**APPLICATION OF AMELIORANTS AND MYCORRHIZA ON SANDY SOIL FOR THE CULTIVATION OF GLUTINOUS CORN (*Zea mays ceratina*)**

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**ABSTRACT**

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| **Aims:** This research seeks to assess the impact of different combinations of ameliorants and mycorrhiza on the growth and productivity of glutinous corn cultivated in sandy soil.  **Study Design:** This study used a Randomized Block Design (RBD).  **Place and Duration of Study:** The experiment was conducted in Moncok Village, Ampenan District, Mataram City, Indonesia  **Methodology:** The study evaluated five different ameliorant mixture treatments: (A1) a combination of 50% cow manure and 50% mycorrhizal biofertilizer, (A2) 50% compost mixed with 50% mycorrhizal biofertilizer, (A3) 50% "Subur" organic fertilizer paired with 50% mycorrhizal biofertilizer, (A4) 50% rice husk charcoal combined with 50% mycorrhizal biofertilizer, and (A5) a blend of various ameliorants, each contributing 50%, with 50% mycorrhizal biofertilizer. The parameters measured included plant height, leaf count, fresh and dry biomass weight, cob weight, soil nitrogen (N) and phosphorus (P) content, plant uptake of N and P, spore count, mycorrhizal colonization, and overall harvest yield.  **Results:** The combination of 50% cow manure and 50% mycorrhizal biofertilizer resulted in the optimal growth and yield of glutinous corn, showing a significant difference (P<0.05) compared to the other treatments. This mixture led to increases in plant height, leaf count, biomass weight, cob weight, cob diameter and length, as well as improved nutrient concentration and uptake by the plants. Moreover, it promoted a higher number of spores and greater mycorrhizal root colonization.  **Conclusion:** The application of a 50% cow manure and 50% mycorrhizal biofertilizer mixture significantly (P<0.05) improved soil fertility, mycorrhizal activity, and growth and yield of glutinous corn cultivated on sandy soil. |

*Keywords: Glutinous corn; ameliorant; mycorrhiza; plant growth; harvest yield*

**1. INTRODUCTION**

Glutinous corn (Zea mays ceratina) is a special type of corn increasingly in demand by consumers and the food industry due to its distinctive taste - more savory, soft, and tender. This special quality is attributed to its high amylopectin content, which reaches up to 90% (Edy et al., 2024). Its high amylopectin level also makes glutinous corn as a potential alternative food source for people with diabetes. As well, this corn can be developed into various valuable and in-high demand products, such as corn porridge and instant corn rice (Serna-Saldivar, 2018).

Despite its many prospective advantages, glutinous corn cultivation still faces challenges, particularly its low productivity. In the “Karya Usaha Bersama” farmer group, the average yield of glutinous corn was recorded only around 2-2.5 tons per hectare. While in another study, with the application of appropriate cultivation technology innovations, the yield of glutinous corn was reported to reach up to 8 tons per hectare (Erenstein et al., 2022). To overcome these problems, cultivation innovations are needed that utilize organic materials as ameliorants to increase the productivity of glutinous corn (Astiko et al., 2023).

Another challenge faced by farmers is the properties of the sandy soil in the cultivation area, which are porous, low water-holding capacity, and minimal organic matter content (Das & Ghosh, 2024). This condition is a major obstacle in increasing crop yields because sandy soil tends to be poor in nutrients and quickly loses moisture. On the other hand, around the cultivation area there is an abundance of organic waste such as cow dung, agricultural waste, and rice husks that have not been utilized properly. As a matter of a fact, all these materials can be processed into ameliorants that function as soil conditioners, improving soil structure and increasing the soil’s capacity to retain water (Ismail et al., 2025).

The integration of indigenous mycorrhizae with ameliorants has the potential to boost nutrient availability for plants and enhance root nutrient absorption efficiency by 2–3 times. Combining organic ameliorants with mycorrhizal biofertilizers presents an innovative approach to sustainably improve the soil’s physical, chemical, and biological properties (Astiko et al., 2025). Various organic materials, such as cow manure, agricultural waste processed into compost, and rice husks transformed into biochar, showed great promise as effective base components for ameliorants (Saletnik et al., 2019). The application of ameliorants to sandy soils, which are naturally low in nutrients, can help to bind loose soil particles into stable aggregates, thereby improving soil structure and enriching nutrient content. This improvement was further supported by the application of the mycorrhizal biofertilizer isolate MAA-001, playing a crucial role in increasing fertilization efficiency and promoting optimal plant growth (Astiko et al., 2019). This study aimed to evaluate the effects of various combinations of ameliorants and mycorrhizae on the growth and yield of glutinous corn cultivated in sandy soil.

**2. methodology**

**2.1. Time and Place**

The research was conducted in Moncok Village, Ampenan District, Mataram City, Indonesia, which is geographically located between approximately 8.5780° and 8.5810° South Latitude and 116.0895° and 116.0935° East Longitude.

**2.2. Experimental Design**

This study used a randomized block design (Gomez & Gomez, 1984) with five different ameliorant mixture treatments: (A1) 50% cow manure combined with 50% mycorrhizal biofertilizer, (A2) 50% compost blended with 50% mycorrhizal biofertilizer, (A3) 50% "Subur" organic fertilizer mixed with 50% mycorrhizal biofertilizer, (A4) 50% rice husk charcoal paired with 50% mycorrhizal biofertilizer, and (A5) a 50% combination of various ameliorants plus 50% mycorrhizal biofertilizer. Each treatment was replicated four times.

**2.3. Ameliorant Plus Indigenous Mycorrhiza**

The mycorrhizal isolates were propagated in a corn plant grown in a pot culture with 1:1 mixture of soil and sterilized cow manure. Mycorrhizal isolates (a blend of soil, roots, spores, and indigenous mycorrhizal hypae - originating from North Lombok, personal collection of Astiko et al., 2023a) were inoculated with the funnel technique (Hodge et al., 2000). A filter paper was folded into a triangular shape, filled with 40 g of the MAA isolate (mycorrhiza from Akar-Akar village), on which the seed of host plant (glutinous corn variety of "Kumala F1.") was set. The filter paper and its contents were then covered with soil to support plant growth (Astiko et al., 2022).

After 50 days, the soil from the culture pot was collected. The plant roots were cut, finely blended, and evenly mixed with the soil from the culture, then passed through a 2 mm diameter sieve. This inoculant mixture was then combined evenly with cow manure, rice husk charcoal, compost, and organic fertilizer, each making up 50% of the total mixture. Finally, the ameliorant mixture was sieved again using a 2 mm diameter sieve, resulting in a fine, powder-like product.

The application of the ameliorant combined with mycorrhiza was carried out at planting time. The bioameliorant mixed with mycorrhiza, in its flour form, was evenly distributed at a depth of approximately 10 cm, forming a consistent layer. This bioameliorant mixture consisted of root fragments, fungal spores, fungal hyphae, and pot culture medium, applied according to the treatment dosage.

**2.4. Fertilization**

Fertilization involved the application of different ameliorant mixtures (applied at planting time at a rate of 15 tons per hectare) and half the recommended dose of inorganic base fertilizer (175 kg/ha of urea and 125 kg/ha of phonska). The inorganic fertilizer was applied in two stages: half of the dose at 10 days after planting (DAP) and the remaining half at 20 DAP.

**2.5.** **Observation Parameters**

2.5.1. Plant Height

Plant height and number of leaves were measured at 14, 28, 42, and 56 days after planting (DAP) on three sample plants per treatment (Astiko et al., 2025).

2.5.2. Wet and Dry Biomass Weight

Measurements of wet and dry biomass weight (oven-dried at 60°C for 48 hours) of shoots and roots were taken at 42 and 56 DAP. Wet and dry stover weight (sun-dried for 7 days) was recorded per plot at 64 DAP. Cob length was measured from tip to base (cm) at 64 DAP, and wet and dry cob weight per plant was measured after harvest (Astiko et al., 2025).

2.5.3. Soil Nutrient Concentration

The concentrations of nitrogen (N) and phosphorus (P) in the soil, along with plant N and P uptake at 42 DAP, were measured using the Kjeldahl and Bray II methods with a spectrometer (Goyal et al., 2022; Bray & Curtis, 1957).

2.5.4. Spore Density and Root Mycorrhization Parameters

Mycorrhizal spores were extracted at 42 and 64 DAP through the wet sieving and decanting technique (Pacioni, 1992). A 100 g soil sample from the rhizosphere was soaked, centrifuged, and separated with a 50% sugar solution. Spore counting was performed using a stereo microscope at 40x magnification.

Root infection percentage at 42 and 64 DAP was determined through the clearing and staining technique (Phillips & Hayman, 1970) and assessed using the Gridline Intersect method (McGonigle et al., 1990) under a stereo microscope with 40x magnification.

**2.6. Statistical Analyses**

All parameters were analyzed using two-way ANOVA and Tukey's HSD (Honestly Significant Difference) means-tested at a 5% level of significance using the Costat for Windows program version 6.451.

**3. RESULTS AND DISCUSSION**

**3.1. Plant Height**

The results showed that the ameliorant mixture treatment of 50% cow manure and 50% mycorrhizal biofertilizer (A1: 50% CM + 50% M) had a significant effect on the height of corn plants compared to other ameliorant mixtures (A5) from 28 to 56 days after planting (DAP) (Table 1). At 56 DAP, the treatment with 50% cow manure and 50% mycorrhizal biofertilizer produced the highest plant height of 148.00 cm, which was significantly different (P<0.05) from the ameliorant mixture treatments (A5).

**Table 1. Average Height of Corn Plants (cm) in Various Ameliorant Mixtures**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | | | |
| **14 DAP** | **28 DAP** | **42 DAP** | **56 DAP** |
| A1:CM 50%+M 50% | 15.00 a | 36.00 a | 138.33 a | 148.00 a |
| A2: C 50%+M 50% | 13.33 ab | 34.33 ab | 111.00 ab | 146.66 a |
| A3: OF 50%+M 50% | 12.33 ab | 32.66 ab | 98.00 bc | 139.66 a |
| A4: HC 50%+M 50% | 11.00 ab | 31.33 bc | 94.00 bc | 128.66 ab |
| A5: MIX 50%+M 50% | 10.00 b | 32.33 c | 82.33 c | 116.66 b |
| HSD 5% | 4.92 | 6.35 | 27.71 | 20.47 |

*Description: The mean values followed by the same letter in the same column are not significantly different according to the 5% HSD test, CM (Cow Manure), M (Mycorrhiza), the meaning of the abbbreviation in the tretment: C (Compost), OF (“Subur” organic Fertilizer), HC (Rice Husk Charcoal), and MIX ( Mixture).*

Table 1 shows that plant height increases as the plant’s age advances. The treatment with a mixture of 50% cow manure and 50% mycorrhizal biofertilizer consistently produced the highest results at each observation period (14, 28, 42, and 56 DAP). This indicates that the combination of cow manure and mycorrhiza provides optimal support for the growth of corn plants.

The increase in plant height is believed to be the result of improvements in the physical, chemical, and biological properties of the soil caused by cow manure. According to Assefa & Tadesse (2019), the application of organic fertilizers like manure supplies essential macro- and micronutrients needed by plants and enhances soil structure, water availability, and aeration. These improvements promote better root penetration and more efficient nutrient absorption. Fu et al. (2022) also stated that well-structured soil supports root system development and increases nutrient uptake efficiency.

In addition, the symbiotic relationship between mycorrhizal fungi and plant roots plays a crucial role in increasing the nutrient absorption capacity of plant, especially phosphorus (P), by expanding the root absorption zone through external hyphal networks (Bhantana et al., 2021). The combination of cow manure and mycorrhiza can stimulate increased photosynthetic activity, thus producing photosynthate that supports vegetative growth, including plant height.

Fall et al. (2022) emphasized that improving the physical, chemical, and biological properties of soil enhances plant metabolic activity and accelerates the growth processes. Therefore, the treatment of 50% cow manure + 50% mycorrhiza (KS 50% + M 50%) proved to be the most effective in creating soil conditions that support optimal corn plant growth, as reflected by the higher plant height compared to other ameliorant treatments.

**3.2. Number of Leaves**

In general, the treatment with a mixture of 50% cow manure and 50% mycorrhiza (A1) had a significant effect (P<0.05) on the number of corn leaves compared to other ameliorant treatments. This treatment, 56 DAP, produced the highest number of leaves and was significantly different from the other treatments (Table 2).

**Table 2. Average Number of Corn Plant Leaves in Various Ameliorant Mixtures**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Number of leaves** | | | |
| **14 DAP** | **28 DAP** | **42 DAP** | **56 DAP** |
| A1:CM 50%+M 50% | 7.33 a | 9.66 a | 11.33 a | 11.66 a |
| A2: C 50%+M 50% | 5.00 b | 8.66 ab | 10.00 b | 10.66 b |
| A3: OF 50%+M 50% | 5.00 b | 8.00 bc | 9.33 bc | 9.66 c |
| A4: HC 50%+M 50% | 4.66 b | 7.33 bc | 8.66 c | 9.00 d |
| A5: MIX 50%+M 50% | 4.66 b | 6.66 c | 7.66 d | 8.33 e |
| HSD 5% | 1.49 | 1.59 | 0.80 | 0.64 |

*Description: A complete descriptions are provided in Table 1.*

The increase in the number of leaves is believed to be related to the availability of sufficient nutrients, particularly nitrogen (N) and potassium (K), which play a crucial role in the formation of plant vegetative organs. Cow manure provides essential macro- and micronutrients that are important for increasing soil fertility and supporting microbial activity (Bello & Yusuf, 2021), while mycorrhiza increases the absorption of nutrients, especially phosphorus (P), thus encouraging optimal leaf growth.

Nitrogen is vital for chlorophyll formation and cell elongation, which increases the number and size of leaves (Muhammad et al., 2022), which is essential in photosynthesis process. This process is supported by Potassium through the regulation of the opening and closing of stomata, contributing to increased photosynthate production as an energy source for growth (Sardans & Peñuelas, 2021). This condition allows the plant to produce more leaves on each stem segment as the plant increases in height.

The combination of cow manure and mycorrhiza has proven effective in providing balanced nutrition, improving soil structure, and supporting optimal leaf growth in corn plants (Ozlu et al., 2019).

**3.3.** **Wet and Dry Biomass Weight of Corn Per Plant**

The results of the variance analysis showed that the application of a mixture of 50% cow manure and 50% mycorrhiza (A1) had a significant effect (P<0.05) on the increase in wet and dry biomass weight of the roots and shoots of corn plants compared to A5 mix treatment. The results of the 5% HSD test indicated that at 42 DAP, the A1 treatment produced wet biomass weights of 121.44 g for shoots and 34.27 g for roots per plant, which were higher than those of the other ameliorant mixture treatments. Similarly, the dry biomass weights of shoots and roots reached 47.00 g and 26.10 g per plant, respectively. At 56 DAP, the increase in biomass was even more pronounced, with wet biomass weights of 186.51 g for shoots and 61.55 g for roots, and dry biomass weights of 96.52 g and 32.21 g per plant, respectively (Table 3).

The increase in biomass weight indicates that the combination of cow manure and mycorrhiza provides essential nutrients in optimal amounts for plant growth. Cow manure is known as a complete source of nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), which support vegetative growth and improve soil structure (Rayne & Aula, 2020). Mycorrhiza enhances nutrient absorption, especially phosphorus, by expanding the root system’s reach and increasing the efficiency of water and nutrient uptake (Wahab et al., 2023).

The significant increase in root biomass weight suggests that the improved soil conditions created by this ameliorant result in a more crumbly and porous texture, which supports better root development (Lee et al., 2024). A well-developed root system improves the plant’s ability to absorb water and nutrients, contributing to the formation of strong, healthy plant tissue (Hamid et al., 2020).

The combination of cow manure and mycorrhiza has been proven to have a significant positive impact on increasing both wet and dry biomass weight in corn plants, for both roots and shoots (Qin et al., 2020). This demonstrates that this ameliorant treatment effectively enhances soil conditions and nutrient availability, supporting overall plant growth.

**Table 3. Average Wet and Dry Biomass Weight of Corn Plant Shoots and Roots in Various Ameliorant Mixtures Per Plant at Ages 42 and 56 DAP**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Shoots (g)** | | **Root (g)** | | | |
| **42 DAP** | **56 DAP** | **42 DAP** | | **56 DAP** | |
| **Wet Biomass** |  |  |  | |  | |
| A1:CM 50%+M 50% | 121.44 a | 186.51 a | 34.27 a | 61.55 a | |
| A2: C 50%+M 50% | 120.64 a | 142.92 ab | 31.14 b | 50.95 ab | |
| A3: OF 50%+M 50% | 112.14 ab | 131.71 b | 26.68 c | 44.40 ab | |
| A4: HC 50%+M 50% | 107.42 b | 111.37 b | 20.94 d | 26.14 c | |
| A5: MIX 50%+M 50% | 96.20 c | 95.65 b | 15.68 e | 19.86 c | |
| HSD 5% | 10.77 | 58.15 | 2.97 | 11.81 | |
| **Dry Biomass** |  |  |  | |  | |
| A1:CM 50%+M 50% | 47.00 a | 96.52 a | 26.10 a | | 32.21 a | |
| A2: C 50%+M 50% | 43.21 ab | 73.31 ab | 20.58 ab | | 29.28 b | |
| A3: OF 50%+M 50% | 42.24 ab | 60,881 bc | 18.27 ab | | 27.68 bc | |
| A4: HC 50%+M 50% | 38.47 b | 58.64 bc | 11.40 bc | | 25.74 c | |
| A5: MIX 50%+M 50% | 27.46 c | 48.02 b | 6.11 c | | 22.39 d | |
| HSD 5% | 5.75 | 24.07 | 11.81 | | 2.47 | |

*Description: A complete descriptions are provided in Table 1.*

**3.4.** **Wet and Dry Weight of Corn Per Plot**

The treatment with a mixture of 50% cow manure and 50% mycorrhiza (A1) had a significant effect (P<0.05) on the wet and dry stover weight of the roots and shoots of corn plants compared to other ameliorant mixture treatments. Treatment A1 produced the highest wet and dry stover weights, namely 6.89 kg and 5.71 kg respectively per plot of corn plants at 56 DAP. In contrast, the mixed treatment of 50% compost and 50% mycorrhiza (A5) showed the lowest wet and dry stover weights, at 3.86 kg and 2.50 kg per plot, respectively (Table 4).

**Table 4. Average Weight of Wet and Dry Stover per Plot (kg) of Corn for Ameliorant Mixture at 56 DAP**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Wet weight stover** | **Dry weight stover** | | |
| A1:CM 50%+M 50% | 6.89 a | | 5.71 a |
| A2: C 50%+M 50% | 5.43 b | 4.05 b | | |
| A3: OF 50%+M 50% | 4.91 bc | 3.07 bc | | |
| A4: HC 50%+M 50% | 4.30 bc | 3.15 cd | | |
| A5: MIX 50%+M 50% | 3.86 c | 2.50 d | | |
| HSD 5% | 1.25 | 1.11 | | |

*Description: A complete descriptions are provided in Table 1.*

The increase in wet and dry stover weight observed in the A1 treatment was caused by the synergistic effect of cow manure and mycorrhiza in providing macro and micronutrients essential for plant growth. Cow manure is recognized as a valuable source of organic nutrients, such as nitrogen (N), phosphorus (P), potassium (K), and beneficial microorganisms that help to decompose organic matter and improve soil structure (Peng et al., 2023). Meanwhile, mycorrhiza enhances root development and increases nutrient uptake efficiency, especially phosphorus, alloowing for stronger plant growth (Shi et al., 2023).

The increase in wet stover weight indicates that the plants received sufficient water and nutrients, supporting vital physiological processes such as photosynthesis and biomass formation. Naeem et al. (2024) stated that most of the weight of plant stover comes from water content, which plays an important role in maintaining cell turgor and supporting plant metabolism. According to Rurangwa et al. (2018), wet stover weight is heavily influenced by plant and environmental humidity conditions. The well-developed root system resulting from the application of 50% cow manure + 50% mycorrhiza (A1) treatment allows for optimal water and nutrient absorption, resulting in higher wet stover weight.

The increase in dry stover weight in the A1 treatment suggests that the plants not only retained water but also produced more dry matter due to efficient photosynthesis. The photosynthates produced were distributed throughout the plant, supporting the development of vegetative tissues such as leaves, stems, and roots (Ortuño et al., 2018). Additionally, microbial activity in the cow manure contributed to improving nutrient availability and the soil’s water-holding capacity, further enhancing overall plant growth (Gavili et al., 2019).

**3.5. Soil Nutrient Concentration**

The application of different ameliorant mixtures had a significant impact on total nitrogen (N) concentration and available phosphorus (P) in the soil. The combination of 50% cow manure and 50% mycorrhiza (A1) gave the highest results, showing a significant difference (P<0.05) compared to other ameliorant treatments both at 42 DAP and 56 DAP (Table 5).

**Table 5. Average Concentration of Total N and Available P Nutrients in Various Ameliorant Mixtures at Age 42 and 56 DAP**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **N total (g kg -1 )** | | **P available (mg kg -1 )** | |
| **42 DAP** | **56 DAP** | **42 DAP** | **56 DAP** |
| A1:CM 50%+M 50% | 1.82 a | 8.87 a | 51.69 a | 67.77 a |
| A2: C 50%+M 50% | 1.62 b | 6.83 ab | 36.34 b | 44.57 b |
| A3: OF 50%+M 50% | 1.60 b | 5.43 b | 26.00 c | 39.26 c |
| A4: HC 50%+M 50% | 1.45 c | 3.01 c | 20.01 d | 24.45 d |
| A5: MIX 50%+M 50% | 0.83 d | 2.21 c | 16.45 e | 19.21 e |
| HSD 5% | 0.026 | 2.54 | 0.04 | 0.24 |

*Description: A complete descriptions are provided in Table 1.*

As shown in Table 5, the combination of 50% cow manure and 50% mycorrhiza (A1) produced the highest levels of total nitrogen (N) and available phosphorus (P) in both observation periods (42 DAP and 56 DAP). This increase is attributed to the role of mycorrhiza in increasing the availability and absorption of nutrients, especially phosphorus. Mycorrhiza facilitates the conversion of phosphorus from insoluble forms to plant-accessible forms by producing organic acids and phosphatase enzymes (Shrivastava et al., 2018). These compounds help release phosphorus bound to elements such as aluminum (Al-P) and iron (Fe-P), thereby increasing the amount of phosphorus available for plant to absorb.

In addition, the high phosphorus uptake observed in the A1 treatment also indicates a strong symbiotic relationship between the ameliorant and the host plant. Mycorrhizal colonization of the root system expands the area of nutrient uptake through external hyphae, which are much finer than plant root hairs and can access soil areas that are inaccessible to root hairs (Ma et al., 2021). This enables plants to absorb nutrients more efficiently from nutrient-depleted zones.

Increasing the availability and absorption of phosphorus also increases the absorption of other essential nutrients, such as nitrogen (N) and potassium (K). According to Saboor et al. (2021), mycorrhiza can increase the absorption of P, N, Zn, Cu, and S, while Shi et al. (2021) reported that mycorrhiza also increases the uptake of P, K, Ca, and Mg. Furthermore, Xue et al. (2022) emphasized that mycorrhizal application increases soil cation exchange capacity (CEC), total nitrogen concentration, and phosphorus availability, ultimately increasing the efficiency of nutrient absorption by plants.

Therefore, the treatment with a mixture of 50% cow manure and 50% mycorrhiza has proven effective in enhancing soil nutrient concentrations and improving nutrient uptake by corn plants. The synergistic interaction between cow manure as an organic material source and mycorrhiza as a biofertilizer contributes significantly to optimizing nutrient availability and absorption efficiency, thereby supporting optimal plant growth and yield.

**3.6. Plant Nutrient Absorption**

The A1 treatment consisting of a 50% combination of cow manure and 50% mycorrhiza caused a significant increase in nutrient uptake with the highest absorption amount compared to other treatments (Table 6). The significant increase in N and P absorption in the mixed treatment of 50% cow manure and 50% mycorrhiza is strongly suspected to be the result of synergy between the two types of fertilizer. Mycorrhiza plays an important role in expanding the range of nutrient absorption through external hyphae, which can reach soil areas inaccessible to the root hairs (Kleinert et al., 2018). These external hyphae increase nutrient absorption efficiency, particularly phosphorus, by breaking down tightly bound phosphate compounds in the soil into forms that are more easily absorbedby plants (Tian et al., 2021).

Moreover, high phosphorus absorption is closely related to the high percentage of mycorrhizal infection in the host plant’s roots. According to Smith et al. (2011), phosphorus plays a important role in cell division, flower, fruit, and seed formation, and accelerates plant maturity. Therefore, plants with optimal P absorption tend to exhibit better growth and higher yields.

**Table 6. Average N and P Nutrient Uptake by Plants in Various Ameliorant Mixtures Age 42 DAP**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **N uptake (g kg -1 )** | | | | **P absorption (g kg -1 )** | | | |
| **42 DAP** | |  | | **42 DAP** | |  | |
| A1:CM 50%+M 50% | 35.24 a | |  | | 3.83 a | |  | |
| A2: C 50%+M 50% | 32.26 b | |  | | 3.05 b | |  | |
| A3: OF 50%+M 50% | 30.28 c | |  | | 2.94 c | |  | |
| A4: HC 50%+M 50% | 28.65 d | |  | | 2.06 d | |  | |
| A5: MIX 50%+M 50% | 20.14 e | |  | | 1.93 e | |  | |
| HSD 5% | 0.191 |  | | 0.063 | | 0, | |

*Description: A complete descriptions are provided in Table 1.*

Zhu & Whelan (2018) demonstrated that the combination of NPK fertilization with ameliorants can increase the availability and absorption of N and P. Organic fertilizers decomposed by microbes produce organic acids that help release fixed phosphorus into available forms, making them more accessible to plants. This mechanism was in line with the research results of Astiko et al. (2025a) which reported that ameliorants increase the activity of phosphate-solubilizing bacteria, which then increases the availability of P in the soil.

In addition to phosphorus, the increase in nitrogen absorption with the 50% cow manure and 50% mycorrhiza treatment is attributed to the optimal mineralization process of organic matter in cow manure. This process releases nitrogen in ionic forms that plants can readily absorb through three main mechanisms: mass flow, diffusion, and cation exchange (Hidalgo et al. 2002). These mechanisms ensure the availability of nutrients in the soil solution, increasing the efficiency of plant nutrient uptake.

Overall, the high N and P uptake in the 50% cow manure and 50% mycorrhiza treatments indicated that the combination provided essential nutrients in sufficient amounts and in easily absorbable forms. As a result, plants can utilize these nutrients more effectively to support vegetative and generative growth, ultimately contributing to increased corn yields.

**3.7. Mycorrhizal Development**

The number of mycorrhizal spores and root colonization in corn plants was highest in the combination of 50% cow manure and 50% mycorrhizae compared to other ameliorant treatments (Table 7).

**Table 7. Average Number of Spores (spores per 100 g of soil) and Colonization Value (%-colonization) in Various Ameliorant Mixtures Aged 42 DAP and 56 DAP**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Number of spores** | | **Colonization** | |
| **42 DAP** | **56 DAP** | **42 DAP** | **56 DAP** |
| A1:CM 50%+M 50% | 1311.33 a | 3981.00 a | 93.33 a | 99.90 a |
| A2: C 50%+M 50% | 1052.33 ab | 2708.33 ab | 86.33 b | 96.66 ab |
| A3: OF 50%+M 50% | 891.66 ab | 1854.33 b | 76.66 cc | 90.00 ab |
| A4: HC 50%+M 50% | 816.66 b | 1507.00 b | 73.33 c | 86.66 bc |
| A5: MIX 50%+M 50% | 757.66 b | 1224.66 b | 63.33 d | 76.66 c |
| HSD 5% | 4.295 | 1.873 | 4.861 | 1.031 |

*Description: A complete descriptions are provided in Table 1.*

The combination of 50% cow manure and 50% mycorrhiza resulted in the highest spore production and mycorrhizal root colonization, namely 1311.33 spores per 100 g of soil at 42 DAP, which surged to 3981.00 spores per 100 g of soil by 56 DAP. Root colonization also reached its peak in this treatment, showing an infection rate of 93.33% at 42 DAP and nearly 100% (99.90%) at 56 DAP. The high spore counts and extensive colonization observed are likely related to the presence of organic matter from cow manure, which serves as an important nutrient source for soil microorganisms, including mycorrhizae. It was previously reported that the addition of organic matter to the soil enhances the population and activity of soil microorganisms by providing a rich carbon source for their energy needs (Srivastava et al., 2020).

The increase in the number of mycorrhizal spores is also thought to be related to increased plant metabolism, particularly photosynthesis, which produces photosynthate. This photosynthate is transported to the roots and serves as a carbon source for the mycorrhizae, promoting their development and causing to the formation of more spores (Salmeron-Santiago et al., 2021).

The high level of mycorrhizal root colonization reflects the formation of an effective symbiotic relationship between corn plants and mycorrhizae. The external hyphae of mycorrhizae expand the root’s absorption area, reaching nutrient-depleted regions surrounding the plant’s roots (Bender et al., 2019). This expanded network improves the plant’s capacity to take up essential nutrients, especially phosphorus and nitrogen, which in turn positively influences the growth and productivity of corn plants (Hafez et al., 2021).

Research by Astiko et al. (2025b) also confirmed these results, showing that the addition of organic matter promotes the growth of soil microorganisms, including mycorrhizal populations. This explains why the combination of 50% cow manure and 50% mycorrhiza, with its rich organic matter content, outperformed other treatments. The high spore count and extensive mycorrhizal colonization observed in this treatment suggest that the blend of cow manure and mycorrhiza effectively fosters the development of beneficial soil microbes and enhances the soil ecosystem. As a result, this improves nutrient uptake efficiency and boosts corn plant productivity.

**3.8. Yield Components**

The results of the study showed that the combination of 50% cow manure and 50% mycorrhiza gave the highest yield compared to other ameliorant mixture treatments. Several key corn yield components such as wet cob weight, dry cob weight, wet cob weight per plot, cob diameter, and cob length gave the results 143.09 g per plant, 87.00 g, 6.89 kg, 4.60 cm, and 23.75 cm, consecutively (Table 8).

**Table 8. Average Components of Corn Crop Yield in Various Ameliorant Mixtures at Age 64 DAP**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **WCW** | **DCW** | **WCWP** | **CD** | **CL** |  | |
| A1:CM 50%+M 50% | 143.09 a | 87.00 a | 6.89 a | 4.60 a | 23.75 a | |
| A2: C 50%+M 50% | 129.75 bc | 74.50 b | 5.43 b | 4.06 ab | 22.34 ab | |
| A3: OF 50%+M 50% | 124.56 b | 61.37 c | 4.91 bc | 3.66 bc | 21.16 b | |
| A4: HC 50%+M 50% | 111.36 bc | 47.42 d | 4.30 bc | 3.46 bc | 19.30 c | |
| A5: MIX 50%+M 50% | 104.98 c | 43.46 d | 3.86 c | 3.16 c | 16.92 d | |
| HSD 5% | 20.29 | 7.45 | 1.25 | 0.85 | 1.43 | | |

*Description: A complete descriptions are provided in Table 1, WCW (Wet cob weight), Dry cob weight (DCW), Wet cob weight per plot (WCWP), Cob diameter (CD), Cob length (CL).*

The combination of cow manure and mycorrhiza proved to be the most effective in increasing corn yield components. Cow manure provides an abundant supply of macro and micronutrients, thereby improving the physical, chemical, and biological characteristics of the soil. Meanwhile, mycorrhizae expand the plant’s nutrient uptake capacity by developing external hyphae that access areas beyond the root zone. As noted by Raya-Hernández et al. (2020), adequate nutrient availability ensures efficient photosynthesis, generating sufficient food reserves to support plant growth and the formation of generative structures like corn cobs.

The synergistic relationship between cow manure and mycorrhiza plays a vital role in boosting both wet and dry cob weight per plant and per plot. By colonizing plant roots, mycorrhiza extends the nutrient absorption zone within the rhizosphere (Gao et al., 2020). Its external hyphae take up key nutrients like phosphorus (P), nitrogen (N), sulfur (S), and zinc (Zn), all essential for plant growth and yield development. The enhanced absorption of N and P in mycorrhiza-inoculated plants is crucial for protein synthesis and the optimization of physiological processes like photosynthesis and respiration (Slimani et al., 2024). As a result, efficient photosynthesis produces abundant photosynthates, which are allocated to support both vegetative growth and generative organ development.

This effect was clearly seen in the mixed treatment of 50% cow manure and 50% mycorrhiza, where the plants exhibited wider and greener leaves, high photosynthatic production indicators, and efficient translocation of photosynthetic products to generative organs like corn cobs. Research by Khan et al. (2022) also supports this finding, stating that higher photosynthetic output resulted in greater biomass accumulation and optimal dry weight formation.

The combination of cow manure and mycorrhiza not only icreased nutrient absorption efficiency but also supported the development of larger, heavier cobs. Therefore, the treatment of 50% cow manure and 50% mycorrhiza was the best choice to increase corn yield components through the synergy of nutrient provision and the role of beneficial soil microbes in increasing nutrient availability and absorption efficiency.

**4. CONCLUTION AND RECOMMENDATIONS**

**4.1. Conclusion**

Based on the analysis and discussion it can be concluded that:

1. The combination of 50% cow manure (CM) and 50% mycorrhiza (M) treatment showed superior performance on various growth and yield parameters of corn such as; plant height, leaf count, wet and dry biomass weight, wet and dry cob weight, wet cob weight per plot, cob diameter, cob length, soil nutrient content, plant nutrient absorption, spore count, and mycorrhizal root colonization. These results highlight the effectiveness of this ameliorant mixture in increasing nutrient uptake efficiency and promoting optimal plant development.
2. The highest wet biomass weight of corn shoots and roots was observed at 56 DAP, with shoot biomass reaching 186.51 g per plant and root biomass at 61.55 g per plant. These findings suggest that the combination of 50% cow manure and 50% mycorrhizal biofertilizer played a crucial role in promoting the robust growth of the plant’s vegetative parts.
3. Soil nutrient concentrations peaked at 56 DAP, with total nitrogen (N) at 8.87 g kg⁻¹ and available phosphorus (P) at 67.77 mg kg⁻¹. Regarding nutrient uptake, corn plants treated with a 50% cow manure and 50% mycorrhiza mixture demonstrated the highest absorption at 42 DAP, with N uptake reaching 1.82 g kg⁻¹ and P uptake at 51.69 g kg⁻¹. This increase was largely due to the enhanced activity of mycorrhiza in expanding the nutrient absorption zone around the plant roots.

**4.2. Suggestions**

Drawing from the findings of this study, the following recommendations can be proposed:

1. For better growth and yield of corn plants, it is advisable for farmers to apply a 50% cow manure (CM) and 50% mycorrhiza (M) mixture as an ameliorant. This combination has been shown to enhance soil fertility, improve nutrient uptake efficiency, and significantly increase corn productivity, promoting sustainable agricultural practices.
2. Further research is suggested to evaluate the yield response of various glutinous corn varieties to the application of a 50% cow manure (CM) and 50% mycorrhiza (M) mixture on different soil types. This would help determine the effectiveness of this ameliorant combination across various soil conditions and assess the adaptability of glutinous corn varieties in improving production yields and quality.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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