Vol. 14, No. 4 (2025): 1496 - 1505 http://dx.doi.org/10.23960/jtep-l.v14i4.1496-1505

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Effect of Fungal Bioformulator Concentrate on the Growth and Yield of Corn (*Zea mays* L.) under Dryland Conditions

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Article History:

Received : 23 March, 2025
Revised : 28 April, 2025
Accepted : 16 August, 2025

Keywords:

Bioformulator,
East Lombok,
Microorganism,
Zea mays L.

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ABSTRACT

The urgency of this research lies in the application of bioformulator fungal concentrate as a renewable product with more economical synthesis costs, utilizing the natural potential of surrounding environment to stimulate the growth of corn in dry land. The primary objective of this study is to increase corn production in in Toya Village, Aikmal District, East Lombok, West Nusa Tenggara (NTB), to meet community needs. The research method used is an experimental method with field trials. This study employs a Randomized Complete Block Design (RCBD) with factorial experiment consisting of four levels of BFK and three levels of variety. Each treatment is repeated three times, resulting in a total of 36 experimental units. The data were analyzed using analysis of variance (ANOVA), and if significant differences are found, the Honestly Significant Difference (HSD) was conducted using test at a significance level of 95%. The application of fungal bioformulator concentrate did not show a significant effect in improving the growth and yield of maize in dryland conditions.

1. INTRODUCTION

In Indonesia, corn (*Zea mays* L.) is widely used in the animal feed industry. This is because corn contains high metabolic energy among other types of feed. Corn is rich in carbohydrates, primarily in the form of starch, and contains nitrogen-free extract (NFE) compounds, with a low nitrogen content, high in fat but low in crude fiber, making it easy for the body to digest. In addition, some corn products can also be used for consumption, from the food industry to the bio-fuel industry (Choudhary *et al*., 2019). Corn is widely planted on dry land in Eastern Indonesia, such as NTT and NTB, while in regions in Sumatra and Java, corn is widely planted in irrigation paddy fields as a rotation crop in rice cultivation. Indonesia has vast dryland areas with great agricultural potential, but low soil fertility remains a major constraint due to limited organic matter and poor nutrient retention. These issues hinder crop productivity. One promising solution is the utilization of bioformulators, which contain beneficial microbes like Trichoderma, that can enhance soil health, promote plant growth, and suppress pathogens naturally (Wati *et al*., 2022). Dryland agriculture refers to cultivation of crops entirely under natural rainfall without irrigation (Permayani *et al*., 2020). The corn on dry land often faces high soil temperature during germination, nutritional deficiency, and also humidity pressure when flowering. Meanwhile, the corn planted on irrigation land faces inundation constraints, so it has difficulty growing and developing (Aninsi *et al*., 2024).

Efforts to increase corn productivity can be done by increasing the harvest area through the use of dry land (Saeri *et al*., 2023). In West Nusa Tenggara (NTB), dry land has an area of 893,758 ha, but only 287,085 ha (32%) have been well utilized (Akhmad, 2021). In East Lombok Regency itself, dry land reaches 71.73% of the total area of the district which has the potential to increase corn productivity to meet the needs of the community (Wulandari *et al*., 2022). The use of dry land in East Lombok is still not optimal, because dry land experiences various problems, such as low soil fertility (Sadiyah, 2023). The solution has to be applied through land engineering techniques to improve fertility and soil health. Another form of intensification in the modernization of agricultural engineering is to implement a plant cultivation system using organic matter (Harahap *et al*., 2021). One of organic material that has been proven to be very effective is the Trichoderma Fungi Bioformulator (TFB). TFB is an organic formula from the fungus *Trichoderma spp*. which is very beneficial for plant growth (Chahyunisa *et al*., 2024).

In addition to such microbial agents, biofertilizers have also gained attention for their role in promoting sustainable and efficient nutrient management in agriculture. Organic fertilizer (biofertilizer) can be used as an alternative fertilizer. Fungi bioformulator is a concentrated material containing spores with a very high density. It is very effective in improving the quality of dry land and the growth of corn plants. The addition of these soil microbes can accelerate the process of decomposition of soil organic matter for the release of nutrients in the soil. *Trichoderma spp*. is a type of soil microbe that plays a role in the decomposition of organic matter. This fungus also acts as a rotting microbe that is useful in the context of making organic fertilizer (Negara *et al*., 2023). In addition, based on research by Sinay *et al*. (2022), the fungus *Trichoderma spp*. can fight pathogenic fungi, as well as become a producer of growth hormone for plants.

Previous studies show that *Trichoderma spp*. can spur the growth of corn plants in the seed planting system directly (Wulandari *et al*., 2022). On the other hand, the use of *Trichoderma spp*. can increase the growth of the peanut plant and its pod count. In addition to bioformulators, dryland optimization can be done using drought-resistant crops, such as corn, soybeans, and beans. According to Permayani *et al*. (2020), to increase dryland productivity, it is necessary to intensify the cultivation of dryland crops such as corn because these plants are resistant to drought and can become an alternative food source. Based on the above explanation, the objective of this research is to determine the impact of concentrated fungi bioformulator on the growth and yield of maize plants in dry land. This research is expected to provide an environmentally friendly biological alternative to increase corn growth and yield in dry lands.

2. MATERIALS AND METHODS

2.1. Research Tools and Materials

The experimental method was applied to this research, namely experiments on the dry land of Toya Village, Aikmal District, East Lombok, West Nusa Tenggara Province from March to August 2024. There was several equipment used in study, including water flow cabinet, oven, autoclave, beaker, hotplate, analytical scales, pipettes, measuring cups, microscopes, needles, knives, preparations, cups, bunsen lights, cover cups, erlenmeyers and Petri cup. As for activities in the field, meter is used, leaf color chart (BWD) and soil treatment equipment. Some ingredients are applied, including PDA medium, *T. harzianum* fungi, water, brown sugar, alcohol, streptomycin, coffee leaves, rice, corn seeds, Phonska and urea fertilizer.

2.2. Design of Experiments and Treatments

This study was designed through a randomized group design experiment with 2 factors, namely bioformulator fungi concentrate (BFC) and variety. The BFC factor consists of 4 levels, namely B0 = without BFC, B1 = 10, B2 = 15, and B3 = 20 g BFC per plant. The variety factor consists of three types of sweet corn, namely Bonanza, Jamboree, and Sweet Boy. There are 12 combinations of treatment with three replications resulting from BFC factors and corn varieties; in the end, 36 units of experiments were obtained. A total of 10% of the total plants are sampled in each random trial plot. The field experiment was conducted on a 180 m² plot, divided into 36 subplots. Each subplot was planted with sweet corn at a spacing of 20 cm × 70 cm, resulting in 35 plants per subplot and a total of 1260 plants across the entire field. From each subplot, six plants were randomly selected as samples for observation and analysis.

2.3. Research Stage

The research process begins with the propagation of *Trichoderma harzianum* which was carried out at the Laboratory of the Faculty of Agriculture, STIE 45 Mataram. Making this growing medium uses potato dextrose agar (PDA). The medium is made by mixing 200 ml of potato water, 4.5 grams of dextrose (sugar), and 4.5 grams of agar flour. Then the potatoes are sliced as thick as 1 cm, boiled until it can produce yellowish boiled water when the potatoes start to be soft. The cooking water is filtered with a filter cloth, the filtrate is added with agar flour and dextrose, all ingredients are heated then stirred until dissolved. The medium grows then sterilized on the autoclave within 2 hours with a temperature of 121 °C and a pressure of 1.5 atm. Streptomycin is added to a growing medium solution that becomes antibacterial and poured into a sterile petri, then allowed to stand in laminar air flow until it becomes hard, in the end the PDA media is formed. Furthermore, the fungus of the *T. harzianum* fungi isolates Sapro-01 is grown on the PDA media. If there is contamination, the propagation procedure will be repeated. *T. harzianum* fungi that grew on the PDA media were reproduced again with rice media.

The fungus that grows on rice media is mixed with 20 liters of water and 1 kilogram of brown sugar to form a biotrichon solution. The next stage of 20 liters of biotrichon is mixed with 225 kg of coffee leaf powder, all ingredients are fermented for 14 days. After being finished, the material will be mixed with 15 kg of starch to be printed into a concentrate solid so as to form a bioformulator fungi concentrate (BFC) product. The next process is to retrieve data from the specified sample, namely by measurement of growth parameters and also corn yields, such as plant height, leaf green pigment using SPAD meter (Soil Plant Analysis Development), wet and dry weighing, weight and diameter of cobs, weighing 100 dry pee seeds, and weighing 1000 seeds dry pee. Soil analyzed in the laboratory.

2.4. Data Analysis

All data were analyzed using diversity analysis (ANOVA) with a significance level of 5% based on the observation results. If there is a real difference between treatments, where a P value of < 0.05 is produced, it will cause the Honest Real Difference (BNJ) test to be carried out using the same level of significance.

3. RESULTS AND DISCUSSION

Various analysis show that variety factors have no significant effect on plant height, likewise the bioformulator factors (Prasetyo *et al*., 2021). The interaction between the two factors is also not significant. Based on the data of Table 1, it is proven that the control group (no bioformulator application) had the average height of 153.5 cm, while the 20 g per plant dose had the average height of 195.23 cm. The plant height treated with 10, 15, and 20 g BFC were 2.3, 2.2, and 9.2% higher than the control, and the average plant height across these three doses was 194.10 cm. However, statistical analysis showed no significant difference in plant height among the BFC treatments (10, 15, and 20 g/plant). Consequently, it can be said that applying 10–20 g of bioformulator treatment per plant increases plant height equally well, indicating that this dose range offers sufficient nutrients for the best vegetative growth. There is also no significant difference in the growth of corn plants between varieties because all three are sweet corn plants have the same phenotype (Sutarman & Prahasti, 2022). The phenotype of a corn plant, which is the visible characteristics of the plant, greatly influences its growth. Mahyuddin *et al.* (2023) and Putri *et al.* (2022) added that optimal growth rate requires adequate nutrient levels, so that the dose of 20 g Trichoderma per plant contained in bioformulator is also known as endophytic fungi that can penetrate plant tissue.

Table 1. Effect of BFC and corn variety on the average plant height on 2 to 7 WAP

Factor	**Plant height (cm)**					
	2 WAP	**3 WAP**	**4 WAP**	**5 WAP**	**6 WAP**	**7 WAP**
BFC Concentration (g per plant)						
0	38.00 a	63.50 a	78.50 a	93.50 a	123.50 a	153.50 a
10	38.89 a	76.72 b	117.72 b	132.72 b	162.72 b	192.72 b
15	38.84 a	78.61 b	119.61 b	134.80 b	164.76 b	194.34 b
20	41.52 b	78.92 b	119.72 b	135.11 b	165.76 b	195.23 b
HSD value at 5% level	2.51*	2.91*	16.53*	16.92*	16.83*	18.86*
Varieties						
Sweet boy	38.77	78.52	119.37	135.67	168.88	198.25
Bonanza	37.63	75.45	117.56	130.78	167.47	195.37
Jambore	37.52	77.76	117.76	131.32	165.93	194.65
HSD value at 5% level	2.98 ns	5.67 ns	3.18 ns	6.98 ns	4.59 ns	4.63 ns

Note: Means followed by the same letter in the same column are not significantly different based on the HSD test at α = 5%. (* = significant, ns = not significant).

The plant height is lower without bioformulator fungi due to low nitrogen absorption which is important for vegetative growth in corn plants. Lack of nitrogen can slow down growth (Amir *et al*., 2023). There is no significant difference in the variety factor because all three are sweet corn varieties with similar plant growth characteristics. According to research (Solihin *et al*., 2019), Sweet Boy, Bonanza, and Jamboree varieties show insignificant results in their growth. Although statistically insignificant, the Sweet Boy variety tabulation shows better growth, which is 23.61 cm every week. The average plant height increases with a higher dose.

Figure 1. Colony (left) and morphology (right) of *Trichoderma* spp. fungi spores isolated from the base of the stem of the corn plant with BFC treatment

Figure 1 shows the colony shape and morphology of *Trichoderma* spp. spores isolated from the base of corn stems with Bioformulator treatment generally show the following characteristics: Colonies grow rapidly, initially white and fluffy, then change to yellowish green to dark green and dense according to Sinay *et al*. (2022). Spores are usually elliptical, smooth, and measure around 3-5 x 2-4 µm.

3.1. Bioformual Fungi in Dry Land

The bioformulator treatment makes corn plants grow higher when compared without bioformulator fungi, indicating its effectiveness increases the height of plants in dry land. The normal evidence of data can be seen in Figure 2. This growth data is obtained in a normal way, which is consistent with the tools and methods of measurement. Plant growth depends on soil fertility and can be optimal if the soil provides enough nutrients (Bononi *et al*., 2020; Choudhary *et al*., 2019). Soil with low organic matter levels can reduce the availability of nutrients and will interfere with plant metabolism and inhibit growth. Increased plant height with fungi bioformulator caused by Trichoderma spp. which helps the decomposition of organic matter in the soil and produces up to 7.72% C/N ratio to facilitate nutrient mineralization. Based on opinions (Sutarman & Prahasti, 2022), Trichoderma spp. can increase plant height because they maximize the absorption of nutrients and water, as shown in Figure 3.

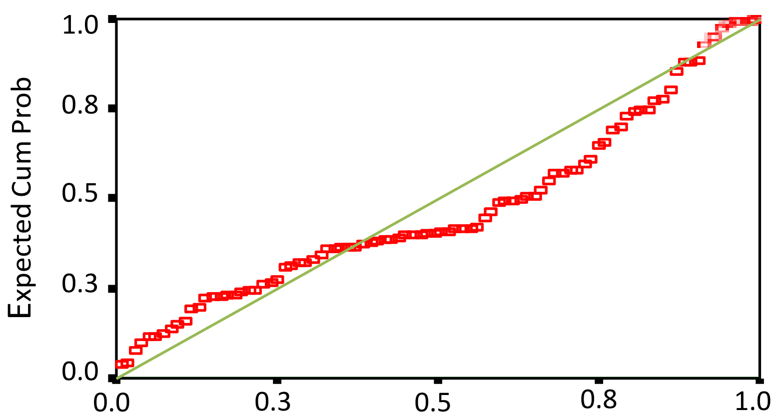

Figure 2. The normality curve for plant height data acquisition

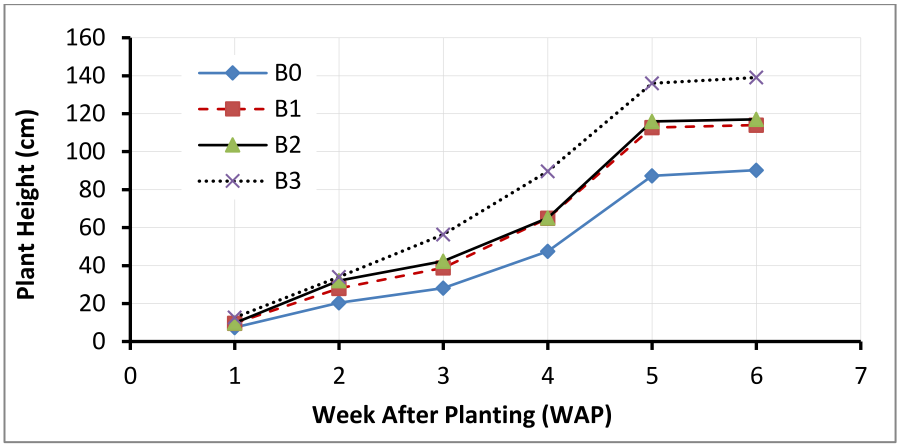

Figure 3. Sigmoid curve of corn plant height development due to BFC treatment

Figure 4. Differences in the root growth of corn plants of the Sweet Boy variety treated with BFC at various doses. (Note: B0 = without BFC, B1 = 10 g/plant, B2 = 15 g/plant, and B3 = 20 g/plant)

Figure 4 explains the differences in treatment of the Sweet Boy (K3) variety with the following details: B0 = without BFC, B1 = 10, B2 = 15, and B3 = 20 g BFC per plant. It concludes that plants with BFC have more optimal root growth than those without treatment. This is in line with the opinion (Prasetyo *et al*., 2021), that the improvement of the root system is due to the presence of *Trichoderma harzianum*. Better root growth increases the ability to absorb water and nutrients, it will then be transported to the leaves through the xylem and converted into assimilates such as protein and fat. This assimilation is then distributed to all parts of the plant to support vegetative growth. On the other hand, the treatment of varieties does not indicate a significant influence on plant height growth, although plants from certain varieties tend to be taller. No significant difference was seen in the growth of corn plants between varieties because all three are sweet corn plants have the same phenotype. The phenotype of a corn plant, which is the visible characteristics of the plant, greatly influences its growth. Characteristics such as plant height, cob size, stem color, and number of leaves all play a role in determining how well the plant will grow and produce (Lu *et al*., 2020). According to (Solihin *et al*., 2019), Sweet Boy, Bonanza, and Jamboree varieties show insignificant differences in their growth.

Table 2 data proves that the phase after harvesting, the wet and dry weights of the plants treated with bioformulator were not significantly different compared to those of plants without the bioformulator treatment. The wet weight of the plants treated with 10, 15, and 20 g BFC were 9.3, 9.4, and 15% higher than the control. Likewise, the dry weight of the plants treated with 10, 15, and 20 g BFC were 29, 20, and 38% higher than the control. These findings imply that the use of BFC, particularly at 20 g/plant, may boost plant biomass accumulation even though the

Table 2. Effect of BFC and corn variety on the average plant height on wet and dry biomass weight after harvest

Factor	Wet Weight (g/plant)	Dry Weight (g/plant)	Cob Length (cm)	Cob Diameter (cm)
BFC Concentration (g per plant)				
0	241.47 b	56.58 b	11.4 b	4.02 b
10	263.93 ab	73.12 a	14.22 a	5.40 a
15	264.22 ab	67.95 ab	14.51 a	5.40 a
20	277.77 a	78.21 a	15.18 a	5.55 a
HSD value at 5% level	25.54*	14.27*	2.61*	1.08*
Varieties				
Sweet Boy	267.64	67.22	12.95	5.17
Bonanza	262.22	69.49	13.72	5.08
Jamboree	255.68	70.19	14.80	5.05
HSD value at 5% level	13.69 ns	4.86 ns	3.48 ns	1.83 ns

Note: Means followed by the same letter in the same column are not significantly different based on the HSD test at α = 5%. (* = significant, ns = not significant).

differences were not statistically significant. This increase in the weight of this pruning is also allegedly associated with soil pH that is suitable for nutrient availability because lower pH can result in strong bonds between nutrients and acid cations, inhibiting nutrient availability (Msimbira & Smith, 2020). Increasing soil pH can also increase the activity of soil microorganisms such as *Trichoderma* spp. Tejowulan *et al*. (2023) added that the availability of nutrient is sufficient to increase biomass synthesis and also increase the weight of the plant. In addition, an increase in the weight of corn plants is also associated with the health of plants that are influenced by *Trichoderma* spp. in fungi bioformulators.

The data in Table 2 prove that the difference in the length and diameter of plant cobs with Fungi Bioformulator treatment is not significantly different compared to plants that are not given Fungi Bioformulator treatment. Although the treated plants exhibited slightly higher average values in both cob length and diameter, these differences were not statistically meaningful. The small size, diameter, and length of the cob for plants without bioformulator fungi treatment may be caused by a lack of nitrogen nutrients (N) and phosphorus (P) as a result of the low ability of roots to absorb the nitrogen nutrients. Lack of nitrogen can reduce plant yields. According to Silletti *et al*. (2021), cobs and corn seeds cannot develop optimally if a lack of nitrogen and phosphorus during the development phase.

Trichoderma harzianum can produce cellulase enzymes, which can break down cellulose in organic matter into lignin-cellulose and transform them into simpler compounds, resulting in plants more easily utilizing them. In addition, *Trichoderma* also produces growth regulators (ZPT) which can increase root growth for more optimal nutrient absorption, causing a higher assimilate formation (Syatrawati *et al*., 2022).

Based on the results of the analysis in Table 3, the weight of the cob and dry seeds in plants that receive bioformulator fungi treatment is not significantly different when compared to plants that do not receive bioformulator fungi treatment. This result indicates that the application of bioformulator fungi did not have a measurable effect on the final yield components, specifically cob weight and dry seed weight, under the conditions of the study. Although bioformulator fungi are often expected to improve nutrient uptake and plant vigor, their effect may depend on several environmental and biological factors, such as, soil nutrient availability may already be sufficient for optimal cob and seed development, reducing the potential benefit of added microbial assistance (Kane *et al*., 2021).

Trichoderma can improve the structure of the soil around the roots by breaking down organic matter that creates a better environment for root growth. This can increase the porosity of the soil, allowing the roots to grow more effectively and absorb more water and nutrients. In addition, *Trichoderma* produces compounds that stimulate root growth. For example, the production of hormones such as abscisic acid (ABA) and auxin by *Trichoderma* can increase root formation and prolong lateral roots. This hormone plays an important role in modulating root growth and differentiation so that nutrient absorption becomes more optimal (Kubiak *et al*., 2023; Sood *et al*., 2020).

Table 3. Effect of BFC and corn variety on the average cob weight, 100-seed weight, and 1000-seed weight

Factor	Cob Weight (g/cob)	100-seed weight	1000-seed weight
BFC Concentration (g per plant)			
0	205.80 b	21.44 b	229.69 b
10	217.12 ab	24.27 a	245.6 ab
15	217.18 ab	24.44 a	243.66 ab
20	221.88 a	25.07 a	257.22 a
HSD value at 5% level	11.79*	2.66*	21.48*
Varieties			
Sweet Boy	216.36	24.80	249.30
Bonanza	215.07	23.79	238.89
Jamboree	215.50	22.82	243.93
HSD value at 5% level	3.18 ns	2.67 ns	13.86 ns

Note: Means followed by the same letter in the same column are not significantly different based on the HSD test at α = 5%. (* = significant, ns = not significant).

The existence of *Trichoderma harzianum* mushrooms in fungi bioformulators can dissolve bound phosphorus, making it available for the growth of a cob. By producing organic compounds that can dissolve phosphorus bound to Al and Fe, converting it into Al-Fe-chelate complex, releasing PO_4^- dissolved, causing plants to easily absorb it. *Trichoderma* spp. can also produce enzymes that convert unavailable nutrient forms into easily absorbed forms by plants. Enzymes such as phosphatase can increase the availability of phosphorus, one of the important nutrients for plants (Abdenaceur *et al*., 2022; Ali *et al*., 2022).

Based on the results of Table 4, the leaf color in plants given bioformulator fungi show an insignificant difference when compared to plants without bioformulator fungi. This result suggests that the application of fungi bioformulator did not significantly influence the greenness or chlorophyll levels in the leaves under the conditions of this study. Leaf color is often used as a proxy for nitrogen status or photosynthetic activity, and bioformulator fungi is sometimes expected to enhance nutrient uptake, including nitrogen. Considering nitrogen as an important element of leaf pigment formation, an increase in color scale at the dose of 20 g per plant is caused by better root development, thereby increasing nitrogen and magnesium absorption is needed for chlorophyll formation. Chlorophyll is important for photosynthesis, which produces photosynthetic products translocated as assimilated and stored energy in the framework of the vegetative development of corn plants (Guo *et al*., 2024).

Table 4. The effects of bioformulator fungi concentrate and variety factors affecting leaf color

Factor	Scale	Leaf Color
BFC Concentration (g per plant)		
0	4.05 b	Light green
10	4.29 ab	Medium green
15	4.51 ab	Slighty dark green
20	4.59 a	Dark green
HSD value at 5% level	0.48*	
Varieties		
Sweet Boy	4.35	Medium green
Bonanza	4.51	Dark green
Jamboree	4.22	Light green
HSD value at 5% level	1.83 ns	

Note: Means followed by the same letter in the same column are not significantly different based on the HSD test at α = 5%. (* = significant, ns = not significant).

Corn leaves on plants that received Fungi Bioformulator treatment had brighter colors (Figure 4) compared to leaves of plants without treatment. This may be related to the presence of *Trichoderma spp*. in Fungi Bioformulator, which plays a role in rhizospheric colonization and produces hormones that can stimulate root development to optimize the absorption of nitrogen and magnesium, which is important in the formation of chlorophyll with the chemical formula $C_{55}H_{72}O_5N_4Mg$ Trichoderma fungus can produce auxin which stimulates the physiological development of leaves (Damanhuri *et al*., 2022). The difference in the color of the leaves given and without bioformulator treatment in the sweet boy variety can be seen in the following Figure 4.

Figure 4. Differences in leaf color without bioformulator fungi (A) and bioformulator fungi treatment (B)

The low color scale of the leaves of the plant without bioformulator treatment is caused by a lack of water and nitrogen. Dry land often experiences a lack of water, as well as the development of less-than-optimal roots inhibits the absorption of nitrogen so that the formation of chlorophyll is not optimal. Lack of nitrogen can result in a decrease in leaf pigment production because nitrogen is an important element in the process of chlorophyll synthesis in chloroplasts. This process begins with the absorption of nitrogen by plants from the soil in the form of nitrate ions (NO_3^-) or ammonium (NH_4^+), then transported into cells, especially to chloroplasts. In cells, nitrogen is used to form amino acids, especially glutamic acid (Grzechowiak *et al*., 2024). Glutamic acid is then converted into Aminolevulinic Acid (ALA) through a reaction catalyzed by the enzyme ALA synthase. ALA is then transferred to the mitochondria to continue porphyrin synthesis. Furthermore, the porphyrin ring binds magnesium ions (Mg^{2+}), thus producing active chlorophyll (Wu *et al*., 2019). Differences in insignificant results between varieties using fungi bioformulators are impossible due to the similarity of characteristics between varieties. The results of research (Cahya & Herlina, 2018) show that the varieties of jamboree, bonanza, and sweet boy do not show significant differences in their growth parameters. Allegedly, the three varieties have similar characteristics because they come from the same type of sweet corn, although different varieties.

4. CONCLUSION

The bioformulator treatment of concentrated fungi can increase the growth and yield of corn plants in dry land. The treatment of varieties has not shown the ability to increase the growth and yield of corn plants significantly. The application of fungal bioformulator concentrate did not show a significant effect in improving the growth and yield of maize in dryland conditions. Therefore, if the use of a bioformulator is needed to support plant growth and yield, a dose of 10 g per plant is sufficient. The results of this study can contribute to the development of dry land and *Trichoderma* products as regional potentials to strengthen food security at the regional, national, and even global levels. For further researchers who study similar problems, use the Fungi Bioformulator in corn cultivation carry out longer fermentation on the concentrated fungi bioformulator before application, and be more careful in measuring parameters when collecting data.

5. ACKNOWLEDGEMENTS

The author would like to express his gratitude to the DRTPM of the Directorate General of Higher Education for providing research funding assistance with the number SK 0667/E5/AL.04/2024, the Head of LPPM who coordinated the implementation of this research, and members of FORDOS STIE 45 Mataram who provided support in the form of knowledge, motivation, thoughts, and facilities.

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