EVALUATION OF THE EFFECTIVENESS OF VARIOUS AMELIORANT SOURCES IN INCREASING NP ABSORPTION AND SWEET CORN PRODUCTIVITY ON SANDY SOIL

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ABSTRACT

Aims:
This study aimed to determine the effectiveness of various ameliorant sources in enhancing NP uptake and the productivity of sweet corn (*Zea mays* L. saccharata) in sandy soil.

Study Design:
The study used a randomized block design with five treatments and four replications.

Place and Duration of Study:
The field experiment was conducted in a sandy soil area in MoncokKarya, PejerukKarya Village,Ampenan District, Mataram City. The analysis part was carried out in Microbiology laboratory, and in the Soil Physics and Chemistry Laboratory, Faculty of Agriculture, University of Mataram. All series of trials were completed in six months.

Methodology:
The experimental tested five treatments, namely; Control, no ameliorant (A0), Rice Husk Charcoal (AA), Cow Manure (AS), Compost (AK), and Fertile Organic Fertilizer (AP). Each treatment was replicated 4 times. Observations were made on biomass weight, crop yield, nutrient concentrations (N and P), nutrient uptake, and mycorrhizal activity.

Results:
Ameliorant treatment with cow manure significantly improved plant growth and productivity by enhancing nutrient availability in the soil. This included increases in biomass, and yield. Cow manure also promoted mycorrhizal activity, improved soil structure and increased nutrient absorption efficiency.

Conclusion:
The research result showed that the cow manure as an ameliorant markedly enhanced NP uptake and productivity of sweet corn in sandy soil. It improved soil fertility, supported mycorrhizal colonization, and strengthened plant resistance to environmental stresses.

Keywords: Ameliorant, sandy soil, sweet corn production

1. INTRODUCTION

Sweet corn (*Zea mays var. saccharata*) is a type of vegetables widely consumed, with demand increasing each year in line with population growth in Indonesia and many other regions, including Latin America, Europe, and Asia (Syukur, 2013). Its sweeter taste compared to other types of corn is attributed to the sugar content in its endosperm. Additionally, sweet corn provides sufficient nutritional value to meet dietary needs (Inverted et al., 2015).

In 100 g of sweet corn contains 85 calories, 3.2 g of protein, 1.2 g of fat, 19 g of carbohydrates, 2 mg of calcium, 270 mg of potassium, 0.5 mg of iron, 400 IU of vitamin A, 0.15 mg of vitamin B, 6.8 mg of vitamin C, and 72.7 g of water (USDA, 2019). Beyond its seeds, other parts of the plant have various uses: young stems and leaves can serve as animal feed, older stems and leaves can be used as green manure or compost materials, and dry stems and leaves can act as an alternative fuel source to replace firewood. Baby corn can also be cooked and consumed as a vegetable (Sofia et al., 2014).

Sweet corn is frequently incorporated into various dishes, such as sour vegetable soup, corn fritters, corn syrup, corn ice cream, corn cakes, and numerous other foods. Ready-to-eat processed sweet corn products are widely available in most cities, sold through small businesses and franchises (Syukur and Aziz, 2013).

The increasing demand for sweet corn, driven by population growth and changing consumption patterns, has encouraged farmers in Indonesia to boost production each season due to its profitable prospects. There has been an average annual increase of 28.81% in sweet corn consumption in Indonesia (Ministry of Agriculture, 2021). However, sweet corn production in Indonesia fluctuates significantly from year to year. In 2019, production reached 22.5 million tons, dropped to 14.37 million tons in 2020, increased to 15.79 million tons in 2021, and rose again to 20.1 million tons in 2022 (Central Statistics Agency, 2022). These fluctuations indicate that sweet corn production remains unstable, leading to an inability to consistently meet the growing market demand.

Cultivating sweet corn on sandy soil has several challenges, including low fertility and limited nutrient availability. The soil's texture makes it difficult to retain water and nutrients. This is because 70% of sandy soil particles are large, resulting in poor soil structure, low organic matter content, and limited water retention in the soil system (Harjowigeno, 1995). However, with proper management, sandy soil can be improved to increase fertility and agricultural productivity. One effective strategy to increase plant productivity on sandy soil is to managethe availability of nutrients by using soil amendments or adding organic matter and other beneficial ingredients (Dariah et al., 2015).

The addition of ameliorant materials as soil amendments plays a crucial role in improving the physical, chemical, and biological properties of soil. Ameliorants, or soil conditioners, are materials added to soil to enhance root environmental conditions and support plant growth (Purba, 2015). Several studies have demonstrated that ameliorants can increase soil pH, improve nutrient availability, enhance water retention, and boost soil permeability (Hendra et al., 2015). Common materials used as ameliorants are compost, cow manure, and rice husk charcoal (Nuryah et al., 2023).

Cow manure is an organic fertilizer that improves soil structure and water retention, provides additional nutrients, enhances cation exchange capacity, and supports the growth of soil microorganisms. It contains high levels of organic carbon, a complete range of nutrients, is readily available, and is cost-effective (Wawo, 2018). Similarly, the application of organic materials like compost helps restore degraded soil by binding nutrients that might otherwise be lost, increasing nutrient availability, enhancing fertilization efficiency, and improving soil physical properties such as aggregate stability, specific gravity, porosity, plasticity, permeability, and water-holding capacity. The nutrients in compost are utilized by soil microbes, which convert complex organic compounds that are unavailable to plants into simpler organic and inorganic compounds that can be absorbed by plants (Situmeang, 2017).

Compost is formed from organic materials such as leaves, grass, straw, and animal waste that decompose due to microbial activity (Muhsanati et al., 2008). The quality of compost depends on its carbon-to-nitrogen (C/N) ratio, which should ideally range between 12 and 15 for optimal effectiveness (Novizan, 2007). Applying compost at a rate of 7.5–15 tons per hectare can significantly improve plant growth, fresh cob weight, and fresh stover weight in sweet corn plants (Situmeang et al., 2016).

Rice husk charcoal contains nutrients such as 0.3% nitrogen (N), 15% phosphorus pentoxide (P_2O_5), 31% potassium oxide (K_2O), and other essential elements, with a pH of 6.8. Husk charcoal has a high water-holding capacity, a crumbly texture, good air circulation, a high cation exchange capacity (CEC), and is effective at absorbing sunlight (Fahmi, 2013). Its additional properties include water-binding ability, resistance to clumping, affordability, good porosity, light weight, sterility, and ease of availability (Prihmantor, 2003).

The application of mycorrhizal biofertilizer is also an effective alternative to enhancing agricultural productivity. Mycorrhiza plays a key role in improving nutrient supply and absorption, thereby reducing the reliance on inorganic fertilizers. Additionally, it enhances plant resistance to drought by assisting in the absorption of water that is otherwise inaccessible to the roots (Rokhminarsi et al., 2011). Consequently, the addition of nutrient sources through fertilization is expected to boost crop yields both quantitatively and qualitatively (Fadwiwati and Tahir, 2013).

The research aimed to determine the effects of different ameliorants on sweet corn growth and productivity. Specifically, it evaluates nutrient concentrations (N and P), plant uptake, growth metrics, yield, and mycorrhizal populations.

2. METHODOLOGY

2.1. Time and Place

This experiment was conducted in MoncokKarya, Ampenan from February to July 2024.

2.2. Experimental Design

This experiment was conducted using a randomized block design with five treatments,namely; Control, no ameliorant (A0), Rice Husk Charcoal (AA), Cow Manure (AS), Compost (AK), and Fertile Organic Fertilizer Ameliorant (AP). Each treatment was repeated four times so that there were 20 experimental plots.

2.3. Preparation and Application of Ameliorants and Indegenous Mycorrhizae

At planting time the Ameliorant and the mycorrhiza were applied. All ameliorants according to treatments were applied at a dosage of 15 tons/ha. The mycorrhiza was applied as powdered mycorrhizal inoculum, made from a mixture of soil, roots, hyphae, and mycorrhizal spores propagated in pot culture. The pot culture was prepared in polybags containing 5 kg of soil, a sterilized mixture of soil and cow manure (1:1), inoculated with 40 g of mycorrhizal inoculum per polybag. These polybags were used for mycorrhizal propagation and planted with maize trap plants.After 50 days, the pots and plants were dismantled, and the roots and soil were air-dried for a week. Then, the soil was sieved using a 2 mm sieve, and the roots were blended into a fine powder and evenly mixed with the sieved soil. The final product was a powdered mycorrhizal inoculum.

2.4. Plant Maintenance

All plots were kept clean from weeds and the soil was maintained wet to approximately field capacity with good drainage system.Sweet corn was harvested after the plants reached 70 days after planting (DAP), when the corn kernels were still soft, not too mature, and the husks were still a fresh green color.

2.5.Observation Parameters

Plant Biomass (wet/dry weight of shoots and roots), yield components (wet and dry stover, cob weight, diameter, and length) were measured and nutrient concentrations (N and P), nutrient uptake, mycorrhizal spores, and root colonization were analyzed in the laboratories.

3. RESULTS AND DISCUSSION

3.1. Biomass Production

The application of cow manure significantly boosted wet and dry biomass weight of both shoots and roots at 42 and 65 DAP(Table 1).

Table 1. The average weight of wet and dry biomass in ameliorant treatments aged 42 and 65 DAP

Ameliorative Treatment	Shoots (g)		Root (g)	
	42 dap	65 dap	42 dap	65 dap
Wet Biomass				
A0: Control	93.34^{e}	148.59^{d}	25.31^{e}	40.45^{d}
AA: Charcoal husk Fertilizer	169.05^{d}	184.43^{c}	51.18^{d}	80.37c
US: Cow Manure	227.40^{a}	252.23^{a}	89.34^{a}	129.07^{a}
AK: Compost Fertilizer	197.74^{b}	228.93^{ab}	77.80^{b}	96.82^{b}
AP: Fertile Fertilizer	183.03^{c}	210.44^{b}	65.43^{c}	86.16^{bc}
BNJ 5%	6.27	24.89	7,02	14.73
Dry Biomass				
A0: Control	42.26^{e}	74.83^{d}	18.04^{and}	23.66^{d}
AA: Charcoal husk Fertilizer	89.81^{d}	134.25^{c}	27.44^{d}	32.99^{c}
US: Cow Manure	148.45^{a}	192.46^{a}	59.58^{a}	69.89^{a}
AK: Compost Fertilizer	128.73^{b}	166.21^{b}	43.83^{b}	49.43^{b}
AP: Fertile Fertilizer	111.75^{c}	154.29^{bc}	34.73^{c}	41.08^{bc}
LSD 5%	13.83	21.91	3.60	8.35

The use of cow manure ameliorant (AS) had a significant effect on the increase of the wet and dry biomass weight of plant shoots and roots at 42 and 65 DAP. At 42 DAP, plants treated with cow manure ameliorant showed a significant increase in both wet and dry biomass weight compared to the control. This was attributed to better nutrient availability from the cow manure, particularly nitrogen, phosphorus, and potassium, which support vegetative growth and root development (Dord et al., 2008; Atmaja et al., 2019). Additionally, the increased mycorrhizal activity resulted from the application of cow manure contributed to the breakdown of organic material into a form more easily absorbed by plants, thereby enhancing the availability of essential nutrients (Suntoro et al., 2018). It was reported that the increase in the number and activity of these microorganisms not only improved soil structure and increases water retention, but also it supported the formation and development of healthier, stronger plant tissues (Reddy et al., 2000).

At 65 DAP, the long-term effects of cow manure became even more apparent, with a significant increase in both wet and dry biomass weights of plant shoots and roots compared to the control. Improved soil fertility, enhanced microbial activity, and better water retention contributed to higher biomass accumulation (Guo et al., 2019). The increase in soil fertility resulted from cow manure application was also thought to support the efficiency of photosynthesis and plant metabolism, ultimately leading to greater biomass accumulation. Improved soil conditions allow roots to develop more effectively, enabling them to absorb water and nutrients more efficiently. Meanwhile, a larger canopy indicates an increased photosynthetic capacity(Golden et al., 2023).

Overall, the use of cow manure as an ameliorant was very effective to increase the wet and dry biomass weight of plant shoots and roots at 42 and 65 DAP. Such improvement was reported to be due to a combination of better nutrient availability, increased mycorrhizal activity, improved soil structure, and enhanced soil fertility (Yunus et al., 2017).

3.2. Yield Components

Cow manure treatment significantly increased yield components, including wet and dry cob weight, cob length, and diameter. This treatment also increased stover weight, demonstrating its efficacy in supporting overall plant productivity (Table 2).

Table 2. Average plant yield components in the ameliorant treatment at 65 days after planting

Ameliorant Treatment	WCW	DCW	WCWP	CD	CL
A0: Control	74.89^{e}	43.89^{d}	4.83^{e}	3.59^{d}	19.24^{e}
AA: Charcoal husk Fertilize	173.25^{d}	76.99^{c}	5.96^{d}	4.19^{c}	22.53^{d}
US: Cow Manure	246.97^{a}	150.49^{a}	9.03^{a}	5.60^{a}	26.02^{a}
AK: Compost Fertilizer	225.55^{b}	125.83^{b}	7.91^{b}	5.33^{a}	24.72^{b}
AP: Fertile Fertilizer	212.50^{c}	111.26^{b}	6.97^{c}	5.00^{b}	23.65^{c}
LSD 5%	12.61	18.35	0.44	0.31	0.54

Note: WCW (Wet cob weight), Dry cob weight (DCW), Wet cob weight per plot (WCWP), Cob diameter (CD), Cob length (CL).

In Table 3, the ameliorant treatment of cow manure with (AS) had a significant effect on the weight of wet and dry stover per plot compared to other treatments. The wet and dry weightsof stover in plots treatedwith cow manure ameliorant were increased one and a half times and two times, respectively, compared to the control (Table 3).

Table 3. Weight of wet and dry stover per plot (kg) in ameliorant treatment at 65 days

Ameliorant Treatment	Wet stover weight	Dry stover weight
A0: Control	6.89^{e}	2.87^{d}
AA: Charcoal husk Fertilizer	7.75^{d}	3.12^{d}
US: Cow Manure	9.42^{a}	4.83^{a}
AK: Compost Fertilizer	8.41^{b}	3.85^{b}
AP: Fertile Fertilizer	8.10^{c}	3.48^{c}
LSD 5%	0.25	0.34

Cow manure ameliorant (AS) had a significant effect on increasing crop production, which can be explained through various interacting mechanisms. Cow manure is rich in macronutrients such as nitrogen, phosphorus, and potassium, which are essential for plant growth (Esmaielpour et al., 2020). Nitrogen plays a role in the synthesis of amino acids and proteins, which are vital for vegetative tissue growth, while phosphorus is involved in the formation of strong roots and energy transfer within plant cells. In line with these two elements, Potassium aids in stomatal regulation and enhances the efficiency of photosynthesis.

In addition to providing nutrients, the application of cow manure also boosts mycorrhizal activity in decomposing organic matter and increasing nutrient availability for plants (Gumu, 2019). Mycorrhiza not only enhances nutrient availability but also improves soil structure, leading to better aeration and the soil's ability to retain water. Furthermore, cow manure increases the cation exchange capacity of the soil, enabling it to store more nutrients that can be absorbed by plants, thereby improving productivity.

The increase in organic matter content in the soil due to cow manure ameliorant treatment also enhances water retention and helps prevent drought, both of which are essential for optimal plant growth (Larney and Angers, 2012). Ultimately, all of these factors contribute to a significant increase in crop yields. This research demonstrates that plants treated with cow manure produced more biomass and higher yields compared to those without organic fertilizer treatment. Therefore, the use of cow manure as an ameliorant not only improves soil quality but also enhances nutrient use efficiency, thereby promoting increased crop production (Jensen, 2013).

3.3. Nutrient Uptake

Cow manure ameliorant doubled the total N concentration and increased available P concentration by up to six times at 42 and 65 DAP (Table 4).

Table 4. Average concentrations of total N and available P nutrients in the ameliorant treatment aged 42 and 65 DAP

Ameliorant Treatment	N total (g.kg^{-1})		P available (mg kg^{-1})	
	42 dap	65 dap	42 dap	65 dap
A0: Control	0.91^{e}	8.31^{e}	15.72^{e}	19.21^{e}
AA: Charcoal husk Fertilizer	1.41^{d}	16.75^{d}	17.82^{d}	27.14^{d}
US: Cow Manure	1.77^{a}	65.15^{a}	61.95^{a}	76.75^{a}
AK: Compost Fertilizer	1.65^{b}	45.46^{b}	35.92^{b}	51.53^{b}
AP: Fertile Fertilizer	1.50^{c}	20.85^{c}	19.14^{c}	35.74^{c}
BNJ 5%	0.01	0.06	0.01	0.03

Ameliorant treatment using cow manure (AS) had a significant effect on the concentration of total nitrogen (N) and available phosphorus (P) in the soil, which are key factors in enhancing soil fertility. Cow manure contains a high nitrogen content, which, when applied to the soil, is decomposed by mycorrhiza into simpler forms that are easily absorbed by plants, thereby increasing the total nitrogen concentration in the soil (Son et al., 2020). This mineralization process is driven by microbial activity, which accelerates the decomposition of organic materials, converting organic nitrogen into inorganic forms such as ammonium (NH_4^+) and nitrate (NO_3^-), making them more available to plants (Rayne and Aula, 2020).

In addition, the phosphorus content in cow manure not only contributes directly to increasing available phosphorus, but also alters the dynamics of phosphorus bound in the soil. Enhanced microbial activity facilitates nutrient mineralization, improving plant nutrient uptake efficiency (Alori et al., 2017). The results of this research also show that the ameliorant treatment of cow manure increased the cation exchange capacity of the soil, which helps retain nutrients better and reduces nutrient leaching due to high rainfall (Deacon and Montemurro, 2011).

Furthermore, the increase in organic material content from cow manure can improve soil structure, which in turn enhances aeration and water retention. All these factors contribute to the increased availability of total nitrogen and phosphorus nutrients, which are essential for optimal plant growth (Astiko et al., 2019). Thus, the use of cow manure as an ameliorant has proven to be effective in improving soil quality and nutrient availability, thereby supporting better plant growth and production (Li et al., 2022).

Cow manure (AS) ameliorant treatment significantly increased plant N and P nutrient uptake compared to other treatments at 42 DAP. Compared to the control itself, the increase in plant N and P nutrient uptake in the cow manure ameliorant treatment was up to twofold in the maximum vegetative growth phase (Table 5).

Table 5. Average N and P nutrient uptake of plants in the ameliorant treatment aged 42 DAP

Ameliorant Treatment	N uptake (g kg^{-1})	P absorption (g kg^{-1})
	42 dap	42 dap
A0: Control	21.46^{e}	2.01^{e}
AA: Charcoal husk Fertilizer	29.74^{d}	2.23^{d}
US: Cow Manure	43.84^{a}	4.07^{a}
AK: Compost Fertilizer	33.42^{b}	3.85^{b}
AP: Fertile Fertilizer	31.94^{c}	3.34^{c}
LSD 5%	0.02	0.02

The use of cow manure (AS) as an ameliorant had a significant impact on the uptake of nitrogen (N) and phosphorus (P) nutrients by plants, as evidenced by an increase in the concentration of these nutrients in plant tissues compared to the control. Cow manure contains nitrogen in an organic form that is easily decomposed and can be converted by mycorrhiza into a more plant-available form, such as ammonium (NH_4^+) and nitrate (NO_3^-), through the mineralization process (Empty et al., 2010). This process not only increases nitrogen availability but also boosts microbial activity in the soil, which is essential for breaking down bound nitrogen compounds, thereby improving the efficiency of nitrogen uptake by plant roots (Geisseler et al., 2010).

On the other hand, better phosphorus availability is also achieved with the application of cow manure. The activity of microorganisms, such as bacteria and mycorrhizal fungi, triggered by the addition of this organic fertilizer, helps the release of phosphorus bound in the soil, making it more accessible to plants (Bear et al., 2005). Additionally, cow manure improves soil structure by increasing organic matter content, which enhances cation exchange capacity and water retention, allowing the soil to store more nutrients and reducing nutrient leaching due to rainfall (Fageria, 2012).

Earlier research showed that plants treated with cow manure ameliorant exhibited a significant increase in nitrogen and phosphorus uptake, which positively impacted plant growth, development, and yield (Reddy et al., 2000). Therefore, applying cow manure as an ameliorant not only increases the availability of nitrogen and phosphorus in the soil but also enhances the ability of plants to efficiently absorb these nutrients, making it crucial for boosting sustainable agricultural productivity (Jala and Goyal, 2006).

3.4. Mycorrhizal Activity

Cow manure significantly increased mycorrhizal spore counts and root colonization at the ages of 42 and 65 DAP. The increase in the number of spores in the ameliorant treatment of cow manure compared to the control was twofold, while colonization increased up to one and a half times (Table 6).

Table 6. The mean number of spores (spores per 100 g of soil) and colonization value (%-colonization) in ameliorant treatments aged 42 and 65 DAP

Ameliorant Treatment	Number of spores		Colonization	
	42 dap	65 dap	42 dap	65 dap
A0: Control	1101[d]	1953[e]	60.00[d]	70.00[d]
AA: Charcoal husk Fertilizer	1218[d]	2384[d]	70.00[c]	80.00[c]
US: Cow Manure	2323[a]	4000[a]	90.00[a]	96.66[a]
AK: Compost Fertilizer	1508[b]	2957[b]	80.00[b]	90.00[ab]
AP: Fertile Fertilizer	1364[c]	2669[c]	76.66[bc]	83.33[bc]
BNJ 5%	140.07	274.97	9.72	8.76

The use of cow manure (AS) as an ameliorant significantly increased the number of mycorrhizal spores and the level of root colonization by mycorrhiza compared to the control, which had positive implications for plant health and productivity. Cow manure is rich in organic materials that support the growth of microorganisms in the soil, including mycorrhizal fungi, which form a symbiotic relationship with plant roots. When these fertilizers are applied, the decomposed organic matter provides a source of nutrients necessary for the development and proliferation of mycorrhizal spores (Ingiehon and Babalola, 2017; Li et al., 2022).

The results of this study indicated that the addition of cow manure ameliorant significantly increased the number of mycorrhizal spores in the soil, as the organic material facilitates the growth and activity of these fungi (Herawati et al., 2021). Additionally, the increase in the number of spores leads to higher root colonization by mycorrhiza. This occurs because mycorrhizal fungi penetrate plant root tissue and form arbuscular mycorrhizal structures, which are effective in enhancing nutrient absorption, especially phosphorus, which is critical for optimal plant growth (Rashid et al., 2016). This symbiotic relationship not only improves nutrient uptake efficiency but also helps plants cope with abiotic stress such as drought(Bhatt et al., 2019).

Thus, the use of cow manure ameliorant not only increases the number and activity of mycorrhizal spores but also strengthens the symbiotic interactions that are vital for plant health and soil fertility (Astiko et al., 2013; Klironomos and Hart, 2002).

4. CONCLUSION

Cow manure was a highly effective ameliorant for improving the growth and productivity of sweet corn in sandy soil. It enhanced the availability of nitrogen and phosphorus (NP), increased biomass and yield, and improved soil fertility while promoting mycorrhizal activity. This study highlighted the importance of organic amendments in 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 no competing interests.

AUTHORS' CONTRIBUTIONS

Wahyu Astiko: Experiment design, interpretation, and manuscript writing.Sudirman: Grammar and English editing andtissue analysis.Ni Made Laksmi Ernawati and IrwanMuthahanas: Data analysis, laboratory observations, and soil analysis. All authors approved the final manuscript.

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