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Biotechnology Utilization for Enhancement the Environmental Carrying Capacity of Former Ex-Coal Mining Land

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Abstract

Environmental management, reclamation, and post-mining should be supervised with good mining principles to create a sustainable ecological life. The purpose of this research is to apply appropriate and effective biotechnological methods to increasing the carrying capacity of the environment based on the parameters of soil fertility and plant growth on mining lands. This type of research was experimental research which 30 stems of the *Indigofera* sp (tarum plant) were examined with Complete Random Design (CRD). The independent variable in this research was the concentration of liquid cow rumen solution, and the dependent variable in this research was the growth of the tarum plant (*Indigofera* sp). The parameters to indicate plant growth including root length, number of root nodules, stem length, number of leave and plant biomass. Based on the data analysis, it was found that the mixture of bovine rumen microbes led to: 1) increased height of tarum compared to control without adding the rumen to the growth medium. 2) Increased tarum leaves compared to the control group and 3) the root nodules were more developed and more numerous than the control group without the addition of the cow rumen. The results showed that the mixture of bovine rumen microbes can increase nutrients in the soil and is able to grow plants on mining land previously.

Keywords: Biotechnology; *Indigofera sp*; Ex-coal Mining; Sustainability; Ecosystem; Carrying Capacity

1. Introduction

Indonesia is a country that is rich in minerals and coal. Minerals and coal play an important role in meeting the various needs of the people, therefore their management must be controlled by the State, and their management must provide real added value to the national economy to achieve prosperity and welfare of the people in a just manner (Garnaut, 2015). It is important to remember that coal mine management that focuses on the interests of the state and the people requires cooperation between government, industry, society and various other stakeholders (Pimentel *et al.,* 2016; Putra *et al.,* 2013). The goal is to achieve long-term prosperity for society and the environment. Suryaningsi *et al* (2019) explain the supervisory authority needs to be regulated as outlined in Government

Regulation of the Republic of Indonesia No 55/2010 concerning "Guidance and Supervision of the Management of Mineral and Coal Mining Business" as referred to in Article 16 and the Principles of reclamation and post-mining follow the Decree of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 1827 K/30/MEM/2018. Based on the principles of reclamation and post-mining following the Decree of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 1827 K/30/MEM/2018, Exploration of Mining license (IUP) and Exploration of Mining Business License (IUPK) holders are required to submit Postmining and reclamation plans, starting from the exploration, production, and post-production stages. This includes revegetation and maintenance of reclamation.

Environmentally sustainable mining companies are required to carry out reclamation and post-mining repairs. For example, the coal mining company PT. Bukit Asam Tbk (PTBA), has planted 1,333,350 trees in the reclamation area, which covers an area of 2,144.26 ha as of June 2022 (Putri *et al.,* 2022). The selection of methods for implementing ex-mining land restoration which refers to ecological aspects and the application of biotechnology is indeed very minimal in Indonesia, therefore there are many mistakes in rehabilitating ex-mining land, especially the wrong choice of plants. The problem that often arises in the management of coal mines is the reclamation of coal mines (Haigh, 1992). Chadwick *et al* (1987), Triantoro (2017), Keenan & Holcombe (2021), and Putra *et al* (2023) described mining activities were temporary land use activities and will ended when mining was no longer economical or after mining materials were no longer available at the local location. After mining activities are completed, the land became very infertile from the chemical, physical, and biological aspects of the soils, therefore it could not use for various agricultural activities requires a rehabilitation process.

The use of conventional biotechnology over time is becoming more and more modern and taking on more and more roles in human civilization. Starting from food production, conventional biotechnology has now been widely used in the health sector, such as making vaccines, insulin, and antibiotics. Glick & Patten (2022) add the basic principles of biotechnology are biological agents (microbes, enzymes, cells), utilizing technology to manipulate DNA, products, services obtained, and the use of various scientific disciplines. Therefore, the researchers here use the cow rumen.

Fu *et al* (2022); Khalil *et al* (2022) explain cow rumen is a large stomach and is the largest part of the stomach in the digestion of ruminants or ruminants. The rumen consists of feed ingredients that are usually eaten by livestock in the form of grass or other forages and feed additives or concentrates. The function of the rumen is as a place for fermentation by microbes, a place for absorption of Volatile Fatty Acids (VFA), and an energy source for livestock which is the result of the degradation of carbohydrates consisting of acetic acid, propionate, butyrate, and a place for mixing food. In the cow rumen, there are cellulosic bacteria as producers of cellulase enzymes to hydrolyze complex cellulose from forage feed into glucose, and bacteria that have high cellulolytic activity can be a source of cellulase enzymes for industry, as applications for refining paper pulp, keeping cloth colors bright in the textile industry, improve quality in the food industry, as a decomposer of organic materials, and improve animal feed nutrition. Lestari *et al* (2017) revealed that cow rumen can increase and optimize the growth of green bean plants.

Related to the above, it is necessary to choose local plant species and appropriate technology. An example of the selection of plants that are often used is *Indigofera* sp. *Indigofera* sp are plants that are highly adaptable to a wide range of environments and have a variety of morphological and agronomic properties that are very important for their use as forages and cover crops (Agustarini *et al.,* 2022). Budiastuti *et al* (2020) describe that the characteristics of the legume *Indigofera* sp are a high protein content and tolerant of drought and salinity. This plant can be used as animal feed which is rich in nitrogen, phosphorus, potassium, and calcium. This is an advantage to carrying out environmental improvements in post-mining areas as well as improving the economy of the community around the mining area.

It is important to understand the conditions before and after the mine (reclamation) later

it is highly recommended to research it first with an ecological perspective based on environmental biotechnology so that the results of reforestation, economy, human, and the environment can be created. The purpose of this research is to apply appropriate and effective biotechnology methods to increasing the environment-carrying capacity based on parameters of soil fertility and plant growth on ex-mining land. With novelty that the use of cow rumen microorganisms can increase environment-carrying capacity (improving soil nutrients) and its relationship with plant growth indicators as a substitute for chemical fertilizers.

2. Methodology

This research is experimental research (Thakur & Kumar, 2022; Isnaeni *et al.,* 2023). The samples were 30 stems of the *Indigofera sp* (tarum plant) with Complete Random Design CRD (Agustarini *et al.,* 2021). The experimental unit used is homogeneous or there are no other factors that influence the response outside of the factors being tried or studied (in the case of the cow rumen). This design is used when the experimental unit is relatively homogeneous. The replicates that were formed did not show heterogeneity in the sources of diversity (Buser-Young *et al.,* 2022). The number of repetitions is determined based on the formula: (t-1) (r-1) $\geq$ 15, where t is the treatment, and r is the repetition according to the Federer formula (Pratiwi *et al.,* 2022).

The 30 stems of the tarum plant (*Indigofera sp*) were planted in the Wire House area of the Biology Department - Universitas Negeri Padang. Meanwhile, the location where research sample was located in PT. Sinamarinda Lintas Nusantara (PT. SLN) coal production operations with a working area of 481.22 Ha. Administratively, the location of the activity is in the Sinamar

and Asam Jujuhan sub-district, Dharmasraya Regency, West Sumatra Province.

The independent variable in this research was the concentration of liquid cow rumen solution, and the dependent variable in this research was the growth of the tarum plant (*Indigofera* sp) with the plant growth indicators being root length, number of root nodules, stem length, number of leave and plant biomass. Where observations made in this research aim to get an overview of reclamation activities, general conditions of the location, and current conditions. Interviews to explore information related to the potential problems of the research area are very necessary. Interviews were aimed at mining workers, entrepreneurs, agency government, and local government preparing land for reclamation, types of soil treatment, mechanisms for handling reclaimed land, and places where microbes (bacteria) will be spread in handling reclaimed land.

The implementation of this research was a series of laboratory-scale test activities by applying the stages of implementing microbial biotechnology methods and seeing their effects on environmental objects (former ex-coal mining land). After the activity, it continued with monitoring and evaluation of the work results with microbial biotechnology methods on soil quality and plant growth. If an error occurs or the results are not optimal, it will be re-enhancement following the research stages. Such as adjusting or increasing/decreasing the dosage of cow rumen administration to *Indigofera sp* plant growing media to obtain optimal growth results when compared to control plant growth. Randomization is carried out on each experimental unit that must have the same opportunity to be given a particular treatment. Randomization of treatment in experimental units can use the table of random number, and number systems manually, or can also use a computer can be seen in Table 1.

Table 1. Observation table for CRD

Test	Treatment				Total
	P1	P2	.....	Pi	
1	Y_{11}	Y_{21}	.....	Y_{i1}	Total
2	Y_{12}	Y_{22}	.....	Y_{i2}	
.....	.....	.....	.....	.....	
j	Y_{1j}	Y_{2j}	.....	Y_{ij}	
Total Treatment (Yi..)	$Y_{1..}$	$Y_{2..}$	.....	$Y_{i...}$	$Y_{...}$

Note: Y_{ij} = observations on the ith treatment repetition

From the observations in Table 1, the P1 to Pi treatment is the giving of the number of rumen. While the 1st repetition is 2 weeks growth, the 2nd repetition is 4 weeks growth and the 3rd repetition is 6 - 8 weeks growth. Furthermore, later it can be analyzed with Statistical Analysis of Variance (ANOVA) with the description in Table 2.

3. Results and Discussion

The plant used for this research is *Indigofera sp* genus has a stature of trees, shrubs, or herbs. Some species have root nodules. According to research by Ni'am & Bintari (2017), these nodules on the roots cause the soil around the roots of *Indigofera sp* plants to become rich in nitrogen and contribute to sufficient soil nutrients. Sheoran *et al* (2010) add soil productivity can be increased by adding various natural amendments such as sawdust, wood residue, sewage sludge, and animal manure because these amendments stimulate microbial activity that provides nutrients (NP) and organic carbon to the soil. The effect obtained from the research is the addition of plant height, the addition of the number of plant leaves, and plant-soil nutrient levels. It is influenced by microorganisms from the cow rumen. Based on research by Dehority (2003) and Sari *et al* (2019), the largest biomass in the rumen is bacteria, where about 50% of the total rumen bacteria live in the fluid and 30 - 40% adhered to food particles. Cow rumen is known as the best compost for the community. Taiwo *et al* (2016) explained that compost is useful for soil bioremediation, where the compost used is made of cow dung, water hyacinth, and sawdust for twelve weeks. In this research, researchers used cow rumen as a bioindicator of soil fertility in the former coal mining area. According to Rabha *et al* (2023), the abiotic components of the rumen consist of gas, carbon dioxide (CO_2), and water. While the biotic components consist of bacteria, protozoa, yeasts, and molds.

3.1 Land nutrients of former mine

3.1.1 Land nutrients of ex-mining before and after treatment

To restore soil fertility in ex-mining land, steps such as post-mining land rehabilitation, the addition of organic and inorganic fertilizers, and the use of soil conservation techniques can be carried out. This effort will help restore nutrient balance and increase the productivity of degraded land. Mine land generally experiences environmental damage (soil degradation) due to mining activities. As a result, the nutrients in the soil and ecosystem are disrupted. The land nutrients of ex-mining before and after treatment can be seen in Table 3 and 4.

Table 2. Analysis of variance for CRD

Source of diversity	Free degrees	Squared sum	Middle square	F-Count
Same repeat r1 = r2 = ... = rt				
Treatment	t-1	JKP	KTP	KTP/KTG
Error	t(r-1)	JKG	KTG	
Total	tr-1	JKT		
Replays are not the same r1 ≠ r2 ≠ ... ≠ rt				
Treatment	t-1	JKP	KTP	KTP/KTG
Error	∑(r-1)	JKG	KTG	
Total	∑r-1	JKT		

Information:
JKP : Sum of Treatment Squares
JKG : Sum of Error Squares
JKT : Sum of Total Squares
t : Treatment
r : repetition

Table 3. Soil test results (before)

No	Parameter	Sample code			Methods
		Mine land	(+lime)	(+lime+rumen)	
1	Nitrogen (N) (%)	0.081	0.088	0.094	Trimetri
2	Potassium (K) (%)	0.038	0.070	0.083	AAS
3	Phosphorus (P) (%)	2.838	1.388	1.800	XRF

Table 4. Soil test results (after)

No	Parameter	Sample code					Methods
		P1	P2	P3	P4	P5	
1	Nitrogen (N) (%)	7.0535	11.7975	8.5604	10.6587	7.4234	Trimetri
2	Potassium (K) (%)	1.6857	0.1291	0.1761	0.4817	0.2914	AAS
3	Phosphorus (P) (%)	6.3170	8.0900	5.3040	5.7230	6.3170	XRF

Information: Treatment P1 to P5 is the provision of the number of rumen. While the 1st repetition is 2 weeks growth, the 2nd repetition is 4 weeks growth and the 3rd repetition is 6-8 weeks growth.

From Table 3, it can be concluded that the contents of N and K after being given lime and cow rumen experienced an increase in contents from normal soil conditions (+ 0.013) for N values and (+ 0.045) for K values, but in P elements the levels decreased of (-1.038) although it is still quite good for a plant to grow well.

From Table 4, it can be concluded that the value of the nutrient content of ex-mining land in each sample varies greatly, and the content values of the element nitrogen, potassium, and phosphorus have increased 2 to 3 times from the initial soil conditions after treatment of the former land mine. The results of soil nutrients were obtained from soil testing conducted at the laboratory of Chemistry Department-Universitas Negeri Padang using methods such as X-ray fluorescence (XRF) and spectrophotometer. Four types of soil were tested for nutrients, namely: 1) Nutrients in mining soil; 2) Nutrients in soil that has been mixed with dolomite lime; 3) Nutrients in soil that has been mixed with dolomite lime and treated with cow rumen [0 mL, 5 mL, 10 mL, 15 mL, 20 mL]; and 4) Nutrients in the soil treated with cow rumen [0 mL, 10 mL, 20 mL, 30 mL, 40 mL].

3.2 Increase in plant height of Indigofera sp

Based on the data analysis that has been carried out, it was found that treatment 5 (P5), or administration of 40 ml of rumen fluid, was the best result obtained to give a real effect on the increase in plant height of *Indigofera* sp. Lestari *et al* (2017) in his research stated that the administration of various doses of rumen fluid on green bean plants affected plant height. The addition of plant height can be seen in Table 5, Table 6 and Table 7.

Based on the data analysis, it was found that treatment P5, or giving 40 ml of cow rumen fluid, was the best result obtained to have a real effect on increasing the height of *Indigofera* sp. Isna (2019) stated that giving different doses of cow rumen compost affected plant height, leaf length, leaf width, number of leaves, and hump diameter. The best dose of cow rumen contents compost is 1000 g. Sari (2016) also revealed in his research that the treatment of cow rumen contents compost on plant seeds affected the parameters of plant height, leaf area, root canopy ratio, and dry weight of seedlings.

3.3 Increase in the leave number of Indigofera sp

The addition of the number of plant leaves is measured by adding up the addition of leaves each week starting from the earliest leaves appear to the top leaves of the plant stem. Each time the tallest leaf is added to the plant stem, it is marked with label paper for each time it is added, more details can be seen in Table 8, Table 9, and Table 10.

Table 5. Addition of *Indigofera sp* plant height

Test (r)	P1(Control)	P2	P3	P4	P5
		Treatment (P)/t			
r1	20	18.5	14	27.5	28
r2	13.5	26	17.5	20.5	27.5
r3	8	20	21	24	29.5
r4	16.5	20	19	33	24.5
r5	11.5	21	27	16	23.5
r6	14	25	21.5	24	19.5
Total	83.5	130.5	120	145	152.5
Average	13.91667	21.75	20.00	24.17	25.42

Description: Treatment P5 had the highest average plant height and P5 was the best treatment.

Table 6. DMRT level of 5% or alpha 0.05 of *Indigofera sp* plant height

Duncan Table 0.05 (5 P/t with 20 Error	2	3	4	5
Duncan's Multiple Range test (DMRT)	2.95	3.097	3.19	3.255
	2023.88585	2124.737111	2188.541	2233.135

Table 7. DMRT follow-up test results of *Indigofera sp* plant height

Treatments	Average	Average + DMRT	Notation
P1	13.91	2037.79585	a
P3	20	2144.737111	b
P2	21.75	2210.29097	c
P4	24.17	2257.305065	d
P5	25.42		e

Conclusion: P5 treatment is the best result of the DMRT follow-up test at 5% level or alpha $\alpha = 0.05$

Table 8. Addition of the leave number of *Indofera sp* plants each treatment

Test (r)	P1(Control)	P2	P3	P4	P5
		Treatment (P)/t			
r1	4	7	5	8	7
r2	6	6	5	6	6
r3	2	6	6	6	6
r4	5	6	6	10	8
r5	5	6	7	6	7
r6	5	7	7	5	7
Total	27	38	36	41	41
Average	4.5	6.33	6.00	6.83	6.83

Note: Treatments P5 and P4 had the highest average number of leaves added, P5 and P4 were the best treatments and the control had the least average number of leaves added.

Table 9. DMRT level of 5% or alpha 0.05 of the leave number of *Indofera sp* plants each treatment

Duncan Table 0.05 (5 P/t with 20 Error	2	3	4	5
Duncan's Multiple Range test (DMRT)	4.5	6	6.3	6.83
	242.8065	323.742	339.9291	368.5263

Table 10. DMRT follow-up test results of the leave number of *Indofera sp* plants each treatment

Treatments	Average	Average +DMRT	Notation
P1	4.5	247.3065	a
P3	6	329.742	b
P2	6.3	346.2291	b
P4	6.83	375.3563	c
P5			

Conclusion: P5 treatment is the best result of the DMRT follow-up test at 5% level or alpha $\alpha = 0.05$

Based on the data analysis, it was found that treatment P5 or administration of 40 ml of rumen fluid was the best result obtained to give a real effect on the addition of *Indigofera sp*. Cow rumen has the potential as a biomineral supplement has a lot of content, and has very potential as an activator for making organic fertilizers (da Silva *et al.,* 2023). The dosage of cow rumen affects the left number (Isna, 2019). Sari (2016) explain, not only the leaf number is affected by the dose of cow rumen, but the leaf area is also affected.

3.4 Biotechnology Indigofera sp with cow rumen

Biotechnology is the process of using biological agents to produce products that are beneficial to humans (Yadav *et al.,* 2022). Biotechnology is widely used in handling or improving environmental quality. The implementation is very flexible and varies depending on the main case/problem. The classification of application of biotechnology in the world of mining is well known as bioremediation (Arora, 2022). Irfan *et al* (2022) explain bioremediation is a strategy or process of detoxification (reducing toxic levels) in soil or other environments using microorganisms, plants, microbial enzymes, or plant enzymes. Some of those mentioned are related to the use of fertilizers, fungi, and the decomposition of biological materials to improve environmental quality levels, especially soil.

This research uses microorganisms originating from cow rumen as biological agents that assist in the bioremediation process. Cow rumen has the potential as a biomineral supplement has many ingredients, and is very potential as an activator for making organic fertilizer. The research results by Kholis *et al* (2019) revealed that microorganisms from the cow rumen can be used as bioactivators in making compost. This is based on the nutrients contained in the cow rumen, such as N (0.40%), P (0.20%), K (0.10%), and water (85%).

The combination of microbes in the cow rumen and *Indigofera* sp plants aims to improve soil nutrients. The research results by Kumar *et al* (2022) revealed that a combination of bioremediation with phytoremediation can reduce pollutants in the soil and at the same time be able to increase nutrients in the soil. Based on data analysis, the research results showed that the combination of microbes in the cow rumen and *Indigofera sp* produce: 1) Tarum plant height has increased compared to the control without the addition of cow rumen to the growth medium; 2) The leave number of the tarum plant has increased compared to the control; and 3) Root nodules are more developed and numerous compared to the control without the addition of the cow rumen. From the data analysis results above, it can be revealed that the combination of microbes in the cow rumen and *Indigofera sp*. This can improve the nutrients in the soil. Research results from Gusprastomo (2018) reveal that the combination of bioremediation with phytoremediation is proven to be able to grow plants on ex-mining land. Barakwan (2017) in his research revealed that cow rumen microorganisms can reduce pollutants in the soil. As a leguminous plant that will be developed as a source of forage, *Indigofera* sp also contributes positively to the stability of soil fertility.

The symbiotic mechanism for fixing air nitrogen with *Rhizobium* bacteria and transferring nutrients and water through symbiosis with mycorrhiza is expected to increase the role of *Indigofera* sp in maintaining soil ecology. The results of observations in controlled pots in the greenhouse showed that the presence of *Indigofera* sp was considered capable of maintaining the content of C, N, and P. In study by Suharlina & Abdullah (2012), *Indigofera* sp was able to increase root residues and organic acids in the soil to increase the level of carbon content, soil organic matter of 16.8%, which means it can provide opportunities for the development of soil microorganisms. *Indigofera* sp is a leguminous plant can symbiosis with *Rhizobium* sp so that it can fix more nitrogen from the air. The presence of nodules formed by *Rhizobium* sp bacteria can provide N in the soil so that these plants can increase the organic matter status of the land, increase the N status, and reduce the use of chemical fertilizers. The results of the comparison of the number of root nodules for each treatment and the diameter of the nodules for each treatment can be seen in Table 11.

Table 11. Comparison of the number of root nodules for each treatment and the diameter of the nodules for each treatment

Treatment	P1	P2	P3	P4	P5
Total	269	1456	1527	1739	2016
Average	3.162	3.068	3.153	3.174	3.211

The cow rumen increased the number of root nodules and the diameter of plant root nodules, with evidence that treatment five (P5) had the most and the largest average addition of the number of root nodules and diameter, P5 was the best treatment, while the control had the least and smallest average increase in the number of root nodules and root nodules. Where P4 had the highest average number of root nodules added.

3.5 Indigofera sp as a plant has many benefits

Indigofera sp can be used for mulch because its leaves contain high protein so it can be used as a source of N. In addition, *Indigofera* sp woody plants are "carbon stores" so they can store carbon. Thus the carbon content in twigs and N in *Indigofera* sp leaves can improve soil physical properties, improve soil biological activity, control weeds, suppress herbicide use, and increase soil fertility. *Indigofera* sp woody plants (trees) can be used as model plants in alley cropping systems in areas with steep contours. Thus this plant can suppress runoff and erosion. It can also be planted around food crops as a companion crop in sloping areas. Hermon *et al* (2019) and Putra *et al* (2024) added that land cover by vegetation in ex-mining areas is very important. This relates to the ability of vegetation to prevent erosion and landslides on existing land. Covering vegetation on ex-mining land will reduce the rate of groundwater and as a filter for grain and other organic materials will be useful for plant growth and planting media for new plants. Yanuartono (2018) describeed one type of tree leguminous plant that is starting to be widely explored is *Indigofera* sp sp, because it is easy to cultivate and resistant to drought, so it can be an alternative source of feed during the dry season.

3.6 Cow rumen can be used as a substitute for chemical fertilizers

Based on the test results for the nutrient content of the soil given to the cow rumen, carbon (C) was 7.4234%, nitrogen (N) was 0.2914%, and phosphorus (P) was 6.317%. It was stated that the cow rumen was proven to increase soil nutrients. From the results of these tests it can be explained that by using low costs or without spending a lot, cow rumen can provide improved nutrition on ex-coal mining land. Al-Busaidi (2013) added that cow rumen is a form of organic fertilizer that can replace chemical fertilizers and inorganic fertilizers.

Inorganic fertilizers generally only contain a small amount of nutrients, such as nitrogen, phosphorus, potassium, and a little sulfur. These nutrients are available in concentrated form and are easily absorbed by plants. One of the drawbacks of inorganic fertilizers is that the nutrients in them can quickly disappear from the soil, so farmers have to apply this fertilization several times throughout the growing season, example in terms of financing, of course, it will be very burdensome. In contrast to organic fertilizers which have a lot of nutrients in low concentration. Nutrients from organic fertilizers can usually be converted into inorganic forms with the help of soil bacteria and fungi, so the release process is slow. Organic fertilizers have many benefits for soil fertility. One of them is reducing soil hardening, as well as improving soil aeration and structure. Organic fertilizers also indirectly function as food for soil microorganisms thereby reducing degradation.

The source of information on soil types, as substracts around the study area, uses references from the West Sumatra II Survey Soil Map (Sawahlunto/Sijunjung, Agam and Tanah Datar Regencies) published by the Center for Soil Research in 1984. Soils in the study area consist of Cambisol, Podsolic, and Oxisol. More details are described as follows.

- Cambisol soils, which are formed from alluvial and colluvial materials and andesite-basaltic tuff materials, have the characteristics of a slightly coarse upper layer and slightly finer lower layer, with a sufficiently deep soil depth of 80 - 90 cm and moderate drainage. Zhang *et al* (2019) add, the chemical properties of the soil are characterized by acid soil, very low nutrient content (N, P, K), low cation exchange capacity and low base saturation, and low fertility.
- Podzolic soils are formed from sedimentary and metamorphic materials, as well as plutonic rocks. Zavyalova (2022) add has the characteristics of the texture of the upper and lower layers smooth, relatively deep depth, good drainage, very acidic soil reaction, very low nutrient content (N, P, K), low cation exchange capacity, and base saturation low and the fertility rate is low.
- Oxisol soils formed from sedimentary rocks and plutonic rocks formed in the tertiary Oligocene period. de Oliveira *et al* (2022) add has the characteristics of smooth top and bottom layers, relatively deep depth, very good drainage, very acid soil reaction, low nutrient content (N, P, K), very low cation exchange capacity, and very low base saturation and low soil fertility.

4. Conclusion

Based on the research that has been done, the implementation of biotechnology of cow rumen Microorganisms provides support for the tarum growth (*Indigofera* sp) and improves soil nutrients with evidence that there is an increase in plant height, an increase in the number of plant leaves, and the development of plant nodules (root nodules). The development of *Indigofera* sp starting from the addition of height, increasing the leave number, and the development of the best root nodules was found in the treatment

given cow rumen fluid with the appropriate amount. This cow rumen biotechnology can improve the natural environment around the mine, especially in biotic and abiotic environmental aspects. The impact of using cow rumen biotechnology has made ex-mining land which was originally poor in nutrients become rich in soil nutrients. This is the basis that the cow rumen is used as organic fertilizer to replace chemical (synthetic) fertilizers, the improvement of soil nutrients in this study can be seen from the development of *Indigofera* sp plant growth as a Research Dependent Variable. Then *Indigofera* sp is beneficial for the surrounding community which will later be used as animal feed. Cow rumen biotechnology changes the pattern of people's lives to produce organic fertilizer from cow rumen waste, replaces chemical (synthetic) fertilizers with organic fertilizers, then cultivates *Indigofera* sp plants as high-nutrient feed plants for livestock, this will greatly affect the price of livestock which will be expensive and of course, can improve the economy of the community around the mine.

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