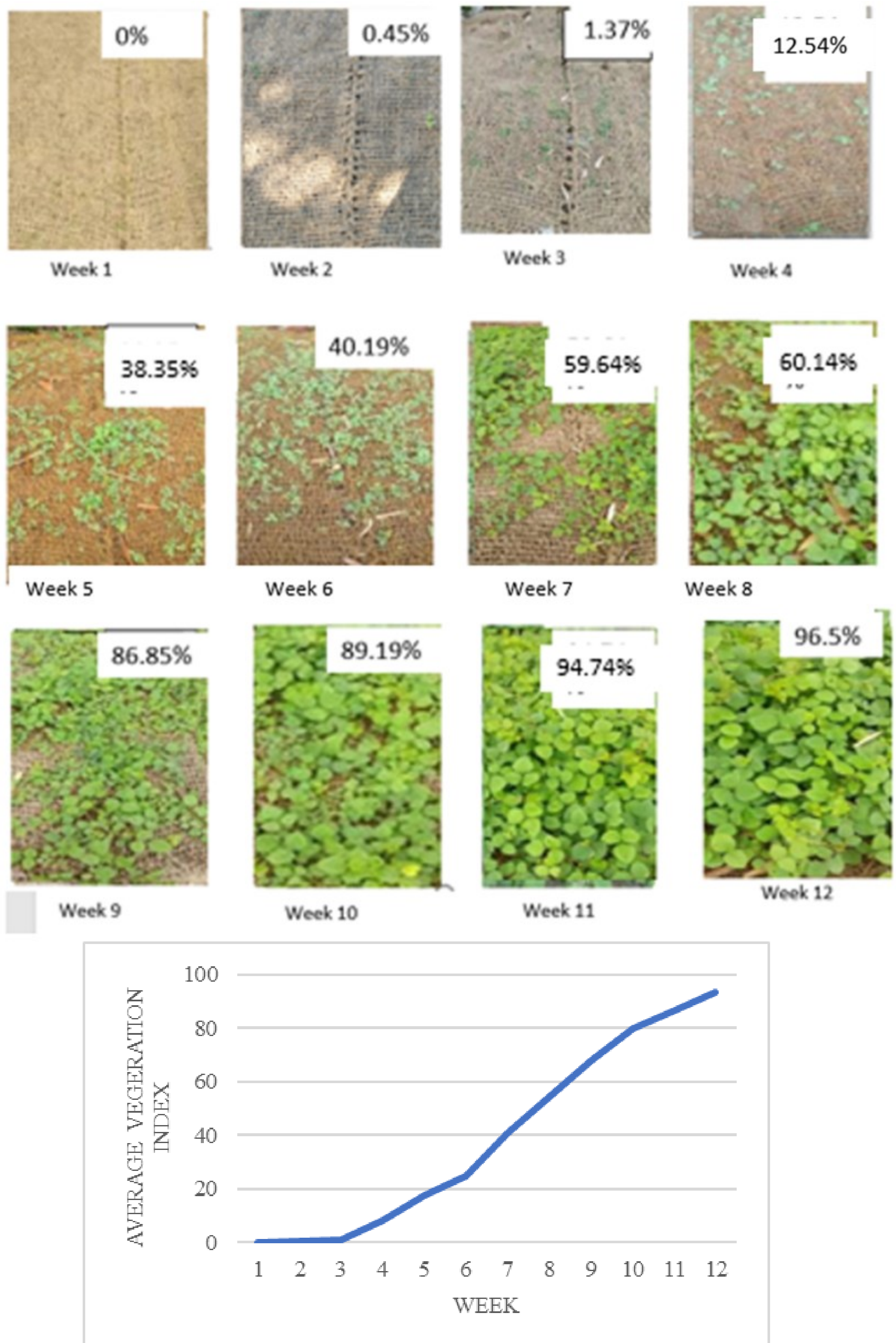


Figure 9. Vegetation index and germination rate of Tropical Kudzu with no fertilizer, 152x152mm spacing, and directly planted (Replication 3), germination rate: 73.68%

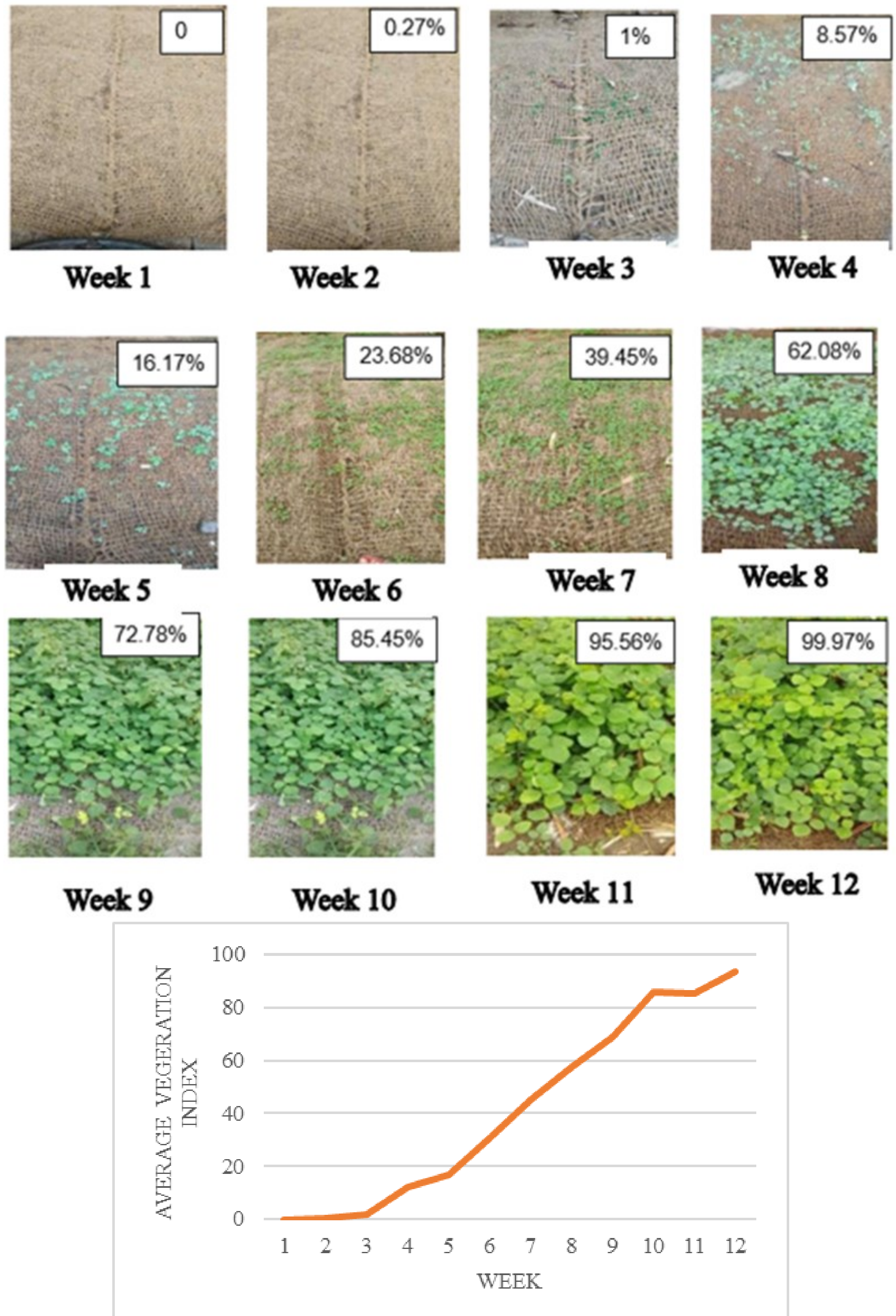


Figure 10. Vegetation index and germination rate of Tropical Kudzu with fertilizer, 152x152mm spacing, and directly planted (Replication 1), germination rate: 70%

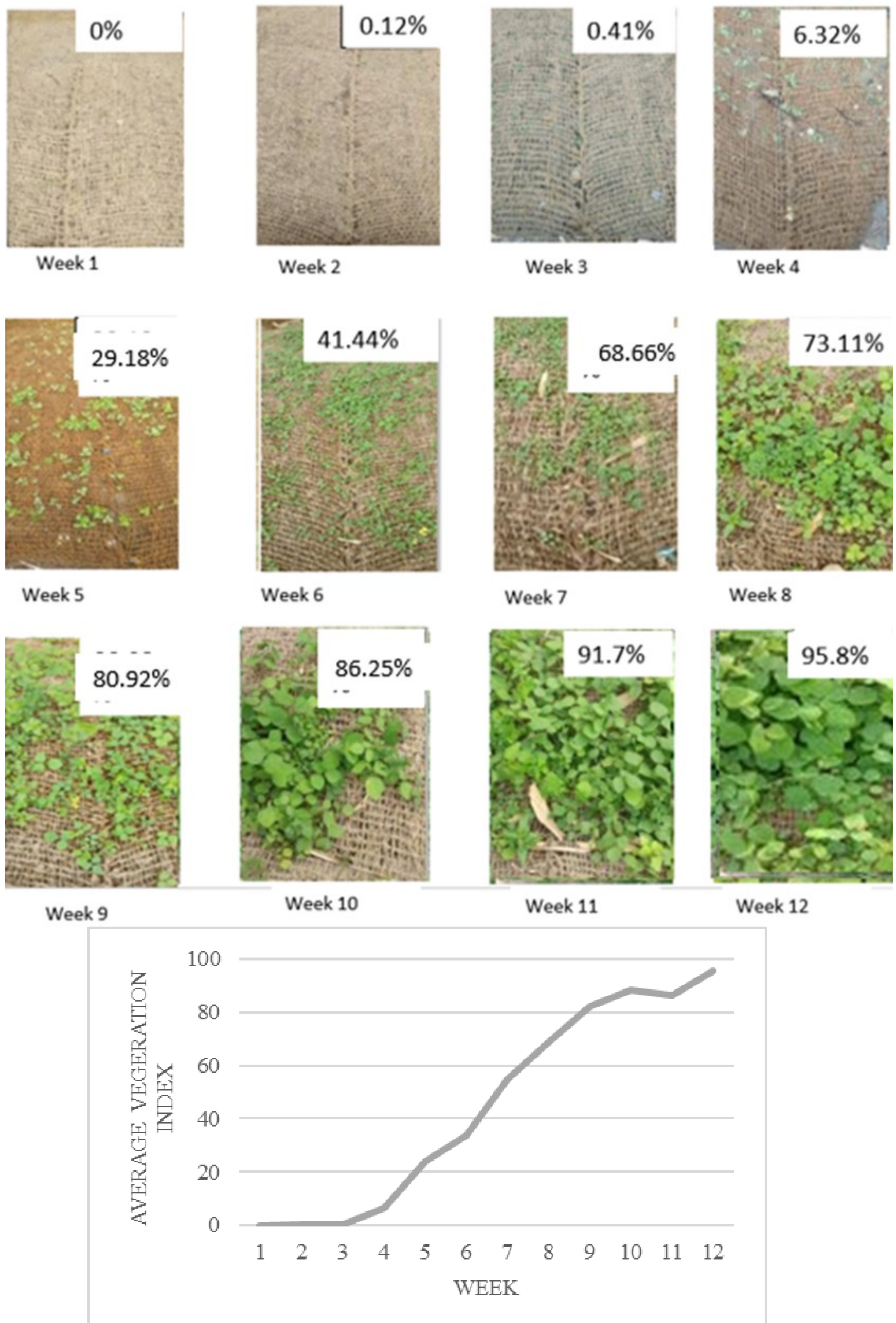


Figure 11. Vegetation index and germination rate of Tropical Kudzu with no fertilizer, 305x305mm spacing, and directly planted (Replication 3), germination rate: 85.71%

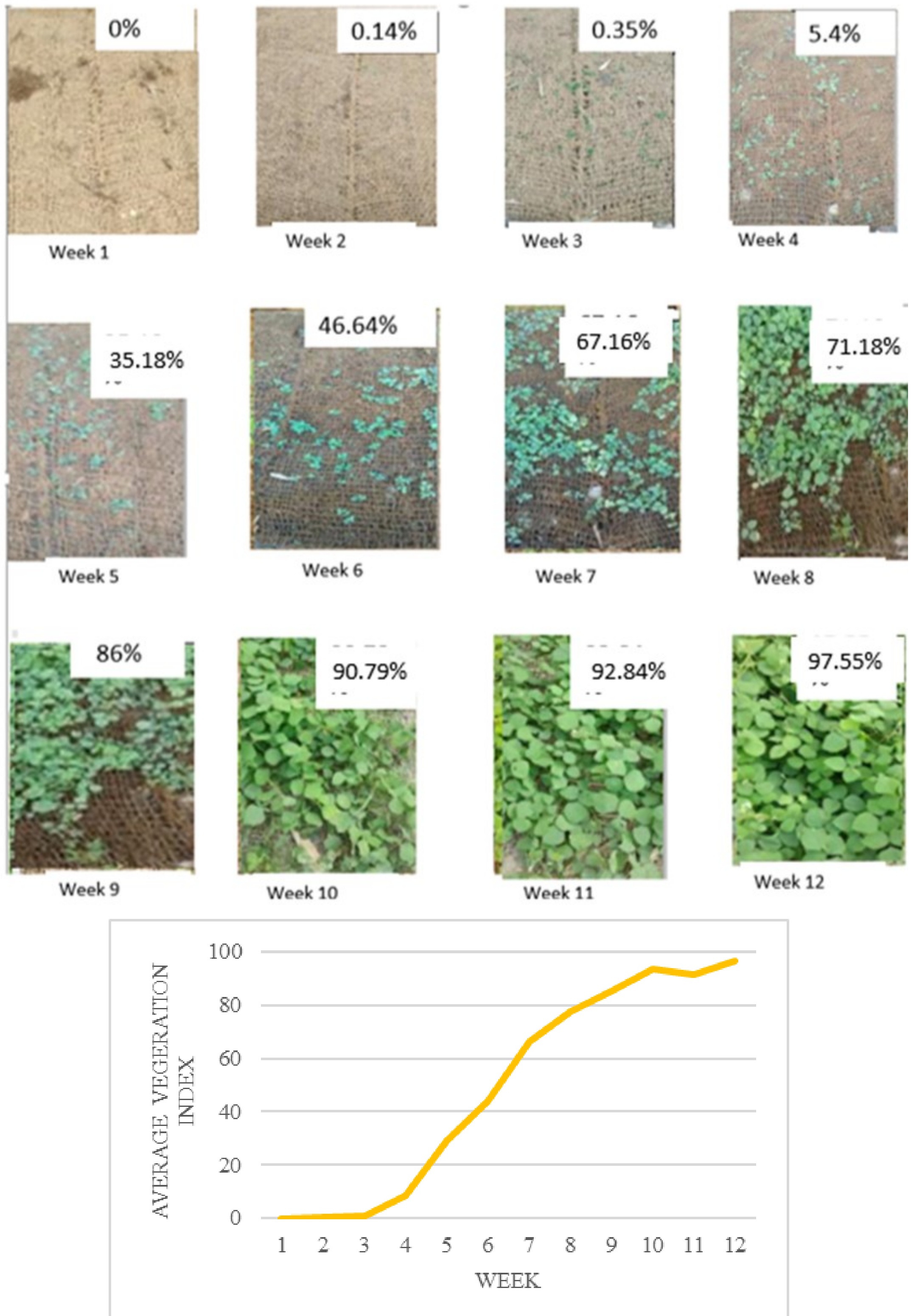


Figure 12. Vegetation index and germination rate of Tropical Kudzu with fertilizer, 305x305mm spacing, and directly planted (Replication 3), germination rate: 78.57%

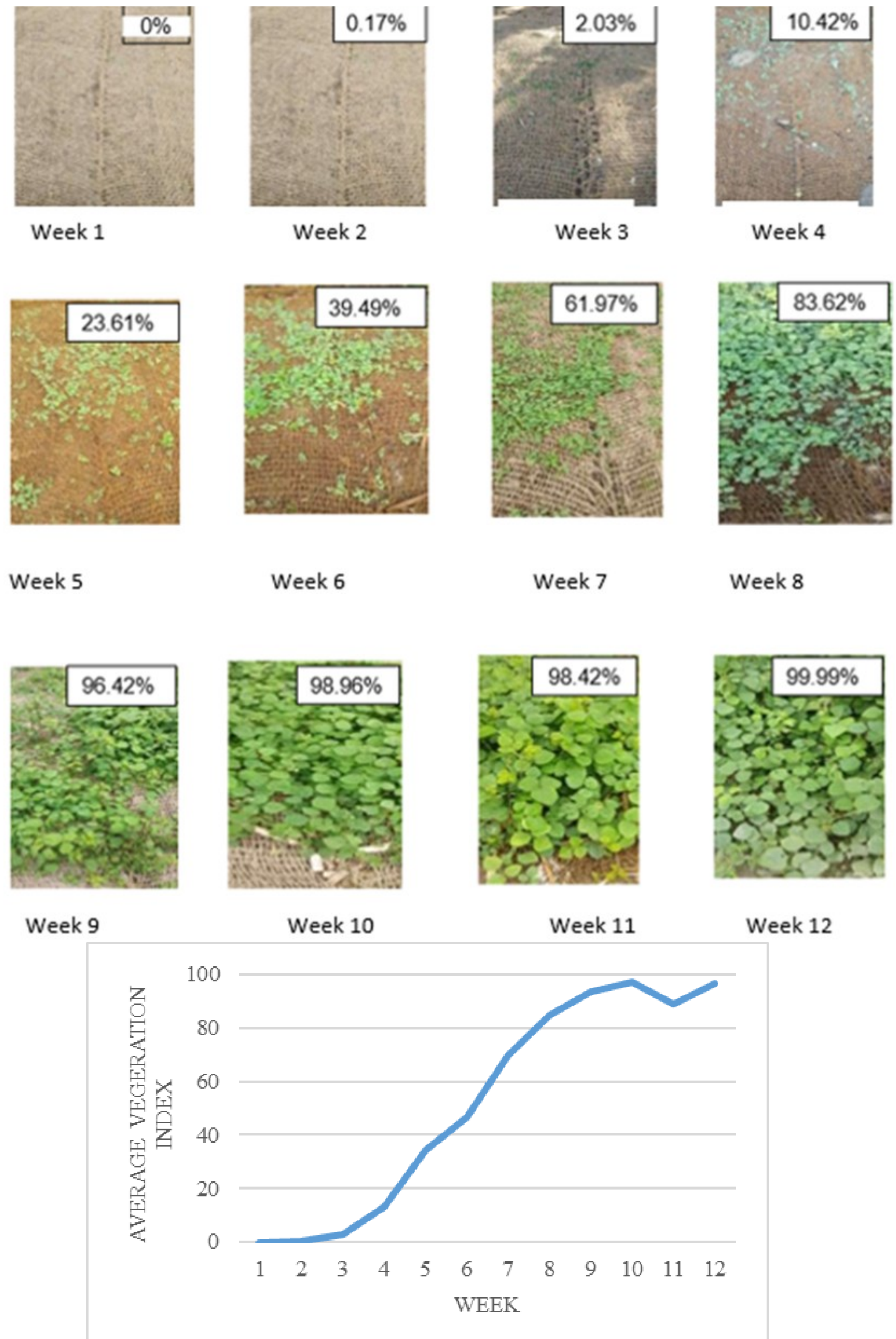


Figure 13. Vegetation index and germination rate of Tropical Kudzu with no fertilizer, 152x152mm spacing, and integrated (Replication 1), germination rate: 93.52%

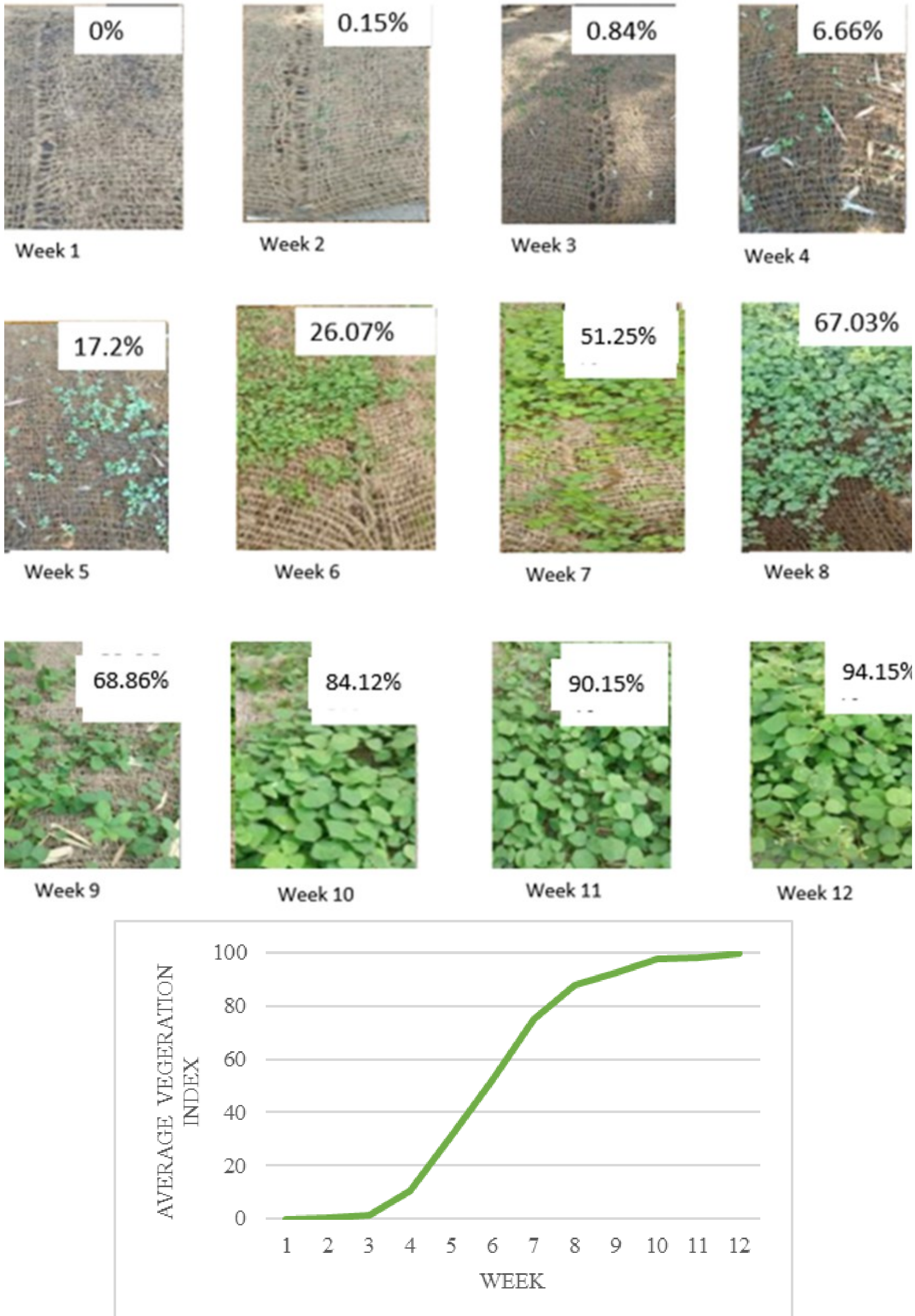


Figure 14. Vegetation index and germination rate of Tropical Kudzu with fertilizer, 152x152mm spacing, and integrated (Replication 2), germination rate: 37.65%

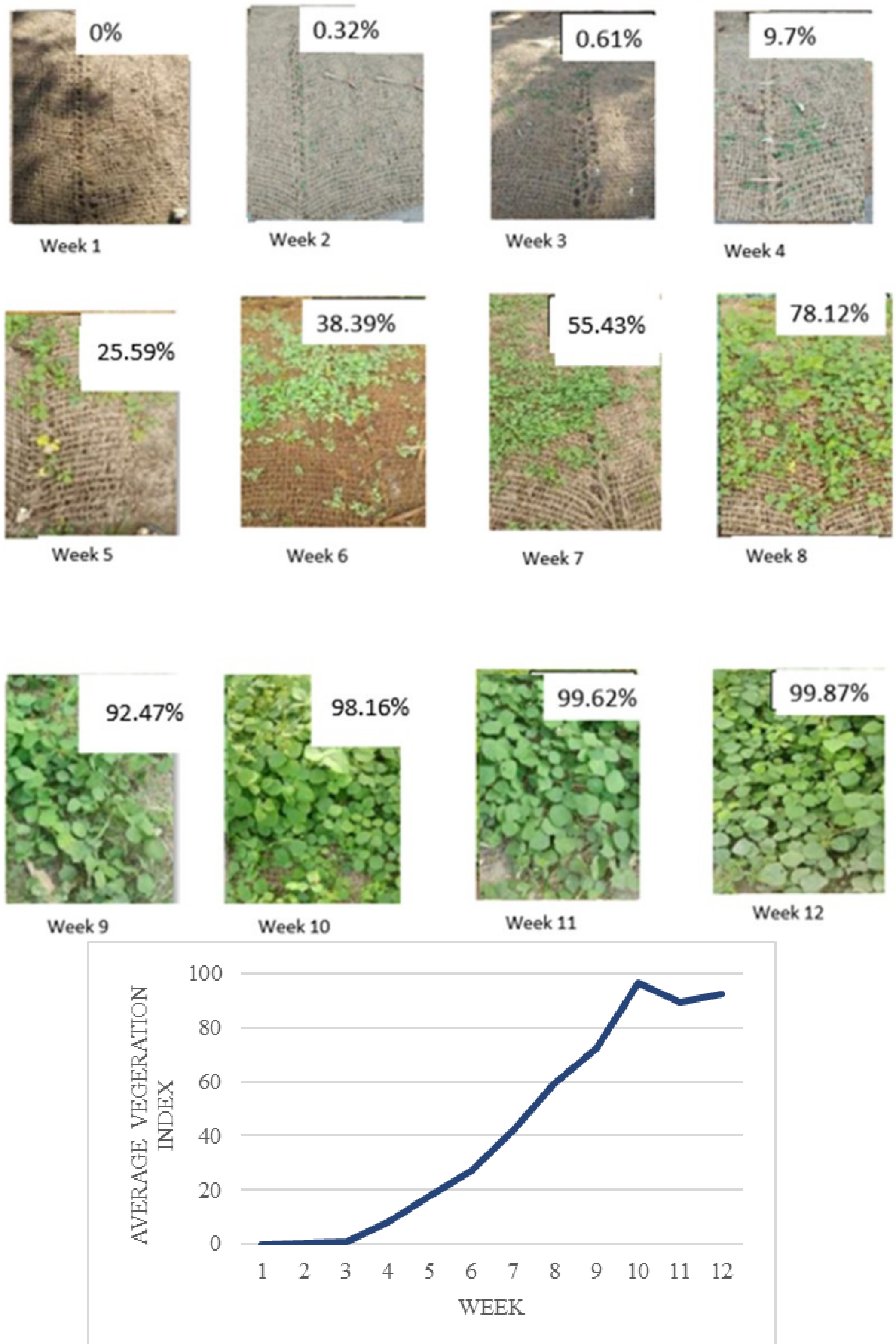


Figure 15. Vegetation index and germination rate of Tropical Kudzu with no fertilizer, 305x305mm spacing, and integrated (Replication 3), germination rate: 87.14%

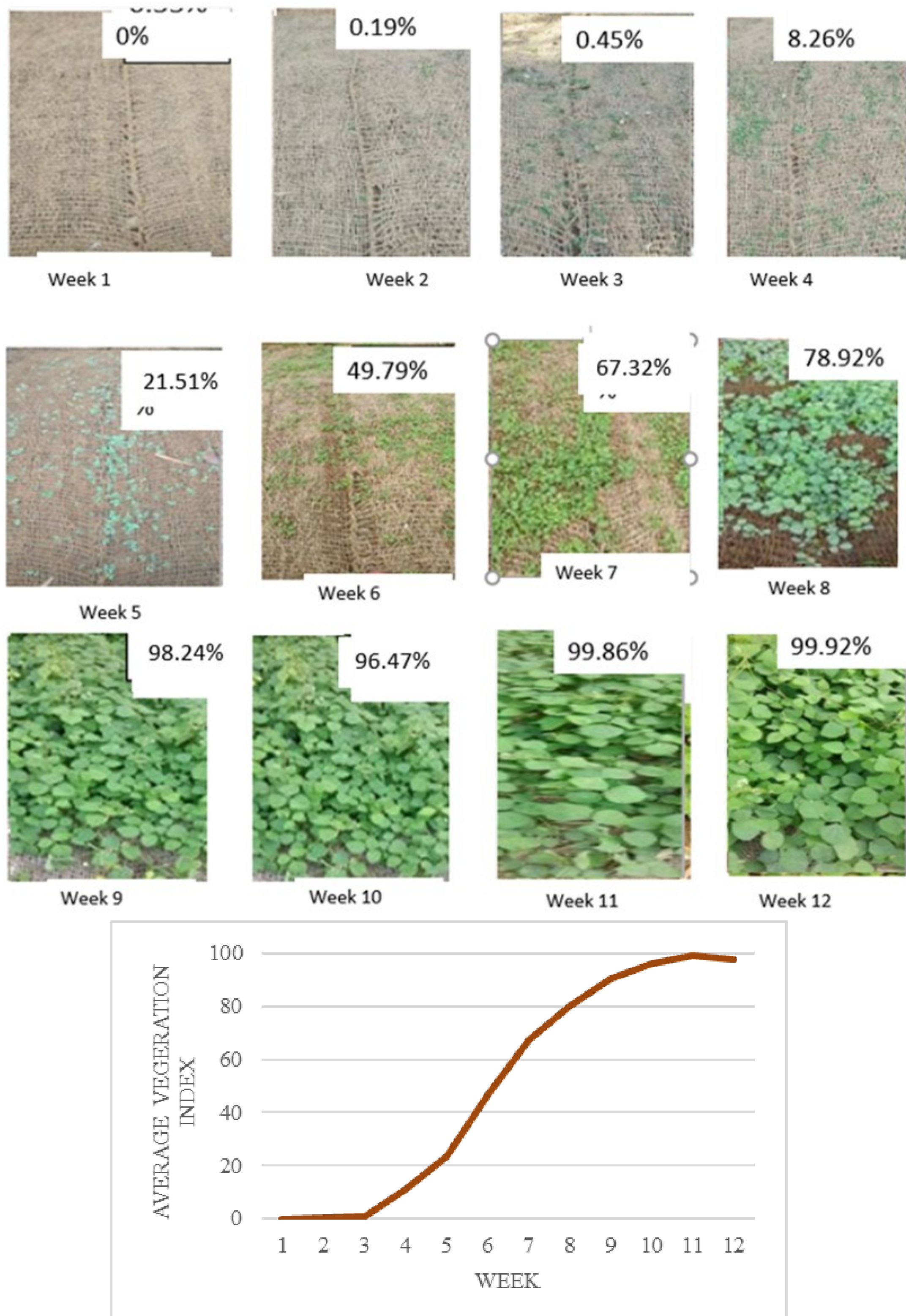


Figure 16. Vegetation index and germination rate of Tropical Kudzu with fertilizer, 305x305mm spacing, and integrated (Replication 3), germination rate: 97.14%

Table 4. Results of ANOVA for vegetation index

SOURCE	DF	SS	MS	F-value	Pr (>F)
Fertilizer	1	539.0328	539.0328	11.87	0.0033
Seeds Integrated	1	37.8006	37.8006	0.83	0.3751
Seed Spacings	1	31.9243	31.9243	0.70	0.4141
Fertilizer x Seeds Integrated	1	1.7496	1.7496	0.04	0.8468
Fertilizer x Seed Spacings	1	0.9600	0.9600	0.02	0.8862
Seeds Integrated x Seed Spacings	1	7.5040	7.5040	0.17	0.6897
Fertilizer x Seeds Integrated x Seed Spacings	1	90.8704	90.8704	2.00	0.1763
Error	16	726.3937	45.3996		
Total	23	1436.2355			

Table 5. Pairwise Mean Comparison of Fertilizer (vegetation index): HSD Test.

Response Variable: Vegetation Index
Pairwise Mean Comparison of Fertilizer
Tukey's Honest Significant Difference (HSD) Test

Alpha	0.05
Error Degrees of Freedom	16
Error Mean Square	45.3996
Critical Value	2.9980
Test Statistics	5.8313

Summary

Fertilizer	Means	N group
A1	43.57	12 b
A2	53.05	12 a

Table 6. Coconut coir net cost per hectare

DESCRIPTION	UNIT	UNIT COST (PHP)	TOTAL COST (PHP)
Dried coco fiber (500 rolls x 50kg)	kgs	14.00	350,000.00
Labor cost			
Weaving (500 roll)	Per roll	100.00	50,000.00
Installation fee (per roll, including clearing of area)	Per roll	700.00	350,000.00
	Total		**750,000.00**

Table 6. Coconut coir net cost per hectare

DESCRIPTION	UNIT	UNIT COST (PHP)	TOTAL COST (PHP)
Tropical Kudzu seeds (3 kgs)	kgs	300.00	900.00
NitroPlus compound Fertilizer (Coating fertilizer) (1500/kg)	Pack @ 1kg (per 3 kg seed)	1,500.00	1,500.00
Labor cost			
A. Twining with seeds integration (500 roll x 24 twine)	Per twine	2.50	30,000.00
B. Mixing fertilizer and seeds (1 day)			500.00
		Total	**32,900.00**

way much cheaper. To further improve this study, the establishment of tropical kudzu in a longer period of time may be pursued to further validate its establishment after the 2-year life span of coconut coir net.

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