The Effect Addition of Soil Amandments and PGPR (*Plant Growth Promoting Rhizobacteria*) on the Growth and Yield of Cotton Plants Intercropped with Corn Plants in Dry Land of North Lombok Regency of Indonesia

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***Abstract**.*

This research investigates the effect of soil amendments in the form of cow, form goat manures and PGPR biofertilizer on cotton plants intercropped with corn in the dry lands of North Lombok Regency. The research aims is to determine the growth and yield response of cotton plants due to the application of soil amendments and PGPR in an intercropped system with corn in dryland areas. The research was conducted from December 2023 to June 2024 in Andalan Village, Bayan District, North Lombok Regency. The method used is an experimental method with field trials. The design used was Randomized Block Design (RBD), incorporating two factors: soil amendment treatment (P) as the main plot and PGPR (K) concentration treatments as the subplot. Soil amendments consisted of three levels: P0 (no cow manure and no goat manure), P1 (20 tons/ha cow manure), P2 (20 tons/ha goat manure). PGPR concentration consisted of four levels: K0 (without PGPR), K1 (20 ml/liter PGPR application), K2 (30 ml/liter PGPR application), and K3 (40 ml/liter PGPR application). The research results indicated that the application of 20 tons/ha of goat manure (P2) produced the highest average across all observed parameters (plant height, number of leaves, branch number, stem diameter, and plant yield). Similarly, the application of 40 ml/liter PGPR produced the highest average for these observed parameters. Based on the results of the land equivalent ratio (LER) analysis, this integration system shows highly suitable and relevant to be applied in the dry lands of North Lombok.

Keywords: *Soil amendments, PGPR, cotton and drylands agriculture.*

1. INTRODUCTION

West Nusa Tenggara (NTB) Province is characterized as a semi-arid (rather dry) region due to its extensive dry land areas. Ritung *et al*. (2015) show that 85.19% (1,716,944 ha) of the total land area of NTB (2,015,358 ha) is classified as dry land. One of the regions in NTB Province that is considered dry land areas is North Lombok Regency, which comprises 41.000 ha of dry land as reported by the North Lombok Regency Central Statistics Agency in 2002. This land is predominantly utilized for the production of food crops such as beans, corn, cassava, and sweet potatoes. One of the crops that has the potential to be developed in the dry land of North Lombok is cotton. Dewi (2014) stated that cotton can grow and adapt to diverse soil types without specific requirements, suggesting its potential to be developed in the dry land of North Lombok.

Cotton production in Indonesia remains insufficient to meet national demands. The textile industry annually requires a minimum of 268,500 tons of cotton fiber, yet domestic production fulfills merely 2.3% (approximately 6,250 tons) of this demand, thus 97% of the raw materials must be imported (Monic, 2019). This low production is caused by farmers' limited interest in cotton cultivation. In North Lombok Regency, the development of cotton-corn intercropping systems on dry land remains constrained, primarily due to unfavorable biophysical conditions and elevated risk of crop failure.

To overcome the challenges in cotton development on the dry lands of NTB, particularly in North Lombok, sustainable strategies for enhancing land productivity are imperative. One potential approach involves the application of soil amendments, such as manure. According to Sigit and Marsono (2008), manure is a safe and primary nutrient source for organic farming systems. Manure can help neutralize soil pH, reduce toxic heavy metals, enhance soil structure, increase water retention, and stabilize soil temperature.

Apart from using soil amendments, the utilization of biological fertilizers such as Plant Growth Promoting Rhizobacteria (PGPR) is also a potential alternative to overcome dry land problems. The advantage of PGPR compared to other biological fertilizers is its capacity to actively colonize plant root areas, thus its playing a crucial role in maintaining soil fertility. Furthermore, PGPR directly influences plant growth and increases plant resistance to pathogen attack in the soil (Rai, 2006).

II. MATERIALS AND METHODS

This research employed a field experimental method conducted from December 2023 to June 2024 in the Field Experimental Station Departement of Soil Science University of Mataram at Andalan Village, Bayan District, North Lombok Regency. The tools used included digital scales, rulers, meters, hoes, pens, and label paper. The materials used were cotton variety Kanesia 22, corn variety Pioner P35, cow manure, goat manure, and Plant Growth Promoting Rhizobacteria (PGPR) fertilizer containing the bacteria Pseudomonas fluorescens, Bacillus subtilis, and B. polymyxa which were inoculated from bamboo roots.

This research was designed using a Randomized Block Design (RBD) consisting of two factors: soil amendment treatment as the main plot and PGPR concentration treatment as the subplot. The soil amendment treatments were divided into three levels: no manure, 20 tons/ha of cow manure, and 20 tons/ha of goat manure; while PGPR concentration treatments were divided into four levels: without PGPR fertilizer, 20 ml/liter PGPR application, 30 ml/liter PGPR application, and 40 ml/liter

PGPR application. Each treatment was repeated three times, resulting in 36 experimental units. The research protocol encompassed land preparation, seed selection, manures application, planting, maintenance, observation, and harvesting. The observed parameters included plant height, number of leaves, branch number, stem diameter, cotton yield, corn yield, and calculation of the Land Equivalent Ratio (LER), which describes land use efficiency and is calculated when the crop is harvested.

III. RESULT AND DISCUSSION

Table 1. Average Effect of Manure and PGPR Concentration on Cotton Plant Height

Single Factor	Plant Height (cm)										Average
	14 HST	21 HST	28 HST	35 HST	42 HST	49 HST	56 HST	63 HST	70 HST	77 HST	
Manure:											
No Manure	7.1^{a}	11.6^{a}	15.1^{a}	22.7a	27.5^{a}	31.4^{a}	34.7^{a}	39.0^{a}	49.1^{a}	53.4a	29.1^{a}
20 tons/ha of Cow manure	9.1^{b}	12.7^{ab}	17.9^{b}	23.9a^{b}	28.3^{b}	35.3^{b}	40.0^{b}	51.2^{b}	58.7^{b}	64.5b	34.1^{b}
20 tons/ha of Goat manure	8.9^{b}	13.4^{b}	19.8^{c}	24.7^{b}	29.0^{b}	35.9^{b}	42.1^{c}	53.2^{c}	60.9^{b}	69.7^{c}	35.9^{c}
PGPR Concentration:											
Without PGPR	5.8^{a}	9.0^{a}	11.9^{a}	15.3^{a}	18.4^{a}	22.4^{a}	26.1^{a}	32.1^{a}	36.9^{a}	41.1a	21.9^{a}
20 ml/liter PGPR	8.0^{b}	12.5^{b}	17.5^{b}	24.0^{b}	28.1^{b}	33.1^{b}	37.5^{b}	46.1^{b}	55.0^{b}	61.8b	32.4^{b}
30 ml/liter PGPR	9.1^{c}	14.0^{c}	19.3^{c}	26.3^{c}	32.2^{c}	38.1^{c}	42.9^{c}	50.6^{c}	59.5^{c}	67.8c	36.1^{c}
40 ml/liter PGPR	10.6^{d}	14.7^{d}	21.5^{d}	29.4^{d}	34.1^{d}	43.1^{d}	49.0^{d}	62.3^{d}	73.4^{d}	79.4d	41.8^{d}

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT follow-up test at the 5% level.

Application of manure consistently increased cotton plant height at each observation stage, from 14 to 77 DAP, with increasingly significant differences. Plants treated with cow and goat manure exhibited greater height than those not treated with manure because manure plays a role in improving soil structure, increasing water retention capacity, and providing essential nutrients such as nitrogen, phosphorus, and potassium which support vegetative growth. These findings align with Atmaja (2017) assertion that plants need these nutrients in sufficient quantities during the vegetative growth phase.

Furthermore, the addition of PGPR at various concentrations demonstrated a significant impact on cotton plant height. The highest concentration of 40 ml/liter yielded the most substantial results, followed by 30 ml/liter, 20 ml/liter, and without PGPR. The higher the dose of PGPR given, the higher the plant growth, because the microorganisms in PGPR are optimal in providing the required nutrients. Iswati (2012) also stated that the higher the dose of PGPR, the greater the effect on plant height.

PGPR promotes plant growth through various mechanisms, including the production of growth hormones such as auxin and cytokinin, solubilization of phosphate, and increased nutrient uptake. Husen *et al*. (2009) explained that Rhizobacteria in PGPR function as plant growth promoters, while Egamberdieva (2009) noted that PGPR such as Azospirillum and Pseudomonas can stimulate growth, reduce salt stress, and increase nutrient uptake. These effects were clearly visible in the increase in cotton plant height from week to week, indicating that PGPR application supported stronger vegetative development. Another study by Anggia and Vinarti (2023) also supports these findings, where the application of biofertilizer and goat manure significantly increased the growth and production of cabbage plants.

Table 2. Average Effect of Manure and PGPR Concentration on the Number of Leaves of Cotton Plants

Single Factor	Number of Leaves (Strands)									
	14 HST	21 HST	28 HST	35 HST	42 HST	49 HST	56 HST	63 HST	70 HST	Average
Manure:										
No Manure	3.4[a]	6.9[a]	7.8[a]	12.7[a]	16.9[a]	26.2[a]	33.3[a]	42.5[a]	51.3[a]	22.3[a]
Cow manure 20 tons/ha	4.2 [b]	7.4[b]	9.2[b]	13.2[a]	19.5[b]	27.4[a]	36.7[b]	46.0[b]	55.9[b]	24.4[b]
Goat manure 20 tons/ha	4.4[b]	8.1[c]	10.3[c]	14.7[b]	20.7[c]	29.2[b]	43.3[c]	52.1[c]	66.1[c]	27.7[c]
PGPR Concentration:										
Without PGPR	3.0[a]	6.1[a]	7.1[a]	8.5[a]	11.3[a]	17.5[a]	25.9[a]	33.7[a]	44.0[a]	17.4[a]
20 ml/liter PGPR	4.0[b]	7.2[b]	8.3[b]	12.8[b]	18.9[b]	26.0[b]	37.2[b]	45.4[b]	55.8[b]	24.0[b]
30 ml/liter PGPR	4.2[c]	7.5[b]	9.2[c]	14.7[c]	22.0[c]	30.7[c]	42.4[c]	50.3[c]	62.5[c]	27.1[c]
40 ml/liter PGPR	4.9[d]	8.9[d]	11.8[d]	18.0[d]	24.0[d]	36.3[d]	45.7[d]	58.1[d]	68.7[d]	30.7[d]

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT follow-up test at the 5% level

The analysis results in Table 2 showed that both manure and PGPR concentration have significant effects on the number of leaves of cotton plants. The application of cow and goat manure at a rate of 20 tons/ha significantly increased the number of leaves compared to without manure. The goat manure treatment yielded the highest number of leaves, ranging from 4.4 to 66.1 leaves at each observation stage (14-70 DAP), with a mean average of 27.7 leaves. Cow manure treatment resulted in 4.3 to 55.9 leaves with a mean average of 24.4 leaves, while the treatment without manure produced 3.5 to 51.3 leaves with an average of 22.4 leaves.

The high number of leaves in the goat manure treatment is thought to be because this fertilizer provides sufficient amounts of the nutrient nitrogen (N), in which is important for the formation of protein in plant parts, especially in young shoots and leaves. This finding is consistent with research by Bara and Chozin (2009), which demonstrated that goat manure significantly influences plant height, leaf number, and stem diameter in cabbage plants, attributed to its capacity to supply adequate N nutrients. Amilia (2011) further emphasized the importance of N, P, and K nutrients in supporting plant growth during the vegetative phase.

Moreover, increasing the concentration of PGPR from 20 ml/liter to 40 ml/liter correlated with an increase in leaf number. The highest PGPR concentration of 40 ml/liter yielded the greatest leaf production, ranging from 5.1 to 68.7 leaves with an average of 30.73 leaves. In contrast, without PGPR it produced the lowest number of leaves, ranging from 2.8 to 44.1 leaves with a mean of 17.5 leaves. PGPR biofertilizer is capable of providing essential nutrients and hormones for plant growth, in line with the research by Vacheron *et al*. (2013) and Etesami *et al*. (2018) which demonstrate that PGPR supports plant growth through the production of growth regulators and enhanced absorption and utilization of nutrients.

Table 3. Average Effect of Manure and PGPR Concentration on the Number of Cotton Plant Branches

Single Factor	Number of Branches						
	35 HST	42 HST	49 HST	56 HST	63 HST	70 HST	Average
Manure:							
No Manure	3.0^{a}	4.9^{a}	6.7^{a}	9.7^{a}	11.9^{a}	14.7^{a}	8.5^{a}
Cow manure 20 tons/ha	4.1^{b}	5.9^{b}	7.9^{b}	10.7^{a}	13.4^{b}	15.4^{b}	9.5^{b}
Goat manure 20 tons/ha	4.5^{c}	6.6^{c}	8.7^{c}	11.8^{b}	14.3^{c}	17.0c	10.5^{c}
PGPR Concentration:							
Without PGPR	0.7^{a}	1.8^{a}	3.3^{a}	6.2^{a}	9.3^{a}	11.9^{a}	5.6^{a}
20 ml/liter PGPR	4.1^{b}	6.4^{b}	8.7^{b}	11.5^{b}	13.4 ^{b}	16.2^{b}	10.0^{b}
30 ml/liter PGPR	4.8^{c}	6.9^{b}	9.0^{b}	12.0^{b}	14.5 ^{c}	16.7^{b}	10.7^{c}
40 ml/liter PGPR	5.8^{d}	8.0^{c}	10.1^{c}	13.2^{c}	15.6^{d}	18.0 ^{c}	11.8^{d}

Note: Numbers followed by the same letter in the same column are not significantly different in the 5% DMRT follow-up test

The analysis results in Table 3 show that the use of cow and goat manure and increasing the PGPR concentration resulted in a greater number of cotton plant branches compared to the treatment without manure and without PGPR concentration. Goat manure at a rate of 20 tons/ha produced the highest number of branches, which significantly different from the treatment with cow manure and without manure. The average number of branches in the 20 ton/ha goat manure treatment ranged from 4.5 to 17.0 branches at each observation stage (35-70 DAT) with an average of 10.5 branches. Cow manure with the same rate produces an average of 4.1 to 15.4 branches with an average of 9.6 branches, while without manure produces an average of 3.0 to 14.7 branches with an average of 8.5 branch.

Goat manure provides essential nutrients that support the growth and development of plant branches. The organic goat manure does not degrade soil quality and enhances the activity of microorganisms which crucial for water retention and nutrients absorption by plants. Atmaja (2017) states that in the vegetative growth phase, plants need sufficient quantities of nitrogen, phosphorus, potassium and other nutrients. Nitrogen, as the primary macronutrient, supports the formation of leaves, stems and branches by encouraging the synthesis of proteins and enzymes that are essential for plant cells growth and development (Smith *et al*., 2020). Phosphorus plays a vital role in developing robust root systems, enhancing the absorption of water and nutrients, as well as cell division which influences branch growth (Jones and Green, 2019). Potassium helps in protein synthesis, photosynthesis, and regulates osmotic pressure and water balance in plants, all of which are important for healthy branches development (Browen and Miller, 2018).

The increase in Plant Growth Promoting Rhizobacteria (PGPR) concentration demonstrated a significant effect on branch number. A PGPR concentration of 40 ml/liter produced the highest number of branches, ranging from 5.8 to 18.0 branches with an average of 11.8 branches, which was significantly different from the other concentrations. The treatment without PGPR produced the lowest number of branches, ranging from 0.7 to 11.9 branches with an average of 5.6 branches. PGPR stimulates enhanced root growth, enabling plants to absorb more water and nutrients, which are important for branch formation. Additionally, PGPR can also produce growth hormones that stimulate branching. Wahyudi (2009) stated that the administration of PGPR containing Bacillus sp. bacteria plays a crucial role in enhancing plant growth and soil fertility. Damanik and Suryanto (2018) explained that the Azospirillum sp. bacteria in PGPR are bacteria that produce growth substances that associate with plant roots and increase the number of plant branches. Furthermore, Guntoro *et al*. (2006) also posited that the use of biological fertilizers can improve fertilization efficiency and nutrient uptake in plants.

Table 4. Average Effect of Manure and PGPR Concentration on Cotton Plant Stem Diameter

Single Factor	Stem Diameter (cm)						
	42 HST	49 HST	56 HST	63 HST	70 HST	77 HST	Average
Manure:							
No Manure	2.0 a	2.4a	2.7a	3.0a	3.3a	3.6a	2.8a
Cow manure 20 tons/ha	2.3b	2.6b	3.0b	3.3b	3.7b	4.0b	3.1b
Goat manure 20 tons/ha	2.6c	2.8c	3.1c	3.5c	3.9c	4.2c	3.3c
Fertilization:							
Without PGPR fertilizer	1.3a	1.6a	2.0a	2.3a	2.7a	3.0a	2.1a
20 ml/liter PGPR	2.2b	2.6b	2.8b	3.1b	3.6b	3.9b	3.0b
30 ml/liter PGPR	2.6c	2.9c	3.2c	3.6c	4.0c	4.2c	3.4c
40 ml/liter PGPR	3.0d	3.2d	3.7d	4.0d	4.4d	4.7d	3.9d

Note: Numbers followed by the same letter in the same column are not significantly different in the 5% DMRT test

Based on the research results, plants without manure showed smaller stem diameters, ranging from 2.0 cm to 3.6 cm at various stages of observation (42 DAT to 77 DAP) with an average of 2.8 cm. This indicates that without manure, the plants lack nutrients that negatively affects stem growth. Jumin (2002) stated that a lack of nitrogen, phosphorus and potassium nutrients can cause stunted plants and inhibit root development, thereby disrupting vegetative growth.

On the other hand, the application of cow manure at a rate of 20 tons/ha resulted in a significant increase in stem diameter, ranging from 2.3 cm to 4.0 cm with a mean of 3.1 cm. Goat manure produced the largest stem diameter, ranging from 2.6 cm to 4.2 cm with an average of 3.3 cm. Goat manure, which is rich in organic matter and microelements, supports optimal stem growth.

The provision of PGPR also had a significant effect on the stem diameter of cotton plants. Plants without PGPR had the smallest stem diameter, ranging from 1.3 cm to 3.0 cm with an average of 2.1 cm. With a PGPR concentration of 20 ml/liter, stem diameter increased significantly, ranging from 2.2 cm to 3.9 cm, because PGPR enhanced the availability and efficiency of nutrient absorption. At a PGPR concentration of 30 ml/liter resulted in stem diameters ranging from 2.6 cm to 4.2 cm, indicating that increasing PGPR concentrations further increased soil microbial activity and stem growth. The highest PGPR concentration of 40 ml/liter produced the largest stem diameter, ranging from 3.0 cm to 4.7 cm, indicating a significant increase in stem growth. PGPR has three main functions when applied to plants, one of which is as a biostimulant. PGPR can produce phytohormones such as IAA (*Indole Acetic Acid*), cytokinins, and gibberellins, which have the potential to increase plant growth and production (Putri *et al.*, 2013).

Table 5. Average Effect of Manure and PGPR Concentration on Cotton Plant Production Results

Single Factor	Cotton Production Results	
	Kg/plot	Tons/ha
Manure:		
No Manure	1.1[a]	0.5[a]
Cow manure 20 tons/ha	1.5[b]	0.7[b]
Goat manure 20 tons/ha	1.6[c]	0.8[c]
Fertilization:		
Without PGPR fertilizer	0.9[a]	0.4[a]
20 ml/liter PGPR	1.3[d]	0.6[b]
30 ml/liter PGPR	1.6[c]	0.8[c]
40 ml/liter PGPR	1.9[d]	0.9[d]

Note: Numbers followed by the same letter in the same column are not significantly different in the 5% DMRT test

The application of goat manure resulted in the highest cotton production, yielding 1.6 kg/plot or 0.8 tons/ha, compared to cow manure (1.5 kg/plot or 0.7 tons/ha) and without manure (1.1 kg/plot or 0.5 tons/ha). Goat manure is more effective due to its higher levels of nutrients and organic matter content, which increases nutrient availability for plants (Hartatik and Widowati, 2006).

Regarding the PGPR concentration, the highest dose of 40 ml/liter gives the highest cotton production yield, namely 1.9 kg/plot or 0.9 tons/ha, followed by 30 ml/liter (1.6 kg/plot or 0.8 tons/ha), and 20 ml /liter (1.3 kg/plot or 0.6 tons/ha). The treatment without PGPR produced the lowest yield (0,9 kg/plot or 0.4 tons/ha). Increasing the dose of PGPR appears to improve nutrient availability and soil conditions, thereby supporting better plant growth. The best result observed at 40 ml/liter PGPR concentration may be attributed to higher microbial concentrations being more effective in supporting plant growth (Istiqomah *et al*., 2017).

Additional studies have demonstrated that PGPR improves stress resistance, disease prevention, and crop yield in various crops (Tamura *et al.*, 2011; Liu *et al.*, 2015). Research by Khan *et al*. (2016) reported that PGPR significantly increases cotton growth and production yields under saline conditions.

Table 6. Land Equility Ratio Value for Each Treatment

Treatment	Integration System Results (kg/plot)		NKL/LER
	Cotton	Corn	
P0K0	0.7	2.9	1.3
P0K1	1.0	4.0	1.9
P0K2	1.1	4.6	2.1
P0K3	1.7	4.7	2.8
P1K0	0.8	3.1	1.4
P1K1	1.4	3.9	2.3
P1K2	1.8	4.5	2.9
P1K3	1.9	5.7	3.3
P2K0	1.0	3.3	1.8
P2K1	1.5	3.6	2.4
P2K2	1.9	5.7	3,2
P2K3	2.0	6.5	3.4
Average	1.4	4.3	2.4
Results of Non-Integrated Systems	0.8	7.2	-

Note: P0: without manure, P1: cow manure 20 tons/ha, P2: goat manure 20 tons/ha, K0: without PGPR concentration, K1: PGPR 20 ml/liter, K2: PGPR 30 ml/liter, K3: PGPR 40 ml/liter

Table 6 indicates that the average value of LER (Land Equivalent Ratio) for the cotton and corn integration system is more than one (>1), suggesting that this planting pattern is effective and suitable for implementation. LER of more than one illustrates that the intercropping system utilizes land more efficiently compared to monoculture (Hernita, 2001).

In the P2K3 (a combination of 20 tons/ha of goat manure and a PGPR concentration of 40 ml/liter) treatment, the highest LER was achieved, namely 3.4, followed by P1K3 (a combination of 20 tons/ha of cow manure and a PGPR concentration of 40 ml/liter) with a value of 3.3, while P0K0 (without manure and without PGPR fertilizer) had the lowest LER value of 1.3. These LER values show that the cotton-corn integration system, either with or without manure and PGPR, is very suitable to be applied.

IV. CONCLUSION

Based on the research results, it can be concluded that the application of soil amendments in the form of cow manure, goat manure, and PGPR at various concentrations has a significant influence on the growth and yield of cotton plants. Application of goat manure at dose of 20 tons/ha produced the highest average for plant height, number of lives, number of branches, stem diameter, and cotton yield.

Apart from that, the application of PGPR at a concentration of 40 ml/liter also gave the highest average for plant height, number of lives, number of branches, stem diameter, and cotton yield.

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