Archives of Agriculture and Environmental Science 10(1): 33-36 (2025)
https://doi.org/10.26832/24566632.2025.100105

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Evaluation of intercropping legumes and green manuring on soil properties in maize field

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ARTICLE HISTORY

Received: 16 December 2024
Revised received: 31 January 2025
Accepted: 15 February 2025

Keywords

Green manure
Intercropping
Maize
Moisture
Temperature

ABSTRACT

A field experiment was conducted at Lamjung campus, Sundarbazar from March to July of the year 2023 to find out the effect of different legumes and green manuring on the improvement of soil moisture. The experiment was set up in a Randomized Complete Block Design (RCBD) with five treatments which are maize, Maize + Cowpea, Maize + French bean, Maize + Soybean and Maize + Green manuring and 4 replications. It was observed that the use of green manuring was better than the control treatment in increasing moisture content by more than 2.34 times ($p<0.05$). The control treated plots had higher bulk density which also meant that there was less moisture in the soil. The use of green manuring was seen to decrease the soil temperature by about 1.17 times as compared to the control. As compared to the control system, green manuring enhanced the organic carbon content by more than 2.21 times that of the control. Maize plant growth with the help of green manuring was excellent, ear length was about 20.72 cm and diameter was 3.22 cm and 2.25 % nitrogen content was found in the green manuring treatment and it is a requirement for cell division and elongation. These results indicate that green manuring notably improves maize productivity by substantially increasing soil moisture retention, maintaining soil temperature, and raising organic carbon content of soil. Therefore, green manuring is a sustainable and successful agricultural technique that improves soil qualities and crop yields, according to the study's findings.

Citation of this article: Gautam, S., Shrestha, A., Shrestha, K., Poudel, G., Shrestha, S., & Shrestha, R. K. (2025). Evaluation of intercropping legumes and green manuring on soil properties in maize field. *Archives of Agriculture and Environmental Science*, *10*(1), 33-36, https://dx.doi.org/10.26832/24566632.2025.100105

INTRODUCTION

Maize (*Zea mays* L.), is a cereal grain which was first domesticated in southern Mexico, and ranks as the third most important cereal grain globally, following rice and wheat (Bohara *et al.*, 2023). It is widely renowned as the "Queen of Cereals" due to its superior genetic yield potential, and its characteristics to highly adaptable in diverse agro-climatic conditions (Sharma & Rayamajhi, 2022). In 2020/21, maize cultivation in Nepal covered total area of 979,776 hectares, yielding 2,997,733 metric tons with an average productivity of 3.06 metric tons per hectare (MoALD, 2021). Green manuring and intercropping are two sustainable agricultural practices which enhances soil fertility and improve crop yields. Green manure, composed of decaying crop residues, serves as a natural soil amendment, enhancing soil structure, moisture retention, aeration, and porosity (Baral *et al.*, 2023). Green manuring showed the increment of macropores by 31%, with Sesbania achieving a 47% improvement in soil porosity, surpassing cluster bean (35%) and rice bean (21%) (Sultani *et al.*, 2007). Intercropping, a traditional farming practices, involves cultivation of two or more crop species together in the same field for a significant portion of their growth period. (Anyoni *et al.*, 2023). Intercropping legumes as a treatment affect the grain yield, the yield components, and the land equivalent ratio (LER) and actual yield loss (AYL) values (Stomph *et al.*, 2020). Intercropping systems have specific

advantages such as increased total yield and land-use efficiency, improved yield stability of cropping systems, enhanced light, water, and nutrient use, and improving soil conservation and controlling weeds, insects, or diseases (Pankou *et al*., 2022). All environmental resources are utilized in an intercropping system to minimize risk and increase crop yield per unit area per unit time. Although most intercropping studies have shown the effectiveness of intercropping and concentrated on cereal-based intercropping (Shrestha *et al*., 2025). These benefits include improved soil nutrient availability, physio-chemical and biological properties, carbon capture and sequestration, soil retention, water retention, habitat provision for biodiversity, and sustainable food production (Gautam *et al*., 2025). On the other hand, water stress, which is brought on by inadequate moisture during crucial growth stages, can impair photosynthesis, limit cell growth, restrict nutrient transport, and ultimately result in stunted growth, smaller fruits with less dry matter, and lower yield quality and quantity (Bhattarai & Chaudhary, 2024). Extensive agricultural expansion has led to serious problems with restricted soil microbial populations, moisture reduction and poor soil health because of the significant use of chemical pesticides and fertilizers. Farmers' willingness to cultivate green manuring crops has declined over the past few decades, so it is crucial to increase their willingness through incentives, education, and awareness. The study aimed to assess how green manuring and legume intercropping can improve soil fertility, soil moisture retention, structure, soil health and enhances crop productivity. This research provides alternative solutions to chemical fertilizers and contribute towards sustainable farming.

MATERIALS AND METHODS

The experiment was carried out in the field of the Institute of Agriculture and Animal Science, Lamjung Campus, Sundarbazar in the western mid hills of the Nepal year 2023. The place has a humid tropical climate with an average temperature of 18 °C. The location is at 28.2765 ° N, 84.3542 °E with an elevation of 625 meters above sea level. The soil at the experimental site has a sandy loam texture and pH with a slightly acidic pH. The primary crop used in the study was Rampur Composite, an improved variety of maize. Local landraces of cowpea (*Vigna unguiculata*), soybean (*Glycine max*), and French bean (*Phaseolus vulgaris*) were sown, and green manurewas provided by the *Justicia adhatoda*. The experiment was conducted in Randomized Complete Block Design (RCBD) with four replications to evaluate the effect of three cropping systems (sole maize, maize-legume intercropping and Maize with green leaf manuring) with fixed dose of 60:60:40 kg NPK/ ha respectively. The experimental area had 20 plots with the total area of 180-meter square (20 m × 9m).

The field was ploughed a month before sowing to decompose leaves, with daily irrigation for the process. Green manure (5 kg per plot) was incorporated, chopped, and watered daily. Farm Yard Manure (15 t/ha) was applied during plowing, and nitrogen was used at half of the recommended dose, supplemented by legumes. Before the starting of experiment, the nutrient status of the research site at IAAS field, Sundarbazar was analyzed. The soil had a Nitrogen (N) of 0.1%, Phosphorous (P) concentration of 529 ppm, and potassium(K) content of 872 ppm. The organic matter (OM) was recorded at 2.1%, while the soil pH was slightly acidic at 6.2. Maize seeds were sown on March 28, 2023, at two seeds per hill, followed by legumes a month later. Nitrogen was applied in two splits: half at planting and the other half six weeks later, following an NPK ratio of 60:60:40 kg/ha. Weeding was done as needed, and earthing up was completed 45 days after sowing. Harvesting was done manually in the 14th of June, followed by data collection. The final soil's nitrogen, phosphorus, potassium, pH, and organic matter levels were analyzed at the experimental site.

Table 1. Table showing different types of treatments.

Treatments	
T1	Maize
T2	Maize + Cowpea
T3	Maize +French bean
T4	Maize+ Soybean
T5	Maize + Green leaf manuring

RESULTS AND DISCUSSION

Soil characteristics

Soil moisture and bulk density: Research showed that different cropping systems significantly impact soil moisture levels. Maize grown with green manure retained the highest moisture during crop development (14.94%) and (15.60%) after harvest. This is due to green manure created a mulch layer that reduces evaporation and enriches organic matter. In contrast, sole maize cultivation depletes soil moisture due to high evapotranspiration whereas, statistical analyses further revealed that green manure treatments lowered soil bulk density, showcasing a negative correlation between soil moisture and bulk density. Similar findings by (Rafiquesajjad *et al*., 2018) confirm these trends, emphasizing green manure's role in enhancing soil health.

Soil temperature: Soil temperature is notably influenced by cropping systems, with maize-green manure intercropping maintaining more stable levels during crop growth (23.4°C) and post-harvest (26.37°C). This stability is due to *Justicia adhatoda* leaves, which act as an insulating layer, absorbing heat during the day and releasing it at night, reducing temperature fluctuations. In contrast, sole maize cultivation experiences higher soil temperatures due to its lack of insulation and greater evapotranspiration, making it more prone to extreme temperature changes.

Organic matter and soil carbon: The soil's organic matter (OM) and organic carbon levels improved significantly with intercropping practices. Initially, OM was 2.1%, while organic carbon was 1.22%. After intercropping, OM ranged from 2.1% to 4.8%, with green manure achieving the highest at 4.8%, due to its effective decomposition and gradual nutrient release. Organic carbon similarly increased, reaching up to 2.7% with green manure. In contrast, the control group showed no change in OM or organic carbon levels. These findings align with (Tripolskaja *et al*., 2023), who noted that higher organic matter boosts soil organic carbon.

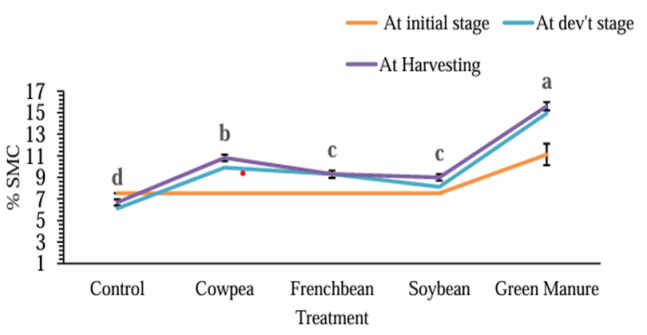

Figure 1. *Effect of different treatment on soil moisture content.*

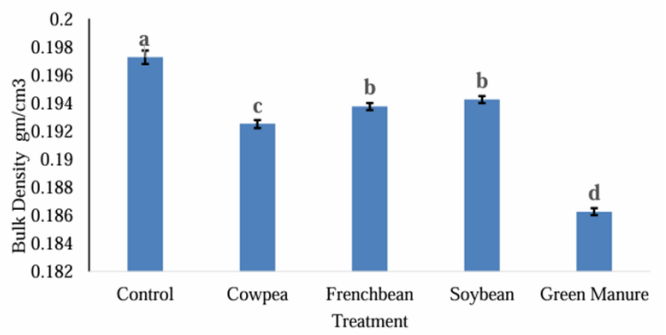

Figure 2. *Effect of different treatment on bulk density.*

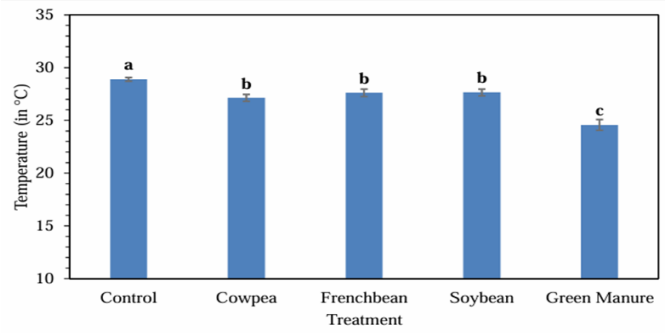

Figure 3. *Effect of different treatment on soil temperature.*

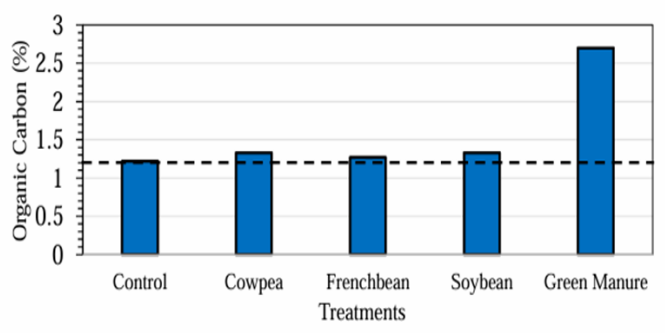

Figure 4. *Effect of different treatment on organic carbon.*

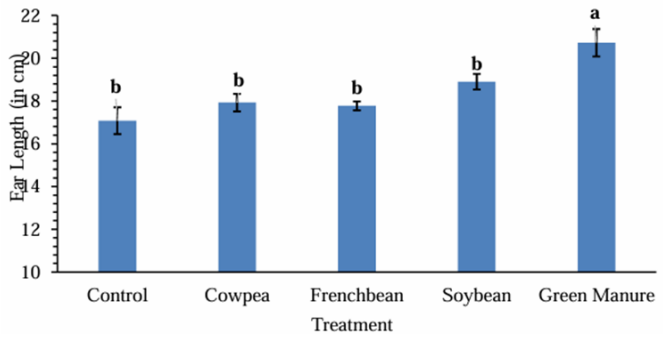

Figure 5. *Effect of different treatment on ear length.*

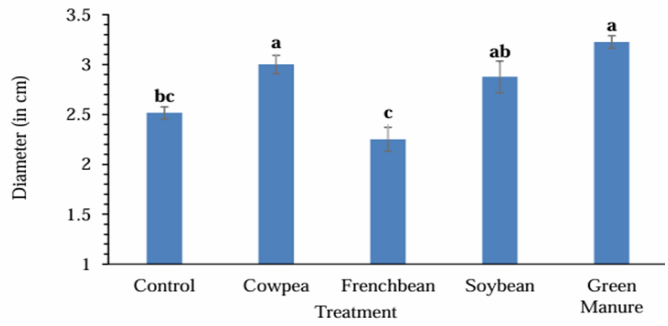

Figure 6. *Effect of different treatment on soil moisture content.*

Maize characteristics

Ear length of maize: Ear length in maize increased significantly with higher nitrogen doses, with green manure treatments producing the longest ears at 20.72 cm, compared to 17.15 cm in the sole maize. This improvement is attributed to nitrogen's role in enhancing cell division, expansion, and photosynthesis, promoting better root and shoot development. Green manure contributed to sufficient nitrogen availability, stimulating plant growth. (Arazmjoo *et al.*, 2022) observed the similar kinds of result that ear length influenced by nitrogen levels.

Ear diameter: The analysis of variance revealed a significant difference in ear diameter among maize intercropping techniques ($P < 0.05$). Ear diameters ranged from 2.25 cm (T3) to 3.22 cm (T5), with the highest recorded in green manure treatments. This increase is likely due to sufficient nitrogen availability, which supports cell division and elongation, as nitrogen is a vital component of plant tissue (Arazmjoo *et al.*, 2022).

Conclusion

The study showed that green manuring and legume intercropping significantly improved soil health and maize yield compared to sole cropping. Green manure as a treatment enhanced soil moisture retention, stabilized soil temperatures, and reduced bulk density, creating ideal conditions for plant growth as compared to other treatments. It also boosted organic matter and organic carbon levels through efficient decomposition and nutrient release. As a result, maize plant produced larger and thicker maize ears due to better nitrogen availability. Green manuring optimized environmental resource use, reduced weed biomass, and promoted sustainable farming. Key observations on soil moisture, temperature, bulk density, organic carbon and maize ear traits highlighted the superior performance of green manure systems, boasted their "complementarity effect" in resource utilization.

ACKNOWLEDGEMENTS

The authors acknowledge Lamjung Campus for providing field to conduct the research.

DECLARATIONS

Author contribution statement

Conceptualization: S.G and A.S.; Methodology: S.G and A.S.; Software and validation: S.G, A.S, K.S., S.S and G.P.; Formal analysis and investigation: S.G, A.S, S.S; Resources: S.G.; Data curation: S.G, A.S, S.S.; Writing—original draft preparation: S.G.; Writing—review and editing: A.S., K.S and S.S; Visualization: S.G.; Supervision: S.G.; Project administration: S.G.; Funding acquisition: S.G, K.S, G.P, A.S., S.S. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethics approval: This study did not involve any animal or human participant and thus ethical approval was not applicable.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: No supplementary data is available for the paper.

Funding statement: No external funding is available for this study.

Additional information: No additional information is available for this paper.

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