OPTIMIZATION OF GROWTH AND YIELD OF GLUTINOUS CORN WITH THE APPLICATION OF AMELIORAN FORMULATION PLUS MYCORRHZA ON SANDY SOIL

ABSTRACT

Aims:
This study aimed at optimizing the growth and yield of glutinous corn through the application of an ameliorant formulation enriched with biological mycorrhizal fertilizer on sandy soil.

Study Design:
The research was carried out using a Randomized Block Design.

Place and Duration of Study:
The research was conducted from March to July 2024 in Telaga Wareng Village, Pemenang Barat District, North Lombok Regency, Indonesia.

Methodology:
Five ameliorant treatments tested were: **F1**: 75% cow manure + 25% biological mycorrhizal fertilizer, **F2**: 75% compost + 25% biological mycorrhizal fertilizer, **F3**: 75% "fertile" fertilizer + 25% biological mycorrhizal fertilizer, **F4**: 75% rice husk charcoal + 25% biological mycorrhizal fertilizer, and **F5**: 20% cow manure + 20% compost + 20% "fertile" fertilizer + 20% rice husk charcoal + 20% biological mycorrhizal fertilizer. Each treatment was repeated four times, resulting in 20 experimental plots. The observed parameters were plant height, number of leaves, wet and dry biomass weight per plant, wet and dry cob weight per plot, soil nutrient concentrations (total nitrogen and available phosphorus), nutrient uptake (nitrogen and phosphorus), mycorrhizal spore count, root colonization, and crop yield. Data were subjected to Analysis of Variance and where necessary followed by Honestly significant Different test at 5% level of significant.

Results:
The 20% mixed ameliorant formulation (F5) produced the best results, significantly optimizing the growth and yield of glutinous corn. This treatment improved plant height, biomass weight, cob weight and length, soil nutrient concentrations (total nitrogen and available phosphorus), nutrient uptake, mycorrhizal spore count, and root colonization.

Conclusion:
The application of a 20% mixed ameliorant formulation consisting of cow manure, compost, "fertile" fertilizer, rice husk charcoal, and biological mycorrhizal fertilizer significantly enhanced growth, yield, and soil nutrient utilization efficiency in glutinous corn grown on sandy soil.

Keywords: Ameliorant, mycorrhiza, glutinous corn, soil sand, growth and yield

1. INTRODUCTION

Corn is one of the primary agricultural commodities in Indonesia, alongside rice and soybeans. In 2021, nationally, household corn consumption reached 391,000 tons, marking a 7.63% increase from the previous year (Kamaludin et al., 2021). Expanding corn cultivation on a larger scale with higher productivity has great potential to support regional economy.

One type of corn with unique characteristics is glutinous corn (*Zea mays* L. var. ceratina), known for its sticky and soft texture due to its high amylopectin content (Saikaew, 2018). In addition, its high protein, fiber, fat, and carbohydrate content makes it a potential food source for development (Loy and Lundy, 2019). However, due to limited promotion and attention, glutinous corn is not yet widely popular among urban communities, posing a risk of losing its status as a valuable germplasm resource.

Despite its low production, less than 2 tons per ha (Khamis and Papenbrock, 2014), glutinous corn has such an advantage of being drought tolerant that is suitable for cultivation in areas with low rainfall. Hence, West Nusa Tenggara, particularly in its sandy soil regions, has strong potential for developing glutinous corn cultivation.

Sandy land is one of the most extensive types of marginal land in Indonesia. It is characterized by a high proportion of macropores, resulting in low water-holding capacity (Dookoohaki et al., 2017). In West Nusa Tenggara, approximately 84% (1.8 million ha) of the area is drylands that can be developed for agriculture (Astiko et al., 2022). In North Lombok Regency, around 30% (38,000 ha) of dryland has been used to grow food crops like corn (Hermanto et al., 2014). However, productivity on this area is not yet optimal, necessitating innovative strategies to increase yields.

increasing corn productivity can be achieved by improving soil fertility through the application of organic and inorganic fertilizers (Gao et al., 2020). One effective approach is the use of ameliorants, soil improvement materials designed to enhance soil fertility and support plant growth.

Bio-ameliorant is a combination of biological agents (e.g., microbial fertilizers) with soil-improving materials such as organic manure, compost, and rice husk charcoal, enriched with microorganisms and organic nutrients (Shimarmata et al., 2016). The application of ameliorants can improve soil fertility, structure, and porosity as well as promote the activity of beneficial soil microorganisms. Additionally, the use of biological fertilizers such as mycorrhizae are also an important alternative for increasing agricultural productivity, as these fungi Mycorrhizal fungi are able toform symbiotic associations with plant roots to increase nutrient absorption (Khaliq et al., 2022).

Previous studies have shown that mycorrhizal inoculation can improve the growth, yield, and nutrient absorption efficiency of corn (Ishaq et al., 2021). On North Lombok's sandy soils, indigenous mycorrhiza application through seed coating was proven to enhance plant growth, yield, and nutrient availability and absorption

(Astiko et al., 2019). Moreover, combination of mycorrhiza with organic and inorganic fertilizers effectively increased corn productivity on drylands (Astiko et al., 2023).

Compost, often used as an ameliorant, provides beneficial nutrients for plants. The quality of compost is determined by its carbon-to-nitrogen (C/N) ratio, which ideally ranges from 12 to 15 (Zhao et al., 2020). The application of compost at rates of 7.5–15 tons per hectare was shown to improve plant growth, fresh cob weight, and yield in sweet corn (Revilla et al., 2021).

This study aimed at optimizing the growth and yield of glutinous corn through the application of an enriched ameliorant formulation combined with biological mycorrhizal fertilizer on sandy soil

2. METHODOLOGY

2.1. Time and Place

This study was conducted from March to July 2024, in Telaga Wareng Village, Pemenang Barat District, North Lombok Regency, Indonesia.

2.2. Experimental Design

The experiment was designed completely Randomized Block with five treatments; F1: 75% cow manure + 25% mycorrhizal biofertilizer, F2: 75% compost + 25% mycorrhizal biofertilizer, F3: 75% "fertile" fertilizer + 25% mycorrhizal biofertilizer, F4: 75% rice husk charcoal + 25% mycorrhizal biofertilizer, F5: 20% cow manure + 20% compost + 20% "fertile" fertilizer + 20% rice husk charcoal + 20% mycorrhizal biofertilizer. Each treatment was replicated four times.

2.3. Preparation and application of Ameliorant Plus Mycorrhiza Indigenous

The ameliorant plus indigenous mycorrhiza was prepared by homogeneously mixing sterilized cow manure and sterile soil in a 1:1 ratio in 10-kg polybag pots. Each pot was inoculated with 40 g of mycorrhizal inoculum, originated from North Lombok (Astiko, personal collection), applied above the seeds of corn as the host plant. The plants were maintained for 50 days, after which they were uprooted, and the roots and soil were air-dried for a week. The dried inoculum was then sieved and ground to produce powdered mycorrhizal inoculum, which was then mixed with the ameliorant materials to form the ameliorant formulation.

2.4. Plant Maintenance

The experimental field was kept free of weeds with sufficient soil moisture. In the case of no rain, irrigation was done with a sprinkler system. Pest and disease control was conducted by spraying a vegetable pesticide (Organem) with a concentration of 2% every 7 days, starting at 1 week after planting (WAP) until the plants reached the age of 8 WAP.

2.5. Observation Parameters

1) **Growth Parameters**: Plant height and the number of leaves were recorded at 2, 4, 6, and 8 WAP for three sample plants per treatment. 2) **Biomass**: Wet and dry (oven-dried at 60°C for 48 hours) biomass weights of shoots and roots were measured at 6 and 9 WAP. 3) **Yield Parameters**: Wet and dry safe weights (air-dried for 7 days) per plot were recorded at 9 WAP. Cob length (measured from tip to base) and wet and dry cob weights (oven-dried at 60°C for 48 hours) were measured after harvest. 4) **Nutrient Concentrations**: Soil total nitrogen (N) and available phosphorus (P), as well as plant N and P uptake, were determined at 6 WAP using the Kjeldahl and Bray II methods with a spectrometer. 5) **Mycorrhizal Spore Count and Root Colonization**: Mycorrhizal spores were extracted at 6 and 9 WAP using the wet sieving and decanting technique. A 100-g soil sample from the rhizosphere was soaked, centrifuged, and separated using a 50% sucrose solution, followed by spore counting under a stereo microscope at 40x magnification. Root colonization percentages were assessed at 6 and 9 WAP using the clearing and staining method (Vierheilig et al., 2005) and the gridline intersect method (McGonigle et al., 1990) under a stereo microscope at 40x magnification.

3. RESULTS AND DISCUSSION

3.1. Plant Height

The analysis of variance revealed that the F5 ameliorant formulation (20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased the height of corn plants from 4 to 8 WAP. Among all treatments, F5 exhibited the highest plant height compared to other formulations (Table 1).

Table 1. Average Height of Corn Plants (cm) Across Different Ameliorant Plus Mycorrhiza Formulations

Treatment	Plant height (cm)			
	2 WAP	4 WAP	6 WAP	8 WAP
F1: 75% CM + 25% M	10.6a	33.0a	77.0a	129.0a
F2: 75% C + 25% M	10.0a	32.6ab	74.0ab	127.6ab
F3: 75% FF + 25% M	9.6a	30.3ab	68.0bc	124.6b
F4: 75% RHC + 25% M	9.6a	30.0b	66.6c	120.0c
F5: 20% MIX	10.3a	33.0a	78.0a	131.3a
HSD 5%		2.7	6.8	4.2

Description: F1: 75% cow manure + 25% mycorrhiza; F2: 75% compost + 25% mycorrhiza; F3: 75% "fertile" fertilizer + 25% mycorrhiza; F4: 75% rice husk charcoal + 25% mycorrhiza; F5: 20% mix (cow manure, compost, "fertile" fertilizer, rice husk charcoal, and mycorrhizal biofertilizer).

The F5 ameliorant formulation significantly enhanced the nutrient supply and improved the physical, chemical, and biological characteristics of sandy soil. Improved soil physical conditions, such as better aeration, moisture retention, and root growth, contributed to improved plant development. Beneficial compounds such as auxins and vitamins that may be derived from plant residues, manure, compost, and soil microbes, were thought to stimulate biological activity and fulfill the plant's nutritional needs, leading to better growth.

Mycorrhiza and other soil microbes played a crucial role in nutrient delivery, especially nitrogen, which is essential for vegetative growth. Nitrogen encourages leaf, stem, and root development (Bücking, & Kafle, 2015). Additionally, potassium supports photosynthesis and cell division, further promoting shoot elongation and an increase in plant height (Hasanuzzamam et al, 2018).

The average of plant height recorded in this study was much shorter than the height of typical glutinous corn (150–225 cm). This shorter plant height may be due to the sandy soil's high porosity, leading to nutrient leaching, and environmental factors such as insufficient sunlight and excessive rainfall. Excessive rain likely caused nutrient loss through leaching, while reduced sunlight due to cloud cover negatively impacted photosynthesis. According to Waqas et al., (2021), climatic factors such as sunlight radiation, temperature, and rainfall significantly influence plant growth. High cloud cover during the rainy season can limit sunlight radiation, reducing crop yields (Yang et al., 2021), which may explain the suboptimal productivity of glutinous corn in this study.

3.2. Number of Leaves

As its effect on plant height, the F5 ameliorant formulation (20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased the number of leaves in corn plants from 2 to 8 weeks after planting (WAP) compared to other treatments (Table 2).

Table 2. Average Number of Corn Plant Leaves Across Different Ameliorant Plus Mycorrhiza Formulations

Treatment	Number of leaves (blades)			
	2 WAP	4 WAP	6 WAP	8 WAP
F1: 75% CM + 25% M	5.3^{ab}	9.0^{ab}	10.6^{b}	11.0^{ab}
F2: 75% C + 25% M	5.0^{ab}	8.3^{bc}	10.3^{ab}	10.6^{ab}
F3: 75% FF + 25% M	4.6^{bc}	9.0^{c}	10.0^{bc}	10.3^{bc}
F4: 75% RHC + 25% M	4.0^{c}	8.0^{c}	9.3^{c}	9.3^{c}
F5: 20% MIX	5.6^{a}	9.6^{a}	11.0^{a}	11.6^{a}
HSD 5%	0.6	0.9	0.9	1.1

Description*:* Treatment descriptions are provided in Table 1.

The F5 ameliorant formulation demonstrated superior performance compared to other treatments. The effectiveness of the F5 mixture can be attributed to its more complete nutrient composition, providing essential elements that support plant growth more effectively.

The total number of leaves observed was influenced by genetic, environmental, and sunlight exposure factors, all of which are crucial for plant growth (Maiti & Singh, 2017). The F5 formulation supplied adequate nitrogen and potassium during the vegetative phase, promoting shoot elongation and an increase in both plant height and the number of leaves. In addition, the F5 formulation provided micronutrients, including copper (Cu) and zinc (Zn), which play an essential role in cell wall formation and overall plant development (Astiko et al., 2025). These nutrients significantly enhanced plant height and leaf production in sandy soils, which typically lack of these critical micronutrients.

3.3. Wet and Dry Biomass Weight of Corn Plants

Besides the positive effects on plant height and number of leaves, the F5 ameliorant formulation (20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased both wet and dry biomass weights of shoots and roots at 6 and 9 WAP compared to other ameliorant formulations with mycorrhiza (Table 3).

Table 3. Average Weight of Corn Shoot and Root Biomass in Wet and Dry Biomass for Various Ameliorant Plus Mycorrhiza Formulations at 6 and 9 WAP

Treatment	Shoot (g)		Root (g)	
	6 WAP	9 WAP	6 WAP	9 WAP
Wet Biomass				
F1: 75% CM + 25% M	109.69 ^{ab}	113.99 ^{b}	13.58 ^{ab}	23.80 ^{a}
F2: 75% C + 25% M	105.30 ^{bc}	112.09 ^{b}	12.21 ^{bc}	21.79 ^{ab}
F3: 75% FF + 25% M	101.14 ^{cd}	105.31 ^{bc}	11.69 ^{bc}	18.22 ^{b}
F4: 75% RHC + 25% M	96.77 ^{d}	99.01 ^{c}	10.35 ^{c}	14.14 ^{c}
F5: 20% MIX	111.99 ^{a}	132.49 ^{a}	16.54 ^{a}	25.66 ^{a}
HSD 5%	5.21	9.63	3.14	3.92
Dry Biomass				
F1: 75% CM + 25% M	13.27 ^{b}	35.70 ^{b}	5.88 ^{b}	12.92 ^{b}
F2: 75% C + 25% M	12.14 ^{bc}	35.32 ^{b}	5.46 ^{bc}	11.06 ^{c}
F3: 75% FF + 25% M	11.33 ^{cd}	33.24 ^{c}	5.25 ^{bc}	10.43 ^{cd}
F4: 75% RHC + 25% M	10.48 ^{d}	30.67 ^{d}	4.60 ^{c}	9.32 ^{cd}
F5: 20% MIX	15.72 ^{a}	38.57 ^{a}	7.63 ^{a}	14.71 ^{a}
HSD 5%	1.43	1.91	0.96	1.27

Description: Treatment descriptions are provided in Table 1.

The application of the F5 ameliorant formulation resulted in significantly higher biomass weights compared to all other treatments. This superior performance can be attributed to the balanced nutrient content of the F5 mixture, which provides a more comp[lete range of essential nutrients for plant growth. This finding was in line with Astiko et al. (2022a), which showed that organic ameliorants enhance dry root weight. Additionally, that organic ameliorants improve soil structure, making it more crumbly and conducive to root development and nutrient absorption.

The F5 formulation was thought more effectively to supply sufficient nitrogen (N) and phosphorus (P), crucial for plant growth, thereby enhancing N and P uptake (Table 6). The increased availability of these nutrients in the soil promotes higher wet and dry biomass weights for both shoots and roots. This becomes more possible since the use of ameliorants improves soil structure and nutrient availability, which in turn enhances nutrient absorption, supports the formation of new roots and branches, and contributes to overall plant growth and biomass accumulation (Astiko et al., 2023a).

3.4. Wet and Dry Weight of Corn Plants Per Plot

Furthermore, the F5 ameliorant formulation (comprising 20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased both wet and dry plant weights at 9 weeks after planting (WAP) compared to other ameliorant formulations (Table 4).

Table 4. Average Wet and Dry Biomass Weight Per Plot (kg) of Corn Plants for Various Ameliorant Plus Mycorrhiza Formulations at 9 WAP

Treatment	Wet vault weight	Dry weight of the stove
F1: 75% CM + 25% M	3.32 [b]	2.25 [b]
F2: 75% C + 25% M	3.15 [c]	2.10 [c]
F3: 75% FF + 25% M	2.74 [d]	1.93 [d]
F4: 75% RHC + 25% M	2.51 [e]	1.77 [e]
F5: 20% MIX	3.51 [a]	2.40 [a]
HSD 5%	0.12	0.10

Description: Treatment descriptions are provided in Table 1.

The application of the F5 ameliorant formulation yielded significantly higher results compared to other treatments. This superior performance of the F5 formulation was thought to be due to its balanced composition, which provides a more wide range of essential nutrients for plant growth.

The combination of ameliorants and mycorrhizal biofertilizer enhances nutrient supply in sufficient and balanced amounts to support corn plant growth. Sun et al. (2022) explained that mycorrhiza increases the root absorption area, improving nutrient uptake efficiency. The F5 formulation significantly increases wet and dry biomass weights because the plants may receive adequate nutrients to support metabolic processes, plant height growth, leaf production, and root development.

Improved of absorption of nutrient availability may enhance the production of dry biomass, as a result of photosynthesis, respiration, and the accumulation of organic compounds (Larney & Angers, 2012). Additionally, the optimal wet biomass weight is achieved because the plants' water requirements are adequately met, which is closely related to physiological and environmental processes (Sofyan et al., 2024).

This comprehensive nutrient and water availability ensures better plant growth and higher biomass production.

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3.5. Soil Nutrient Concentration

The results also indicated that the F5 ameliorant formulation (20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased the changes on the soil nutrient concentrations compared to other ameliorant formulations. The F5 formulation increased the total nitrogen (N) concentration from 1.85 g/kg at 6 WAP to 1.95 g/kg at 9 WAP. It also significantly increased the available phosphorus (P) concentration from 45.65 mg/kg at 6 WAP to 69.31 mg/kg at 9 WAP (Table 5).

Table 5. Average Concentration of Total N and Available P Nutrients in Various Ameliorant Plus Mycorrhiza Formulations at 6 WAP and 9 WAP

Treatment	Total N (g/kg)		P available (mg/kg)	
	6 WAP	9 WAP	6 WAP	9 WAP
F1: 75% CM + 25% M	1.65 [b]	1.75 [b]	40.11 [b]	61.85 [b]
F2: 75% C + 25% M	1.15 [c]	1.25 [c]	35.61 [c]	59.43 [b]
F3: 75% FF + 25% M	1.02 [d]	1.18 [d]	16.85 [d]	35.64 [c]
F4: 75% RHC + 25% M	0.98 [e]	1.02 [e]	15.54 [e]	20.02 [e]
F5: 20% MIX	1.85 [a]	1.95 [a]	45.65 [a]	69.31 [a]
HSD 5%	0.03	0.01	0.02	0.02

Description: Treatment descriptions are provided in Table 1.

The highest soil nutrient concentrations were observed in the treatment with the 20% MIX formulation (Table 5). This difference is due to the varied nutrient content in each formulation. The 20% MIX formulation performed better than treatments containing 75% rice husk charcoal + 25% mycorrhiza, 75% cow manure + 25% mycorrhiza, 75% "fertile" fertilizer + 25% mycorrhiza, and 75% compost + 25% mycorrhiza. The fertilizer mixture is more effective because it provides a diverse range of nutrients, optimizing nutrient absorption.

Additionally, plants associated with the 20% ameliorant + mycorrhiza formulation were more efficient in absorbing nitrogen (N), phosphorus (P), sulfur (S), zinc (Zn), and other essential nutrients. Mycorrhizal hyphae expand the root absorption area, enhancing nutrient uptake from the surrounding soil. This was in line with Mohammadi et al. (2011), who stated that nutrient absorption by plants occured through mass flow, root interception, and diffusion. These processes facilitate nutrient uptake by enabling water movement and root growth, which allow direct contact with essential nutrients in the soil.

3.6. Nutrient Uptake

The study also demonstrated that the F5 ameliorant formulation (20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased nutrient uptake by plants compared to other treatments (Table 6).

Table 6. Average N and P Nutrient Uptake by Plants in Various Formulations of Ameliorant Plus Mycorrhiza at 6 WAP

Treatment	N uptake (g/kg)	P absorption (g/kg)
	6 WAP	6 WAP
F1: 75% CM + 25% M	32.26 b	3.05 b
F2: 75% C + 25% M	30.28 c	2.94 c
F3: 75% FF + 25% M	28.65 d	2.06 d
F4: 75% RHC + 25% M	20.14 e	1.93 e
F5: 20% MIX	35.24 a	3.83 a
HSD 5%	0.14	0.05

Description*:* Treatment descriptions can be found in Table 1.

The higher uptake of nitrogen (N) and phosphorus (P) in the F5 treatment may be due to the symbiotic relationship between the mycorrhiza and the host plants. The mycorrhizal hyphae enhance the absorption area, increasing the uptake of N, P, and other essential nutrients. Mycorrhizal colonization facilitates the conversion of insoluble phosphates into a form that can be absorbed by the plants (Wang et al., 2017). Additionally, the bio-ameliorant, which is rich in organic ingredients, improves soil fertility, increases nutrient concentration, and promotes mycorrhizal activity, all of which support plant growth and nutrient absorption (Etesami et al., 2021).

3.7. Number of Spores and Mycorrhizal Colonization

The results of the study revealed that the F5 ameliorant formulation (20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased the number of spores and root colonization at 6 WAP and 9 WAP. The F5 treatment exhibited the highest colonization, with 2383 spores/100 g of soil and 86% colonization at 6 WAP, and 3344 spores/100 g of soil with 100% colonization at 9 WAP (Table 7).

Table 7. Average Number of Spores (per 100 g of soil) and Colonization Percentage (%) in Various Ameliorant Plus Mycorrhiza Formulations at 6 WAP and 9 WAP

Treatment	Number of spores		Colonization (%)	
	6 WAP	9 WAP	6 WAP	9 WAP
F1: 75% CM + 25% M	2062 b	3212 ab	80.00 ab	83.33 b
F2: 75% C + 25% M	1670 c	2898 bc	73.33 b	80.00 bc
F3: 75% FF + 25% M	1266 d	2642 c	60.00 c	73.33 cd
F4: 75% RHC + 25% M	1248 d	1980 d	53.33 c	66.66 d

F5: 20% MIX	2383 [a]	3344 [a]	86.66 [a]	100 [d]
HSD 5%	123.13	430.24	9.09	6.87

Description: Treatment descriptions can be found in Table 1.

The number of mycorrhizal spores and the percentage of root colonization in the F5 treatment (20% mixed ameliorant) were significantly higher than those of on the other ameliorant + mycorrhiza treatments (Table 7). This difference may be attributed to the balanced nutrient content in the F5 formulation, which provides more complete nutrition to the plants. The combination of organic materials and mycorrhizal fungi in the F5 formulation enhanced spore production and root colonization through symbiosis, expanding the nutrient absorption area and supporting plant metabolism.

Additionally, the mycorrhiza in the F5 formulation was thought to utilize photosynthates from the plant as a carbon source, promoting the formation of more spores. This was in line with Wahab et al. (2023), who found that mycorrhiza thrive optimally in well-aerated soils, such as sandy soils, especially under less fertile conditions. Mycorrhizal fungi help plants to absorb nutrients and water more efficiently, enhance disease resistance, and improve soil structure, particularly in dry farmlands. Furthermore, the higher nitrogen (N) content in the F5 formulation may contribute to mycorrhizal growth. Hartmann & Six (2023) stated that nitrogen availability positively influenced mycorrhizal activity, while organic matter, soil structure, and water content also supported spore development and root colonization.

High water content, however, can reduce oxygen availability, hindering spore germination, as noted by Barazetti et al. (2019). The organic materials present in the F5 formulation may further increase mycorrhizal infection rates and the number of spores around corn plant roots.

3.8. Plant Yield

The other and most encouraging result of this study was the F5 ameliorant formulation (20% cow manure, 20% compost, 20% "fertile" fertilizer, 20% rice husk charcoal, and 20% mycorrhizal biofertilizer) significantly increased the wet cob weight, dry cob weight, wet cob weight per plot, and cob length compared to other ameliorant formulations. The F5 treatment resulted in the highest cob weight and size, with 150 g wet cob weight, 94 g dry cob weight, 3 kg wet cob weight per plot, and 24 cm cob length (Table 8).

Table 8. Average Corn Yield Components in Various Ameliorant Plus Mycorrhiza Formulations at 9 WAP

Treatment	WCW	DCW	WCWP	CL
F1: 75% CM + 25% M	138.41 [a]	86.99 [b]	3.84 [a]	23.45 [ab]

F2: 75% C + 25% M	128.35 ^{ab}	87.30 ^{b}	3.67 ^{ab}	22.83 ^{abc}
F3: 75% FF + 25% M	123.84 ^{abc}	89.21 ^{b}	3.36 ^{bc}	22.49 ^{bc}
F4: 75% RHC + 25% M	114.20 ^{c}	82.24 ^{c}	3.20 ^{c}	21.74 ^{c}
F5: 20% MIX	150.01 ^{a}	94.60 ^{a}	3.97 ^{a}	24.10 ^{a}
HSD 5%	22.99	4.60	0.34	1.28

Description: WCW: Wet cob weight), DCW: Dry cob weight, WCWP: Wet cob weight per plot, CL: Cob length, Treatment descriptions can be seen in Table 1

The Increase of corn yield on treatment F5 was likely due to the balanced nutrient content, which supports key of plant physiological processes, such as photosynthesis and transpiration, leading to more efficient nutrient utilization. Phosphorus (P), which plays a crucial role in flower and fruit formation, supports the transport of photosynthates to the cob, resulting in larger cobs (Ocwa et al., 2024).

Additionally, the high nitrogen (N) and phosphorus (P) contents in the F5 formulation support both vegetative and generative plant growth. During the generative phase, phosphorus is mobilized for seed formation and filling, playing a role in energy storage (ATP and NADPH) and supporting nitrogen fixation activity (Nugraha et al., 2022).

Furthermore, the role of mycorrhiza in the F5 formulation may help to improve soil structure, increase nutrient absorption (especially phosphorus and nitrogen), and support photosynthesis. Mycorrhiza colonizes the roots, expanding their absorption area and reaching micro-pores in the soil, enhancing water and nutrient uptake. This increased absorption supported plant biomass growth and leads to higher seed yields per plot (Gujre et al., 2021; Atkinson et al., 2010).

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

The application of the 20% mixed ameliorant formulation (cow manure, compost, "fertile" fertilizer, rice husk charcoal, and mycorrhizal biofertilizer) resulted in the best plant growth and yield. This was demonstrated by improvements in plant height and leaf number (2–8 WAP), shoot and root biomass weight (6–9 WAP), weight per plot (9 WAP), cob weight and length, total nitrogen (N) and available phosphorus (P) nutrient concentrations, N and P nutrient uptake (6 WAP), and the highest spore count and root colonization (6–9 WAP).

4.2. Suggestions

Based on the results of this study, the following suggestions can be made:

1. Use a mixed organic ameliorant formulation (cow manure, compost, rice husk charcoal, and mycorrhizal biofertilizer) to improve the fertility of sandy soils.

2. Apply mycorrhizal biofertilizer to enhance nutrient absorption, particularly nitrogen (N) and phosphorus (P), and support plant growth.
3. Implement crop rotation or intercropping systems with legumes to naturally enrich the soil with nitrogen.
4. Utilize water-saving irrigation technologies, such as drip irrigation, and incorporate mulch to improve water retention in sandy soils.
5. Optimize the use of locally available ameliorant materials to reduce costs and promote sustainable agricultural practices.

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

The authors declare that they have no competing interests.

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