**EFFECTS OF CATTLE MANURE AND INDIGENOUS MYCORRHIZAL INOCULATION ON MYCORRHIZAL COLONIZATION, GROWTH, AND YIELD OF SWEET CORN IN SANDY SOIL**

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**ABSTRACT**

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| **Aims:** This study aimed to evaluate the combined effects of cattle manure and indigenous arbuscular mycorrhizal fungi (AMF) inoculation on root mycorrhizal colonization, the growth performance, and yield of sweet corn cultivated in sandy soil.**Study Design:** A randomized complete block design (RCBD) with four replications was employed to account for variability within the experimental field.**Place and Duration of Study:** The field experiment was conducted in Moncok Karya, Ampenan Subdistrict, Mataram City, West Nusa Tenggara, Indonesia (coordinates: 8°34′7″ S, 116°5′42″ E), from April to June 2025.**Methodology:** The experiment was conducted using a RCBD with five treatments and four replications, resulting in a total of 20 experimental units. The treatments were: P0: control (no cattle manure or mycorrhizal inoculation); P1: application of cattle manure 10 t/ha; P2: application of mycorrhizal 3 t/ha; P3: combination of cattle manure 5 t/ha and mycorrhizal 1.5 t/ha; and P4: combination of cattle manure 10 t/ha and mycorrhizal 3 t/ha. Parameters observed were plant height, number of leaves, fresh and dry biomass weight, ear weight, spore count, root mycorrhizal colonization, and final yield.**Results:** The combined application of cattle manure 10 t/ha and indigenous AMF 3 t/ha significantly improved the growth performance, yield, and soil biological activity of sweet corn cultivated in sandy soils. This treatment resulted in greater plant biomass and cob production compared to either sole applications or the control. Moreover, a substantial increase in root mycorrhizal colonization and spore density was observed, indicating improved symbiotic activity and microbial proliferation in the rhizosphere.**Conclusion:** The combined application of cattle manure 10 t/ha and indigenous AMF 3 t/ha significantly improved sweet corn growth, yield, and soil biological activity in sandy soils by increasing nutrient availability and promoting mycorrhizal colonization. |

*Keywords: Cattle manure, indigenous mycorrhiza, sweet corn, sandy soil*

**1. INTRODUCTION**

Sweet corn (*Zea mays* var. saccharata) has significant economic and nutritional value, driven by increasing consumer demand and widespread food processing applications. Its high sugar content, delicious texture, and improved organoleptic qualities have encouraged its widespread cultivation and processing into products such as corn porridge, canned corn, and instant corn-based foods (Singh et al., 2014; Aziz et al., 2019).

However, sweet corn yields remain constrained in many regions due to suboptimal soil conditions. In particular, sandy soils - characterized by low organic matter content, poor water-holding capacity, and limited cation exchange capacity (CEC) - pose serious constraints to crop productivity (Chen et al., 2018; da Silva et al., 2014). These soils also suffer from deficiencies in essential macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), which are crucial for plant growth, root development, and grain yield (Kiruthika et al., 2022; Dhaliwal et al., 2019).

Traditional fertilization regimens for sandy soils often rely on high doses of synthetic fertilizers to compensate for soil nutrient deficiencies. However, these practices are financially unsustainable and pose environmental risks, including nutrient leaching and soil degradation (Litskas, 2023). Consequently, agronomic research is shifting to more sustainable soil fertility management strategies.

One such strategy involves adding organic amendments. Cattle manure is rich in organic carbon, essential nutrients, and a soil microbial inoculant, all of which contribute to improved soil structure, increased water retention, and gradual nutrient release (Parham et al., 2002). Studies show that long-term application of cattle manure increases soil aggregation, microbial biomass, and soil enzymatic activity - key indicators of improved soil health (Ozores-Hampton et al., Naorem et al., 2023). However, in severely degraded sandy soils, manure alone may not fully restore nutrient cycling dynamics or optimize plant uptake efficiency (Ajayi & Horn, 2016).

To further improve nutrient use efficiency, particularly for immobile nutrients such as phosphorus, biological soil amendments are increasingly important. Arbuscular mycorrhizal fungi (AMF) - particularly indigenous strains - form symbiotic associations with plant roots that significantly extend nutrient uptake beyond the rhizosphere (Smith & Read, 2010). Furthermore, AMF colonization has been shown to increase plant resistance to drought and phosphorus limitation by improving root architecture and osmotic regulation (Astiko & Fauzi, 2016; Bahadur et al., 2019).

The integration of cattle manure with indigenous AMF inoculation is hypothesized to produce synergistic benefits. While the manure provides a sustained release of macronutrients and improves soil physical properties, the AMF enhances the uptake of essential nutrients, particularly phosphate, and promotes beneficial soil microbial interactions (Medina & Azcón, 2010). This integrated approach supports sustainable agriculture by optimizing soil fertility, reducing reliance on chemical inputs, and utilizing local resources.

In this context, our study aimed to investigate the combined effects of cattle manure and indigenous mycorrhizal inoculation on root mycorrhizal colonization, the growth performance, and yield of sweet corn cultivated in sandy soil. The findings are expected to inform sustainable soil management practices and support increased productivity for smallholder farmers in marginal environments.

**2. METHODOLOGY**

**2.1. Time and Place**

The field experiment was conducted in Moncok Karya, Ampenan Subdistrict, Mataram City, West Nusa Tenggara, Indonesia (coordinates: 8°34′7″ S, 116°5′42″ E), from April to June 2025.

**2.2. Experimental Design**

The experiment was conducted using a RCBD with five treatments and four replications, resulting in a total of 20 experimental units. The treatments were: P0: control (no cattle manure or mycorrhizal inoculation); P1: application of cattle manure 10 t/ha; P2: application of mycorrhizal 3 t/ha; P3: combination of cattle manure 5 t/ha and mycorrhizal 1.5 t/ha; and P4: combination of cattle manure 10 t/ha and mycorrhizal 3 t/ha. Parameters observed were plant height, number of leaves, fresh and dry biomass weight, ear weight, spore count, root mycorrhizal colonization, and final yield.

**2.3. Ameliorant and Mycorrhiza Indigenous**

Cattle manure and mycorrhizal biofertilizer were applied at planting time by spreading and mixing evenly into a 10 cm layer of soil. Mycorrhizal biofertilizer powder, consisting of a mixture of root fragments, fungal spores, hyphae, and pot culture media, was applied according to the treatment dosage. The indigenous mycorrhizal fungi used in this study originated from North Lombok and were maintained in the laboratory.

**2.4. Fertilization**

Fertilization was carried out using inorganic fertilizer at half the recommended dosage, namely 175 kg/ha of urea and 125 kg/ha of Phonska compound fertilizer (Astiko et al., 2016a). Inorganic fertilizer was applied twice, namely at 7 and 14 days after planting, each time at half the dosage..

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

Plant height and leaf number were observed at 14, 28, 42, and 56 days after planting (DAP). Fresh and dry shoot and root biomass (oven-dried at 60°C for 48 hours) were measured at 42 and 56 DAP. Fresh and dry stover weights per plot (sun-dried for 7 days) were recorded at 64 DAP. The number of mycorrhizal spores was observed at 42 and 64 DAP using the wet-and-pour sieving method. A 100-g soil sample from the rhizosphere was soaked, centrifuged, and separated using 50% sucrose solution. Spores were counted under a stereomicroscope at 40x magnification. The percentage of root colonization was determined at 42 and 64 DAP using the clearing and staining method (Kormanik & McGraw, 1982) and the Gridline Intersect technique (Giovannetti & Mosse, 1980), also under a stereo microscope at 40x magnification.

**3. RESULTS AND DISCUSSION**

**3.1. Plant Height**

Plant height as a response of sweet corn plants to the application of cattle manure and indigenous mycorrhizal inoculants was evaluated at 14, 28, 42, and 56 days after planting (DAP) presented in Table 1. Significant differences in plant height (p < 0.05) were observed between treatments at all measurement intervals, indicating that both organic and biological amendments affected early vegetative growth.

**Table 1. Average Plant Height of Sweet Corn (cm) at Different Growth Stages**

|  |  |
| --- | --- |
| **Treatments** | **Plant Height (cm)** |
| **14 DAP** | **28 DAP** | **42 DAP** | **56 DAP** |
| P0 | 34.23ᵈ | 55.63ᵉ | 112.08ᵉ | 120.52ᵉ |
| P1 | 41.36ᶜ | 63.46ᵈ | 126.30ᵈ | 134.80ᵈ |  |
| P2 | 45.46ᵇᶜ | 75.46ᶜ | 138.25ᶜ | 142.21ᶜ |  |
| P3 | 49.13ᵇ | 84.83ᵇ | 140.86ᵇ | 150.98ᵇ |  |
| P4 | 93.86ᵃ | 145.95ᵃ | 165.15ᵃ | 93.86ᵃ |  |
| LSD 5% | 4.042 | 4.444 | 1.437 | 2.076 |

Note: Means followed by the same letter in each column are not significantly different at the 5% level based on Least Significant Difference (LSD) test, P0: Control (no manur, no mycorrhiza), P1: Cattle manure 10 t/ha, P2: Mycorrhiza 3 t/ha, P3: Manure 5 t/ha + Mycorrhiza 1.5 t/ha, P4: Manure 10 t/ha + Mycorrhiza 3 t/ha

At 14 DAP, treatment P4 (10 t/ha manure + 3 t/ha mycorrhizae) showed the highest average plant height (57.06 cm), significantly outperforming all other treatments. The lowest value was recorded in the control (not fertilized) treatment P0 (34.23 cm). Similar trends were observed at 28, 42, and 56 DAP, with P4 consistently producing the highest plants at each growth stage, followed by P3 (5 t/ha manure + 1.5 t/ha mycorrhizae), P2 (mycorrhizae only), P1 (manure only), and P0. These results indicate that the combination of manure and mycorrhizae has a synergistic effect on plant growth.

The positive impact of manure on plant height can be attributed to its high organic matter and nutrient content, especially nitrogen (N), which plays a role in cell elongation and vegetative biomass accumulation (Leghari et al., 2016). Organic amendments improve soil structure, aeration, and moisture retention, which are important factors in sandy soils that typically experience rapid drainage and low nutrient retention (El-Nagar & Mohamed, 2019).

In addition, the presence of arbuscular mycorrhizal fungi (AMF) contributed significantly to increased plant height, especially in the early stages of growth. AMF form symbiotic associations with plant roots, expanding the effective root zone and enhancing the uptake of relatively immobile nutrients, especially phosphorus (P) [3]. Phosphorus is a key element in energy transfer and root development, both of which are essential for vigorous vegetative growth. Furthermore, mycorrhizal colonization has been associated with increased water uptake and drought tolerance, which is particularly beneficial in porous sandy soil conditions (Askari et al., 2019; Zhao et al., 2015).

The superior performance of the P4 treatment indicates that the integration of organic and biological amendments not only improves soil nutrient status but also enhances the efficiency of nutrient uptake by plants. This synergistic interaction between cow manure and indigenous AMF can also stimulate beneficial microbial activity in the rhizosphere, thereby improving nutrient cycling and root health (Zhu et al., 2016).

These results are consistent with previous studies demonstrating the benefits of integrated organic and microbial fertilization strategies on plant performance. For example, Astiko et al. (2013) reported increased vegetative growth and nutrient uptake in corn grown in sandy soil modified with cow manure and mycorrhizal fungi. Similarly, Mäder et al. (2002) observed increased root development and plant viability in an organic system incorporating AMF, resulting in increased plant growth and yield.

**3.2. Number of Leaves**

The number of sweet corn (Zea mays saccharata) leaves with various fertilizer treatments were observed at 14, 28, 42, and 56 days after planting. As presented in Table 2, all treatments significantly affected the number of leaves (p < 0.05) throughout all vegetative growth stages.

At 14 DAP, plants treated with a combination of 10 t/ha of cow manure and 3 t/ha of indigenous mycorrhizal inoculum (P4 treatment) showed the highest average number of leaves, namely 6.66 leaves per plant, significantly higher than other treatments. A similar trend was also observed at 28, 42, and 56 days after planting, where plants treated with P4 reached 12.33, 16.00, and 18.00 leaves, respectively, indicating increased leaf initiation and expansion compared to single treatments or untreated controls.

**Table 2. Average Number of Leaves per Sweet Corn Plant at Various Growth Stages**

|  |  |
| --- | --- |
| **Treatments** | **Number of Leaves** |
| **14 DAP** | **28 DAP** | **42 DAP** | **56 DAP** |
| P0 | 3.00ᵈ | 5.33ᵈ | 7.66ᵉ | 9.66ᵉ |
| P1 | 4.33ᶜ | 7.33ᶜ | 11.00ᵈ | 14.00ᵈ |  |
| P2 | 5.33ᵇᶜ | 8.66ᵇᶜ | 12.66ᶜ | 15.00ᶜ |  |
| P3 | 10.33ᵇ | 14.66ᵇ | 16.00ᵇ | 10.33ᵇ |  |
| P4 | 6.66ᵃ | 12.33ᵃ | 16.00ᵃ | 18.00ᵃ |  |
| LSD 5% | 0.687 | 1.140 | 0.972 | 0.486 |  |

Notes: Treatment descriptions are provided in Table 1.

The control treatment (P0) consistently showed the lowest number of leaves at all observation times, with only 9.66 leaves recorded at 56 DAP. Treatments with single cow manure (P1) or single mycorrhizae (P2) showed moderate effects, while the low-dose combination treatment (P3) performed better but did not surpass P4.

The higher leaf number observed with the integrated organic and mycorrhizal treatments can be attributed to several physiological and soil-related mechanisms. Cow manure increases soil organic matter content and nutrient availability, particularly nitrogen (N), phosphorus (P), and potassium (K), which are essential for leaf primordia formation and expansion (Liu et al., 2020; Eckhardt et al., 2018). Furthermore, organic amendments increase soil water-holding capacity and aeration, facilitating optimal root function and shoot growth in sandy soils known for poor nutrient and moisture retention (Das & Maharjan, 2023).

Indigenous AMF colonize plant roots and expand the effective root surface area, promoting more efficient nutrient uptake, particularly immobile nutrients such as phosphorus, which plays a crucial role in energy metabolism and cell division during leaf development (Khan et al., 2022; Smith & Read, 2008). Furthermore, AMF symbiosis can improve plant hormone balance by increasing the production of growth-promoting substances such as cytokinins and auxins, which directly influence the rate of leaf initiation (Pons et al., 2020)

The synergistic effect between cattle manure and AMF was expressed in the superior vegetative growth observed in the combined treatment. This synergy likely occurs because the organic amendment provides a favorable environment and substrate for AMF proliferation, which subsequently improves nutrient cycling and plant nutrient uptake, collectively stimulating leaf production and overall plant viability (Khan et al., 2022; Peng et al., 2023).

Previous studies have also reported that the integrated use of organic fertilizers and mycorrhizal inoculants improves vegetative growth parameters, including leaf number, in maize and other cereal crops cultivated on marginal or degraded soils (Khan et al., 2022; Liu et al., 2020). These findings underscore the importance of implementing an integrated soil fertility management approach to optimize crop growth and productivity sustainably.

**3.3. Weight of Fresh and Dry Biomass of Shoots and Roots**

The application of cattle manure and indigenous AMF significantly affected the accumulation of sweet corn shoot and root biomass at 42 and 65 days after planting (Table 3). There were significant differences (p < 0.05) between treatments in both fresh and dry biomass.

**Table 3. Average Weight Fresh and Dry Biomass of Shoots and Roots at 42 and 65 DAP (g/plant)**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Shoot** | **Root** |
| **42 DAP** | **65 DAP** | **42 hst** | **65 DAP** |
| **Fresh Biomass** |  |  |  |  |
| P0 | 77.26ᵉ | 102.66ᵉ | 14.47ᵉ | 11.33ᵉ |
| P1 | 124.33ᵈ | 26.02ᵈ | 24.00ᵈ | 124.33ᵈ |
| P2 | 210.00ᶜ | 31.47ᶜ | 35.33ᶜ | 210.00ᶜ |
| P3 | 241.33ᵇ | 42.25ᵇ | 55.66ᵇ | 241.33ᵇ |
| P4 | 368.00ᵃ | 77.56ᵃ | 74.66ᵃ | 368.00ᵃ |
| LSD 5% | 3.539 | 0.740 | 3.279 | 3.539 |
| **Dry Biomass** |  |  |  |  |
| P0 | 37.28ᵉ | 19.33ᵉ | 6.00ᵉ | 37.28ᵉ |
| P1 | 72.36ᵈ | 27.66ᵈ | 14.00ᵈ | 72.36ᵈ |
| P2 | 90.59ᶜ | 34.66ᶜ | 20.66ᶜ | 90.59ᶜ |
| P3 | 138.55ᵇ | 46.66ᵇ | 26.33ᵇ | 138.55ᵇ |
| P4 | 171.51ᵃ | 55.66ᵃ | 35.00ᵃ | 171.51ᵃ |
| LSD 5% | 1.869 | 2.318 | 1.286 | 1.869 |

Notes: Treatment descriptions are provided in Table 1.

At 42 DAP, plants treated with a combination of 10 t/ha of cattle manure and 3 t/ha of indigenous AMF (P4) achieved significantly higher shoot fresh biomass (342.24 g/plant) and root fresh biomass (77.56 g/plant) compared to all other treatments. The lowest shoot (77.26 g/plant) and root (14.47 g/plant) biomass were observed in the control (P0). A similar pattern was observed at 65 days after planting with the highest shoot (368.00 g) and root (74.66 g) biomass observed in P4. This indicates sustained growth and biomass accumulation in the combination of organic and biological amendments.

The increase in plant biomass is primarily due to the synergistic effect between organic nutrient input and biological nutrient mobilization. Cattle manure contributes to improved soil structure, water-holding capacity, microbial activity, and the slow release of nutrients such as nitrogen (N), phosphorus (P), and potassium (K) (Lal, 2015; Brady et al., 2008). These nutrients are essential for cell division and tissue expansion, which directly impact vegetative biomass formation.

AMF, on the other hand, increases nutrient uptake efficiency by expanding the effective root reach through extraradical hyphae, particularly enhancing phosphorus uptake in phosphorus-deficient soils such as sandy substrates (Smith & Read, 2008; Mohammadi et al., 2011). Mycorrhizal colonization also increases plant tolerance to abiotic stress and enhances photosynthetic activity by supporting better water and nutrient status (Smith et al., 2011).

Dry biomass data confirmed the pattern observed for fresh biomass. At 42 DAP, the highest shoot dry weight was found in P4 (171.51 g), followed by P3 (138.55 g), P2 (90.59 g), and P1 (72.36 g), with the lowest weight in the control treatment (P0) (37.28 g). At 65 DAP, dry shoot biomass remained highest in P4 (55.66 g), while dry root biomass reached 35.00 g, again higher than the other treatments.

The increase in dry matter reflects greater photosynthetic assimilation and allocation of structural carbohydrates to plant organs. Dry biomass is a key indicator of productivity and is often correlated with grain yield potential (Dordas et al., 2008). The presence of both organic matter and AMF not only stimulates vegetative growth but also promotes root system development, which is critical for water and nutrient absorption and plant anchorage (Zou et al., 2020).

The consistent superiority of P4 suggests that combining a high dose of cattle manure with indigenous AMF provides a balanced nutrient supply and enhances soil biological activity, thereby maximizing biomass accumulation. Previous studies support this finding, indicating that the integration of organic fertilizers and mycorrhizal fungi can lead to improved plant performance in degraded or marginal soils (Mäder et al., 2002; Astiko et al., 2025).

**3.4. Weight of Fresh and Dry Biomass Yield**

The application of cattle manure and indigenous AMF, either individually or in combination, had a significant effect (p < 0.05) on biomass accumulation per plot at 65 DAP (Fig. 1).

**Fig 1. Weight Fresh and Dry Stover Biomass of Sweet Corn per Plot at 65 DAP (kg/plot)**

The highest fresh biomass was observed in treatment P4 (8.46 kg/plot), which combined 10 t/ha of cattle manure with 3 t/ha of indigenous mycorrhizae, which was significant compared to P3 (7.20 kg), P2 (6.40 kg), P1 (5.50 kg), and the control P0 (4.23 kg). This indicates that integrated organic and biological inputs is more effective in stimulating vegetative growth than either a single input or no input at all.

The superior fresh biomass yield under P4 can be attributed to the synergistic effect of cattle manure and mycorrhiza in improving soil physicochemical properties and enhancing nutrient availability. Cattle manure serves as a source of organic matter, nitrogen, phosphorus, and potassium, as well as beneficial microorganisms, all of which contribute to increased plant growth and canopy development (Brady et al., 2008). The mycorrhizal association enhances the uptake of relatively immobile nutrients such as phosphorus and micronutrients, and also improves root architecture, which supports better plant vigor and biomass accumulation (Smith & Read, 2008; Chen et al., 2018).

Similar to fresh biomass, treatment P4 recorded the highest dry biomass yield (2.61 kg/plot), significantly higher than P3 (2.23 kg), P2 (2.03 kg), P1 (1.67 kg), and P0 (1.25 kg). This result confirms that the combination of cattle manure and mycorrhizal inoculation not only increased fresh biomass but also resulted in greater dry matter partitioning, which is crucial for yield prediction and soil organic matter recovery through crop residues.

Dry biomass is a more reliable indicator of photosynthetic efficiency and nutrient assimilation than fresh biomass, as it excludes the influence of variable water content (Tolk et al., 2016). The increase in dry matter accumulation under P4 reflects more efficient nutrient uptake and utilization, leading to greater structural biomass production. This suggests improved metabolic function under the integrated input system, which is consistent with the findings of Mäder et al. (2002) and Astiko et al. (2021), who reported that organic-biological fertilization enhances soil health and plant performance, particularly in sandy soils.

These results collectively demonstrate the agronomic potential of combining organic and biological fertilization to improve stover yield, which has implications not only for grain production but also for livestock feed, bioenergy, and soil organic matter restoration.

**3.5. Spore Density and Mycorrhizal Colonization**

The application of cattle manure and indigenous AMF significantly influenced both spore density and root colonization percentage in sweet corn (*Zea mays saccharata*) at 42 and 65 DAP. The highest values observed in the combined treatment (P4) (Table 4) suggest that the integration of organic and biological inputs enhances the establishment and symbiotic functioning of AMF in sandy soils .

At 42 DAP, spore density ranged from 1,069 spores/100 g soil in the control treatment (P0) to 2,325 spores/100 g soil in the combined treatment P4 (10 t/ha cattle manure + 3 t/ha indigenous AMF). This trend became more pronounced at 65 DAP, with spore numbers increasing to 5,014 spores/100 g soil in P4, representing a 4.7-fold increase over the control (1,961 spores/100 g soil). The sole AMF treatment (P2) also demonstrated elevated spore densities at both time points, but still significantly lower than P4.

**Table 4. Average Spore Density (per 100 g soil) and Mycorrhizal Root Colonization (%) of Sweet Corn at 42 and 65 DAP**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Spore Density** | **Root Colonization** |
| **42 DAP** | **65 DAP** | **42 DAP** | **65 DAP** |
| P0 | 1,069ᵉ | 1,961ᵉ | 1,069ᵉ | 1,961ᵉ |
| P1 | 1,221ᵈ | 2,389ᵈ | 1,221ᵈ | 2,389ᵈ |
| P2 | 2,323ᶜ | 2,665ᶜ | 2,323ᶜ | 2,665ᶜ |
| P3 | 1,335ᵇ | 2,980ᵇ | 1,335ᵇ | 2,980ᵇ |
| P4 | 2,325ᵃ | 5,014ᵃ | 2,325ᵃ | 5,014ᵃ |
| LSD 5% | 49.13 | 10.81 | 49.13 | 10.81 |

Notes: Treatment descriptions are provided in Table 1.

The significant increase in AMF spore production under organic-amended treatments is consistent with findings by Brundrett & Tedersoo (2018), who reported that organic matter supports microbial diversity and provides substrates for fungal growth and reproduction. Cattle manure likely enhances the rhizosphere environment, stimulating microbial activity and promoting sporulation of mycorrhizal fungi (Gianinazzi et al., 2010).

High levels of root colonization were observed in treatments with high spore production. At 42 DAP, root colonization ranged from 48.33% (P0) to 91.00% (P4). At 65 DAP, colonization increased further, reaching 96.66% in P4, indicating optimal symbiosis formation. Treatment P3 (5 t/ha manure + 1.5 t/ha AMF) also showed a high colonization rate (89.66%), indicating that even lower combined input doses significantly enhanced AMF-plant interactions compared to single input applications.

Mycorrhizal colonization is a critical indicator of functional symbiosis between plant roots and AMF, which enhances nutrient uptake, particularly phosphorus, and improves plant tolerance to drought and other abiotic stresses (Smith & Read, 2008; Khan et al., 2022). The superior colonization in the integrated treatments indicates that cattle manure not only improves the soil environment for fungal development but may also increase root exudation, which facilitates mycorrhizal signaling and infection (Kumar et al., 2018).

These findings reinforce the role of integrated nutrient management in improving biological soil fertility and sustaining AMF populations, especially in nutrient-poor sandy soils. The elevated spore production and colonization under combined manure and AMF treatments demonstrate their potential to improve soil microbiological activity and support long-term agroecosystem productivity.

Microscopic observations of root colonization and mycorrhizal spore mass are presented in Fig. 2.

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**Fig. 2. Root colonization and spore mass of mycorrhizal fungi under the microscope.**

**3.6. Yield Components**

The application of cattle manure and indigenous AMF, either individually or in combination, significantly affected the yield components of sweet corn at 65 DAP. The measured parameters included fresh cob weight (FCW), dry cob weight (DCW), and FCW per plot (FCWP), as summarized in Table 5.

**Table 5. Average Yield Components of Sweet Corn at 65 DAP**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **FCW (g/plant)** | **DCW (g/plant)** | **FCWP (kg/plot)** |
| P0 | 109.66ᵈ | 34.66ᵉ | 3.20ᵉ |
| P1 | 134.33ᶜ | 44.33ᵈ | 4.43ᵈ |
| P2 | 165.33ᵇ | 56.33ᶜ | 5.40ᶜ |
| P3 | 185.33ᵇ | 68.33ᵇ | 6.13ᵇ |
| P4 | 265.00ᵃ | 94.66ᵃ | 7.40ᵃ |
| LSD 5% | 15.135 | 1.835 | 0.459 |

Notes: Treatment descriptions are provided in Table 1.

The FCW per plant showed a statistically significant increase across treatments. The control treatment (P0) recorded the lowest FCW (109.66 g), while the highest was observed in P4 (265.00 g), which involved the combined application of cattle manure at 10 t/ha and AMF at 3 t/ha. Intermediate values were found in P1 (134.33 g), P2 (165.33 g), and P3 (185.33 g), demonstrating a clear incremental trend with the increasing complexity of nutrient input.

The increase in FCW under organic and biological input treatments, particularly the synergistic P4, can be attributed to improved nutrient availability-especially phosphorus and nitrogen-as a result of both manure mineralization and mycorrhizal activity (Smith & Read, 2008). Higher cob weights are typically associated with improved sink-source relationships and better assimilate partitioning, supported by enhanced photosynthetic activity in plants grown on more fertile soils (Chen et al., 2021).

A similar trend was observed in DCW. The P4 treatment produced the highest DCW (94.66 g), which was significantly higher than P3 (68.33 g), P2 (56.33 g), P1 (44.33 g), and the control (34.66 g). Dry weight is a more stable indicator of yield potential, as it reflects net assimilate accumulation and final biomass allocation (Tian et al., 2020).

The improvement in DCW under P4 suggests that nutrient uptake and water-use efficiency were enhanced by the combined treatment. Organic matter from manure improves soil structure and water-holding capacity, while AMF increases drought resistance and nutrient acquisition (Gianinazzi et al., 2010; Basu et al., 2018).

Fresh cob weight per plot followed the same statistical pattern. The highest yield was obtained from P4 (7.40 kg/plot), followed by P3 (6.13 kg), P2 (5.40 kg), P1 (4.43 kg), and P0 (3.20 kg). The significant increase in FCW under P4 demonstrates the agronomic advantage of integrated soil fertility management, where both organic inputs and microbial inoculants work synergistically to optimize plant performance (Mäder et al., 2002).

These findings highlight the value of integrating cattle manure and indigenous AMF inoculation as a sustainable strategy to improve sweet corn productivity in sandy, low-fertility soils.

**4. CONCLUTION AND RECOMMENDATIONS**

**4.1. Conclution**

Based on the results of this study, the following conclusions can be drawn:

1. **Combined application of cattle manure and indigenous AMF** significantly improved plant growth parameters, including plant height and leaf number, from early vegetative stages up to 56 days after planting.
2. The **highest biomass production** (both shoot and root, fresh and dry) was obtained under the integrated treatment of 10 t/ha cattle manure and 3 t/ha AMF (P4), indicating enhanced better plant vigor.
3. **Yield components**, including fresh and dry cob weight and total cob weight per plot, were significantly increased in the P4 treatment, suggesting improved soil nutrient status and more efficient resource utilization.
4. AMF spore density and root colonization percentage were markedly enhanced under the combined application of cattle manure and AMF, confirming strong mutualistic symbiosis and elevated biological activity in the rhizosphere.

**4.2. Suggestions**

The combined use of 10 tons/ha of cattle manure and 3 tons/ha of local AMF is recommended to increase sweet corn productivity and soil biological activity on sandy soils. This integrated approach offers a sustainable alternative to synthetic inputs, especially in areas with low fertility. Further research is needed to assess long-term impacts and refine application strategies across a range of agroecological conditions.

**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.

**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.

**REFERENCES**

Askari, A., Ardakani, M. R., Paknejad, F., & Hosseini, Y. (2019). Effects of mycorrhizal symbiosis and seed priming on yield and water use efficiency of sesame under drought stress condition. *Scientia Horticulturae*, *257*, 108749.

Astiko, W., I.R. Sastrahidayat, S. Djauhari dan A. Muhibuddin. 2013. The role of Indigenous mycorrhiza in combination with cattle manure in improving maize yield (*Zea mays* L.) on sandy loam of Northern Lombok, Eastern Indonesia. Journal of Tropical Soils. 18 (1): 53-58. DOI: 10.5400/jts.2012.18.1.53

Astiko, W., & Fauzi, M. T. (2016). Nutrient status and mycorrhizal population on various food crops grown following corn inoculated with indigenous mycorrhiza on sandy soil of North Lombok, Indonesia. *Journal of Tropical Soils*, *20*(2), 119-125.

Astiko, W., Fauzi, M. T., & Sukartono, S. (2016a). Mycorrhizal population on various cropping systems on sandy soil in dryland area of North Lombok, Indonesia. *Nusantara Bioscience*, *8*(1).

Astiko, W., Ernawati, N. M. L., & Silawibawa, I. P. (2021). The effect of row proportion of maize and soybean intercropping on growth and yield of component crops in sandy soil North Lombok, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 637, No. 1, p. 012005). IOP Publishing.

Astiko, W., Fauzi, M. T., Muthahanas, I., & Ernawati, N. M. L. (2025). Nitrogen and Phosphorus Status, Mycorrhizal Development and Crop Yields in Maize-Soybean Intercropping for Sustainable Agriculture in Drylands. *Journal of Lifestyle and SDGs Review*, *5*(3), e04667-e04667.

Ajayi, A. E., & Horn, R. (2016). Comparing the potentials of clay and biochar in improving water retention and mechanical resilience of sandy soil. *International Agrophysics*, *30*(4).

Aziz, M. S., Nawaz, R., Haider, N., Rehman, Z. U., Aamir, A. U. H., & Imran, M. (2019). Starch composition, antioxidant potential, and glycemic indices of various varieties of Triticum aesitivum L. and Zea mays L. available in Pakistan. *Journal of Food Biochemistry*, *43*(8), e12943.

Brady, N. C., Weil, R. R., & Weil, R. R. (2008). *The nature and properties of soils* (Vol. 13, pp. 662-710). Upper Saddle River, NJ: Prentice Hall.

Brundrett, M. C., & Tedersoo, L. (2018). Evolutionary history of mycorrhizal symbioses and global host plant diversity. *New Phytologist*, *220*(4), 1108-1115.

Bahadur, A., Batool, A., Nasir, F., Jiang, S., Mingsen, Q., Zhang, Q & Feng, H. (2019). Mechanistic insights into arbuscular mycorrhizal fungi-mediated drought stress tolerance in plants. *International journal of molecular sciences*, *20*(17), 4199.

Chen, Y., Camps-Arbestain, M., Shen, Q., Singh, B., & Cayuela, M. L. (2018). The long-term role of organic amendments in building soil nutrient fertility: a meta-analysis and review. *Nutrient Cycling in Agroecosystems*, *111*(2), 103-125.

Chen, M., Arato, M., Borghi, L., Nouri, E., & Reinhardt, D. (2018a). Beneficial services of arbuscular mycorrhizal fungi–from ecology to application. *Frontiers in plant science*, *9*, 1270.

da Silva, A. P., Babujia, L. C., Franchini, J. C., Ralisch, R., Hungria, M., & de Fátima Guimarães, M. (2014). Soil structure and its influence on microbial biomass in different soil and crop management systems. *Soil and Tillage Research*, *142*, 42-53.

Das, S., & Maharjan, B. (2023). Manure improves soil health and provides yield stability and reliability. *Consulted on august*, *22*, 2024.

Dhaliwal, S. S., Naresh, R. K., Mandal, A., Walia, M. K., Gupta, R. K., Singh, R., & Dhaliwal, M. K. (2019). Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems: a review. *Journal of Plant Nutrition*, *42*(20), 2873-2900.

Dordas, C. A., Lithourgidis, A. S., Matsi, T., & Barbayiannis, N. (2008). Application of liquid cattle manure and inorganic fertilizers affect dry matter, nitrogen accumulation, and partitioning in maize. *Nutrient Cycling in Agroecosystems*, *80*(3), 283-296.

Eckhardt, D. P., Redin, M., Santana, N. A., Conti, L. D., Dominguez, J., Jacques, R. J. S., & Antoniolli, Z. I. (2018). Cattle manure bioconversion effect on the availability of nitrogen, phosphorus, and potassium in soil. *Revista Brasileira de Ciência do Solo*, *42*, e0170327.

El-Nagar, D. A., & Mohamed, R. A. A. (2019). Characterization and impact of cattle manure particle size on physical properties of Sandy soils. *Journal of Geoscience and Environment Protection*, *7*(08), 180.

Gianinazzi, S., Gollotte, A., Binet, M. N., van Tuinen, D., Redecker, D., & Wipf, D. (2010). Agroecology: the key role of arbuscular mycorrhizas in ecosystem services. *Mycorrhiza*, *20*(8), 519-530.

Giovannetti, M., & Mosse, B. (1980). An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. *New phytologist*, 489-500.

Khan, Y., Shah, S., & Tian, H. (2022). The roles of arbuscular mycorrhizal fungi in influencing plant nutrients, photosynthesis, and metabolites of cereal crops—A review. *Agronomy*, *12*(9), 2191.

Kumar, M. S., Reddy, G. C., Phogat, M., & Korav, S. (2018). Role of bio-fertilizers towards sustainable agricultural development: A review. *Journal of Pharmacognosy and Phytochemistry*, *7*(6), 1915-1921.

Kiruthika, G., Poonkodi, P., Angayarkanni, A., Sundari, A., & Sriramachandrasekharan, M. V. (2022). Effect of different organic manures on the nutrient release pattern in sandy loam soil. *Indian Journal of Natural Sciences*, *13*(71), 40060.

Kormanik, P. P., & McGraw, A. C. (1982). Quantification of vesicular-arbuscular mycorrhizae in plant roots.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, *7*(5), 5875-5895.

Leghari, S. J., Wahocho, N. A., Laghari, G. M., HafeezLaghari, A., MustafaBhabhan, G., HussainTalpur, K., & Lashari, A. A. (2016). Role of nitrogen for plant growth and development: A review. *Advances in environmental biology*, *10*(9), 209-219.

Litskas, V. D. (2023). Environmental impact assessment for animal waste, organic and synthetic fertilizers. *Nitrogen*, *4*(1), 16-25.

Liu, S., Wang, J., Pu, S., Blagodatskaya, E., Kuzyakov, Y., & Razavi, B. S. (2020). Impact of manure on soil biochemical properties: A global synthesis. *Science of the Total Environment*, *745*, 141003.

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). Soil fertility and biodiversity in organic farming. *Science*, *296*(5573), 1694-1697.

Medina, A., & Azcón, R. (2010). Effectiveness of the application of arbuscular mycorrhiza fungi and organic amendments to improve soil quality and plant performance under stress conditions. *Journal of soil science and plant nutrition*, *10*(3), 354-372.

Mohammadi, K., Khalesro, S., Sohrabi, Y., & Heidari, G. (2011). A review: beneficial effects of the mycorrhizal fungi for plant growth. *Journal of Applied Environmental and Biological Sciences*, *1*(9), 310-319.

Naorem, A., Jayaraman, S., Dang, Y. P., Dalal, R. C., Sinha, N. K., Rao, C. S., & Patra, A. K. (2023). Soil constraints in an arid environment—challenges, prospects, and implications. *Agronomy*, *13*(1), 220.

Ozores-Hampton, M., Stansly, P. A., & Salame, T. P. (2011). Soil chemical, physical, and biological properties of a sandy soil subjected to long-term organic amendments. *Journal of Sustainable Agriculture*, *35*(3), 243-259.

Parham, J. A. S. P., Deng, S., Raun, W., & Johnson, G. (2002). Long-term cattle manure application in soil: I. Effect on soil phosphorus levels, microbial biomass C, and dehydrogenase and phosphatase activities. *Biology and Fertility of Soils*, *35*(5), 328-337.

Peng, G. A. O., Zhang, T., Huang, J., Zhang, Z. H., & Zhang, H. M. (2023). Improvement of soil fertility and rice yield after long-term application of cow manure combined with inorganic fertilizers. *Journal of Integrative Agriculture*, *22*(7), 2221-2232.

Pons, S., Fournier, S., Chervin, C., Bécard, G., Rochange, S., Frei Dit Frey, N., & Puech Pagès, V. (2020). Phytohormone production by the arbuscular mycorrhizal fungus Rhizophagus irregularis. *PLoS One*, *15*(10), e0240886.

Singh, I., Langyan, S., & Yadava, P. (2014). Sweet corn and corn-based sweeteners. *Sugar tech*, *16*(2), 144-149.

Smith, S. E., & Read, D. J. (2008). Mycorrhizal symbiosis (3rd ed.). Academic Press.

Smith, S. E., & Read, D. J. (2010). *Mycorrhizal symbiosis*. Academic press.

Smith, S. E., Jakobsen, I., Grønlund, M., & Smith, F. A. (2011). Roles of arbuscular mycorrhizas in plant phosphorus nutrition: interactions between pathways of phosphorus uptake in arbuscular mycorrhizal roots have important implications for understanding and manipulating plant phosphorus acquisition. *Plant physiology*, *156*(3), 1050-1057.

Tolk, J. A., Evett, S. R., Xu, W., & Schwartz, R. C. (2016). Constraints on water use efficiency of drought tolerant maize grown in a semi-arid environment. *Field Crops Research*, *186*, 66-77.

Zhao, R., Guo, W., Bi, N., Guo, J., Wang, L., Zhao, J., & Zhang, J. (2015). Arbuscular mycorrhizal fungi affect the growth, nutrient uptake and water status of maize (Zea mays L.) grown in two types of coal mine spoils under drought stress. *Applied Soil Ecology*, *88*, 41-49.

Zhou, J., Zang, H., Loeppmann, S., Gube, M., Kuzyakov, Y., & Pausch, J. (2020). Arbuscular mycorrhiza enhances rhizodeposition and reduces the rhizosphere priming effect on the decomposition of soil organic matter. *Soil Biology and Biochemistry*, *140*, 107641.

Zhu, C., Ling, N., Guo, J., Wang, M., Guo, S., & Shen, Q. (2016). Impacts of fertilization regimes on arbuscular mycorrhizal fungal (AMF) community composition were correlated with organic matter composition in maize rhizosphere soil. *Frontiers in Microbiology*, *7*, 1840.