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Comparing Effects of Legume Intercropping and Green Leaf Manuring on Performance of Maize and Residual Soil Properties

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Authors' contributions

This work was carried out in collaboration among all authors. Author KS conducted the experiment, data collection, data analysis and write-up of the research article. Authors SG, AP and GP assisted in data collection and data analysis. All authors read and approved the final manuscript.

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ABSTRACT

In Nepal, there is a significant disparity between demand and supply for maize. Given that most smallholder farmers lack resources and hence cannot afford to purchase the necessary quantity of fertilizer. Hence, the use of different legumes intercropping and green leaf manure incorporation could be alternatives for increasing maize yield and enhancing soil properties. A field experiment was conducted at Lamjung Campus, Sundarbazzar, from March to July 2023 to study the response

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of maize to different legumes intercropping and green leaf manure incorporation and its effect on soil residual nutrients. The experiment was laid out in a randomized complete block design with five treatments (maize as a control, cowpea + maize, French bean + maize, soybean + maize, and green leaf manure + maize) and four replications. Nitrogen fertilizer was applied 60 kg ha-1 (half of the recommended dose), phosphorous and potassium were applied 15 kg ha-1 and 10 kg ha-1 (one-fourth of the recommended dose) respectively as its availability was already high in the soil. All the maize yield-related attributes were higher (P <0.05) in intercropping as compared to control. Significantly higher maize yield was obtained in green leaf manuring (2.21 times more than control), followed by soybean, cowpea, and French bean with 0.65, 0.25, and 0.09 times higher than control. In addition, nitrogen (2.25%) and organic matter (4.8%) were found higher in green leaf manure than others. It can be concluded that the input of green leaf manure to the soil enhances the yield of maize and soil properties.

Keywords: Green leaf manure; intercropping; maize yield; soil properties.

1. INTRODUCTION

Smallholder farmers cultivate several species for food and sale, and yields are the most important considerations in crop choices (Smithson & Giller, 2002). Increasing soil productivity can be achieved by boosting organic matter. It is crucial in triggering soil fertility through biological activities, thereby enhancing the physical, chemical, and biological properties of soil (Ziblim et al., 2013). Forage legumes are frequently used as green manure crops in crop rotations to boost soil fertility and crop yields. They improve the cycle of phosphorus and other nutrients for succeeding crops and are a good source of nitrogen (Turgut et al., 2005). Green manures can boost soil health by improving organic matter, reducing bulk density, enhancing microbial biomass, and water infiltration, as well as supplying nitrogen when legumes are turned under (McGuire et al., 1998). Green manure works as a source and buffer of nutrients through the process of decomposition and its role in providing soil organic matter and soil microbes. Furthermore, the application of green manure can increase the organic matter and nutrient content of the soil, resulting in improved soil physical, chemical, and biological qualities, as well as greater soil productivity and erosion resistance (Rayns & Rosenfeld, 2010).

Malabar nut (*Justicia adhatoda L*.) is a small, herbaceous, evergreen plant that belongs to the *Acanthaceae* family. It is well-known in Ayurvedic and Unani systems of medicine due to its unique phytochemistry (Nawaz et al., 2018). The leaves can be used as green manure due to their high levels of potassium nitrate. Additionally, while the alkaloid vasicine found in the leaves can be harmful to cold-blooded species such as fish, it is harmless to mammals (Adhaota Vasica (Malabar Nut), n.d.).

Intercropping (IC) is a centuries-old multiple-cropping technique that is popular among smallholder farmers in poor countries today because to its higher land and nutrient usage efficiency, higher economic returns, and reduced pest and disease incidence as compared to solitary crops (HUANG et al., 2019). The general direction and extent of changes in soil physical characteristics can be managed via cropping strategies that generate significant amounts of crop residues as a source of organic matter (Latif et al., 1992). In an intercropping system, all environmental resources are capitalized to maximize crop yield per unit area per unit time while also minimizing risk. While the majority of intercropping research have focused on cereal-based intercropping and demonstrated the efficacy of intercropping (H. Seran & Brintha, 2010). The poor management technology, lack of judicious use of nitrogen and high cost of cultivation are major causes for low production of maize in Nepal resulting wide gap between supply and demand of maize in Nepal. The main target of this research is to enhance the productivity and effectiveness of maize while enhancing soil properties and compare the yield of crops under green leaf manuring and legume Intercropping.

2. MATERIALS AND METHODS

The experiment was carried out on Institute of Agriculture and Animal Science, Lamjung Campus, Nepal (28.2765 ^{o} N, 84.3542 ^{o} E, altitude 625 m above sea level). The average of 30 years rainfall was 2800 mm and temperature was 18^{o} C. A factorial field experiment at randomized complete block design with four

replications was carried out to investigate the effect of three cropping systems (maize vs. maize intercropped with legumes vs. green leaf manuring) with a constant dose of NPK (60, 15, and 10 Kg/ha respectively). Five rows with five plants each were sown in each 3.0 m long by 1.25 m wide plot. Total plots were 20 covering 180 square meter area (20 m x 9 m). The treatments detail is given below.

Table 1. Table presenting treatments

	Treatments
T_1	Maize
T_2	Maize + Cowpea
T_3	Maize + French bean
T_4	Maize + Soybean
T_5	Maize + Green leaf manuring

For green leaf manuring, we used Malabar nut leaf, as they are locally available plants. We chopped the leaf into around 5 cm and applied 5kg/plot. The land was ploughed one month earlier to sowing for leaf decomposition of Malabar nut. Irrigation for leaf decomposing plot was practiced daily. Plot was designed by that time. Further, final plot preparation was performed 2 days prior to sowing for more pulverized soil. All the stubbles and weeds were removed. Maize (Rampur composite) was sown in the last week of March. Maize resowing was performed as per requirements. And other intercrops were sown after 1 month of maize sown. The row spacing was 60 cm, while the plant spacing was 25 cm.

Farm Yard Manure (FYM) was applied by farmer procedure (about 15 t/ha), each plot received 5kg manure. Before ploughing the field, well-decomposed manure was incorporated into the soil. Potassium and phosphorus were applied 1/4 of recommended does (15 and 10 kg/ha respectively) as its availability was already high in soil, but nitrogen was applied at half the required rate since we assumed legumes and leaf manuring would meet the remaining demand. The first half of the nitrogen dosage was applied at planting, followed by the second half six weeks later.

NPK = 60: 15: 10 kg/ha

Weeding was performed as per requirements and earthing up was done 45 days after sowing. In the early stage of maize growth, cutworm was a problem so to control it, we applied Cartap hydrochloride as recommended. Harvesting was performed manually in the middle of July and thereby data was collected. Nitrogen, Phosphorous, Potassium, pH and Organic matter level of experimental site's soil were examined.

3. RESULTS

3.1 Anthesis Silking Interval

The finding showed that intercropping and green manuring had no significant effect on ASI. Despite that, ASI of maize incorporated with green leaf manuring was the shortest as compared to others. ASI of maize in green manuring was shifted 2 days earlier as compared to control; however, highest ASI of maize was observed in French bean which was slightly longer than control though significant difference was not observed as shown in Fig. 1**.**

3.2 Maize Yield

Different intercropping and green leaf manuring showed significant difference in maize grain yield. Maize grain yield under green leaf manuring was 2.21 times more as compared to control then followed by intercropping with soybean and cowpea yielded 0.65 and 0.25 times respectively as shown in Fig. 2. French bean enhanced only 0.9 times more yield as compare to control. Maize yield in intercropping was lower than green manure was due to competition of intercropping legumes with maize while there was no competition in green leaf manuring during maize growth stages. Besides high and slow release of nutrient (primarily N) by green leaf manuring to the soil ultimately increased the yield than others.

Table 2. Nutrients status before research

Experimental site	Nitrogen %	Phosphorous %	Potassium %	Organic matter %	Soil pH
IAAS, Sundarbazzar	0.1	529	872	2.1	6.2

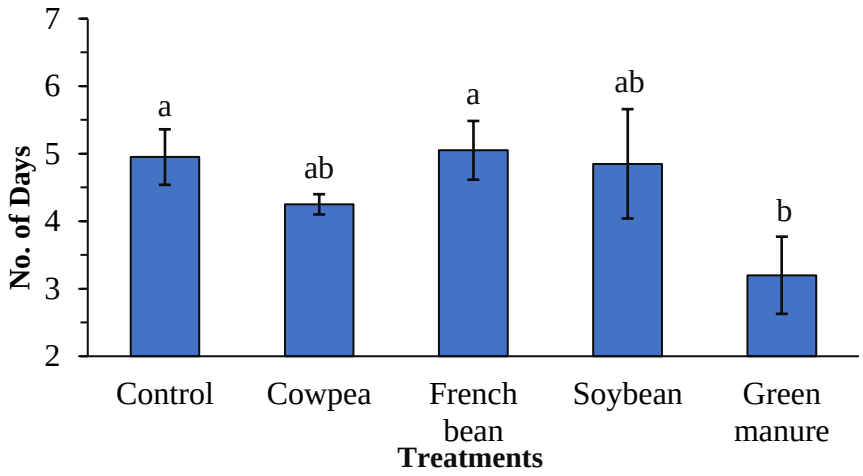

Fig. 1. Effect of Intercropping and green manuring on ASI on maize

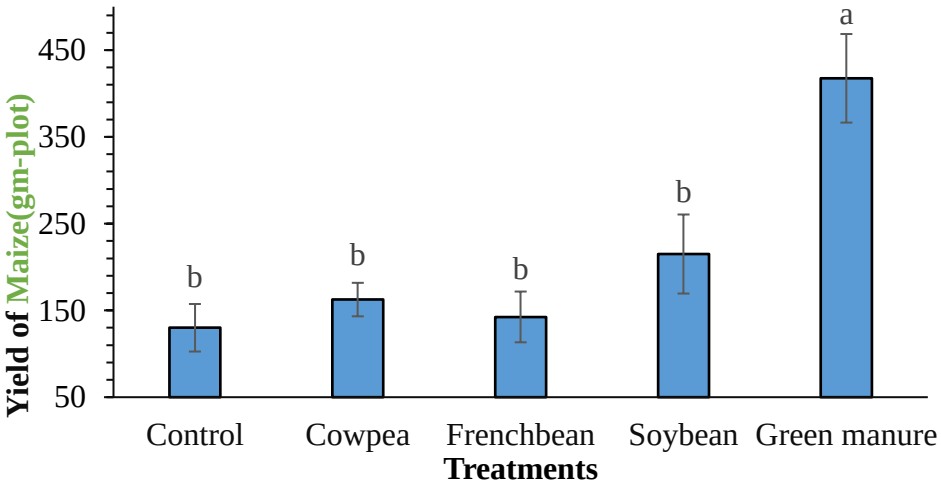

Fig. 2. Effect of Intercropping and green leaf manuring on Maize yield

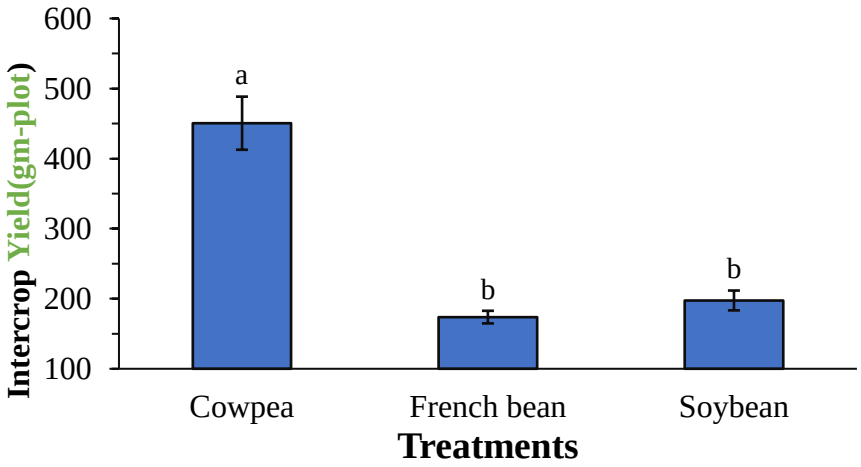

Fig. 3. Yield of different intercrop legumes

3.3 Intercrop Yield

As represented in Fig. 3, yield of cowpea significantly differed with other intercropping. Cowpea yield was found 1.6 times more as compare to French bean yield (which was the lowest). Soybean yield was slightly higher than French bean though significant difference was not observed. Intercropping French beans with maize does not significantly impact maize yield but drastically reduces the output of French beans.

3.4 Soil Nutrients and pH

The Nitrogen level in the soil was measured at 0.1% before planting maize in the field. As the soil was intercropped with various nitrogen-fixing crops, the soil nitrogen content ranged from 1.01% to 2.25%. The soil intercropped with green manure had higher N (2.25%), while the soil with no intercropping had lower N (1.01%). The remaining intercropped soils fell in between these two extremes, as indicated in Fig. 4. Total N level in green leaf manuring was higher as *Justicia Adhatoda* provides potassium nitrate in decomposition and also enhanced OM which ultimately increased total N.

The initial Phosphorus and Potassium level in the soil were measured 529 kg/ha and 872 kg/ha respectively. P and K fertilizer were applied as required only due its high availability in soil. Across various intercropped soil types in the field, the recorded P & K level ranged from 200 to 301 kg/ha and 302.36 to 375.45 kg/ha respectively. Among these, the soil intercropped with green leaf manure exhibited higher P & K content i.e. 301 kg/ha & 375.45 kg/ha, while the soil with no intercropping had lower P & K content i.e. 200 kg/ha & 302.36 kg/ha respectively. The remaining intercropped soils showed P & K level that fell between these two extremes, as represented in Fig. 5.

The organic matter (OM) percentage in the soil before maize planting was recorded at 2.1%. After planting and implementing various intercropping practices, the OM % in the field ranged from 2.1% to 4.8%. Notably, the soil intercropped with green manure exhibited higher OM % (4.8%), while the soil in the control group maintained its OM % at the initial 2.1%. In the control group, the OM percentage remained constant before and after maize plantation. Fig. 6 illustrates that the other intercropped soils displayed OM percentages that fell between these two extremes. OM in green leaf manure was high due to well decomposition of manure and slow release of nutrient in soil.

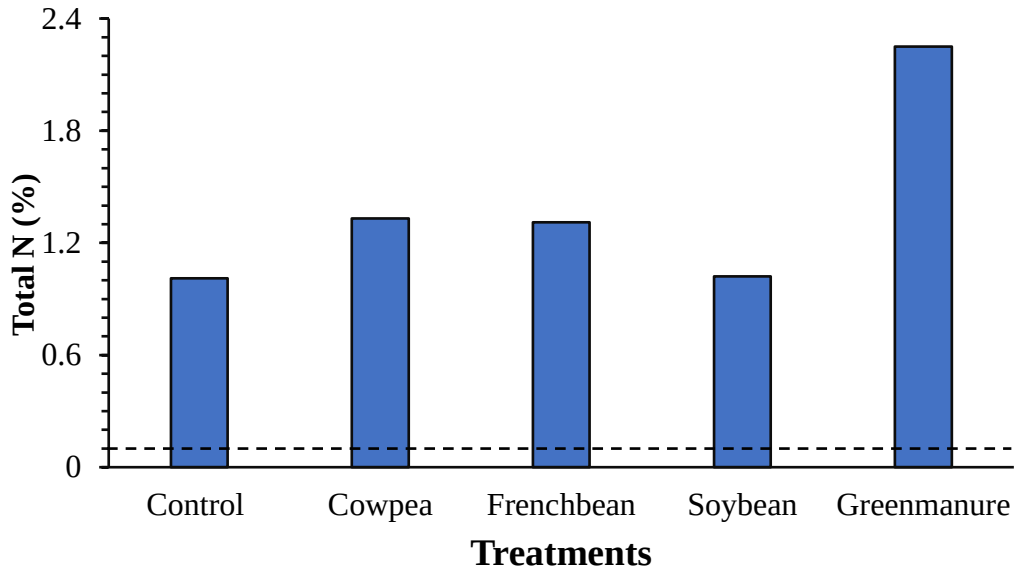

Fig. 4. Changes in total N in soil due to different types of intercropping and green manuring in maize field. Dash line in the figure indicates the level of total N in soil (which is 0.1%) before intercropping

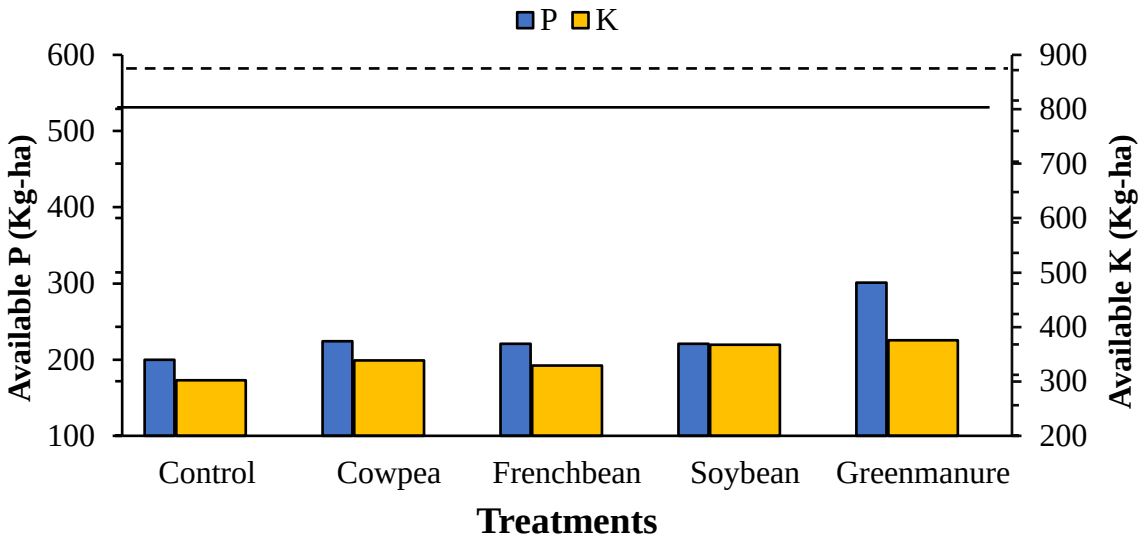

Fig. 5. Changes in available P & K in soil due to different types of intercropping and green leaf manuring in maize field. Straight line in the figure indicates the level of initial available P in soil (which is 529). Dash line in the figure indicates the level of initial available K in soil (which is 872)

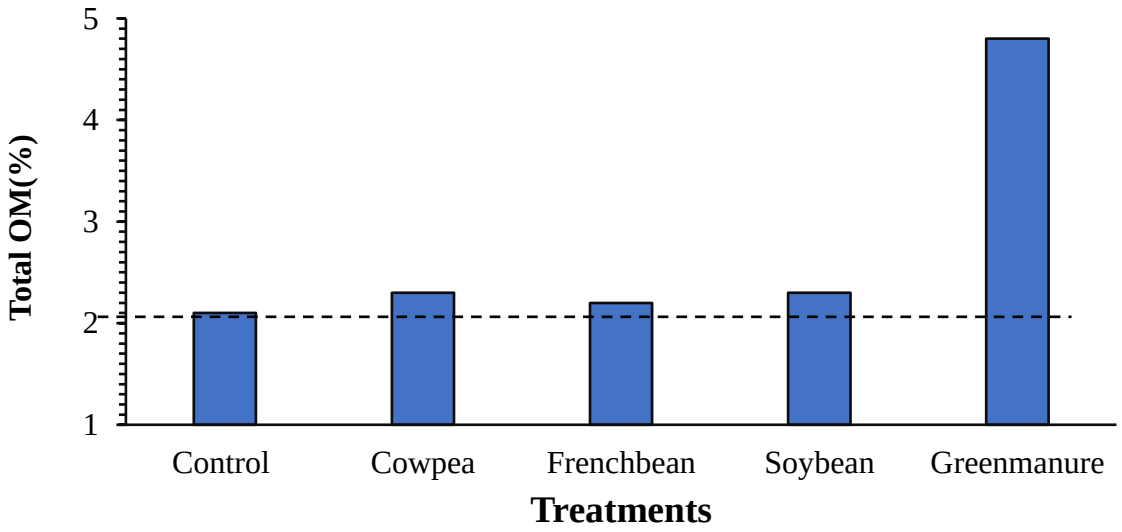

Fig. 6. Effects of various intercropping and green leaf manuring on total OM % in soil

The initial soil pH level was noted 6.2. The pH values in the field ranged from 4.8 to 6.5 after maize planting and the use of various intercropping strategies. Notably, the soil intercropped with French beans had higher pH level at 6.5, suggesting a more neutral state, while the soil with green manure had lower pH level at 4.8, indicating excessive acidity. Excess acidity in green manure was due to use of Malabar nut which provides potassium nitrate (*Adhaota Vasica (Malabar Nut)*, n.d.). P Singh et al, (2011) reported that *Justicia adhatoda L.* contains major elements Ca, Na, Mg, and K, as well as trace elements Ni, Co, Cd, Cr, Mn, Fe, Zn, Pb, and Cu. The pH level in the control group was stable before and after maize planting. Due to present of such elements might increase acidity and lowers soil pH. Fig. 7 shows that the remaining intercropped soils had pH value ranging from acidity to neutral.

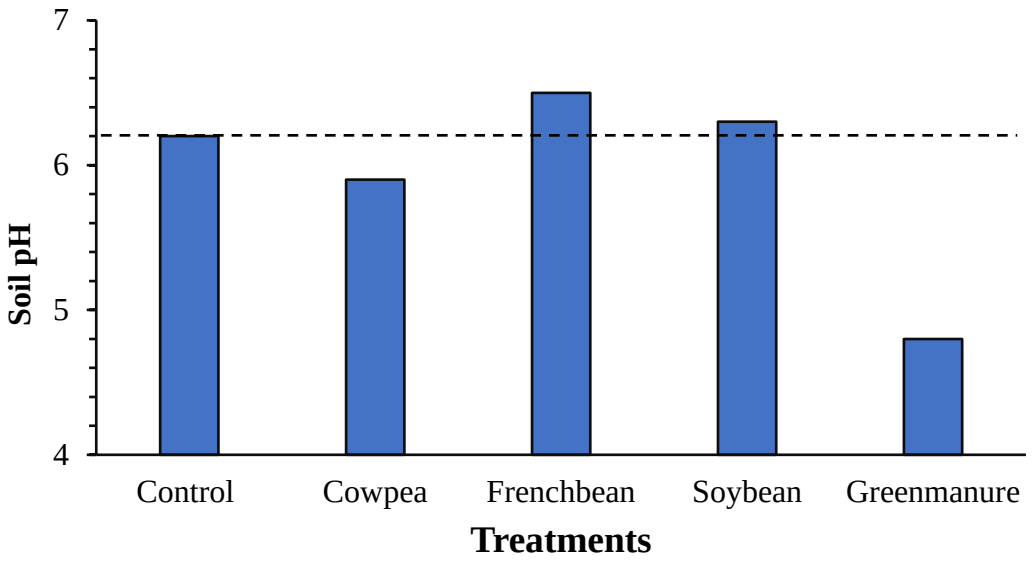

Fig. 7. Effects of different intercropping and green leaf manuring on soil pH

Table 3. Nutrient status after research

Treatments	Nitrogen %	Phosphorous Kg/ha	Potassium Kg/ha	Organic matter %	Soil pH
Sole Maize	1.01	200	302.36	2.1	6.2
Maize + Cowpea	1.33	224	338.61	2.3	5.9
Maize + Frenchbean	1.31	221	329.26	2.2	6.5
Maize + Soybean	1.02	220.8	367.21	2.3	6.3
Green leaf manure + Maize	2.25	301	375.45	4.8	4.8

Table 4. Effects of maize- legumes intercropping and green leaf manuring on ASI and yield of maize and legumes

Factors	Intercrop yield	Maize yield	ASI
T_1	0.00^{c}	130.0^{b}	4.95^{a}
T_2	450.50^{a}	162.5^{b}	4.25^{ab}
T_3	173.75^{b}	142.5^{b}	5.05^{a}
T_4	197.50^{b}	215.0^{b}	4.85^{ab}
T_5	0.00^{c}	417.5^{a}	3.20^{b}
Sem±	17.31	37.60	0.53
LSD	53.35	115.87	1.62
CV	21.069	35.24	23.53
F-test	***	***	NS
MS error	1199	5656	1.1013

*Means followed by the common letter within each column are not significantly different at 5% level of significance by Duncan Test. ('***'= 0.001, ** = 0.01 and * = 0.05)*

4. DISCUSSION

The impact of intercropping of maize with cowpea, French bean, soybean was not significant in terms of ASI, although there was a marginal delay, which again illustrated the impact of the stress factors due to competition, which delays ASI (Westgate et al., 2000). Furthermore, the research showed there is no influence of intercropping in drought tolerant despite, it is influenced by green manuring slightly. Intercropping with green manure is the option to enhancing maize yield even in nitrogen-depleted soil (H. Li et al., 2023). Instead of creating accessible N for the maize, legumes in the intercropped plot may compete for soil N. Hiebsch (1981), who researched corn-soybean intercropping systems, found evidence of probable N competition by a legume in a grass-legume intercropping system.

The production of accessible N by a legume through biological N2 fixation for an adjoining grass was not advantageous for intercropping in the same season. Further, discussing about intercropping, greater influence might be seen on next cropping as nutrient release in soil is slow process. In a maize-soybean intercropping system, the taller maize crop alters the light environment perceived by the lower soybean crop in terms of both light quantity and quality, resulting in reduced branching of soybean plants and ultimately, poorer soybean yield (Liu et al., 2017).

The primary advantage of intercropping is that it optimizes resource utilization and enhances total production compared to individual crops (Hamd Alla et al., 2014). Unkovich & Pate (2000) stated that the percentage of nitrogen in a legume is not only influenced by the connection between the bean genotype and its rhizobia but also by the relationship between soil nitrogen availability and legume growth. In addition to this, initial N% in soil was found low in the plot which might be the reason for lower N% in intercrop plot. Further research might be needed to conduct to find for more reason. Cavigelli & Thien (2003) reported that green manure has been shown to boost phosphorus availability from rock phosphate in rice; in general, we can conclude that they increase phosphorous availability and utilization. Maize being a heavy nutrient feeder, it absorbed P & K from soil and also intercropping and green leaf manuring help to mobilize nutrient in soil. P Singh et al., (2011) reported that *Justicia adhatoda L.* contains major elements Ca, Na, Mg, and K, as well as trace elements Ni, Co, Cd, Cr, Mn, Fe, Zn, Pb, and Cu. Due to present of such elements might increase acidity and lowers soil pH. The pH level in the control group was stable before and after maize planting.

5. CONCLUSIONS

The study conducted at IAAS, Lamjung Campus in March 2023 evaluated the effects of legume intercropping and green leaf manuring on the Rampur Composite variety of maize. we can conclude that the incorporation of locally available Malabar nut green leaf enhances the yield and yield-related attributes of maize. The grain yield under green leaf manuring appeared to be significantly higher in comparison to other legumes intercropping. Also, soil nutrients under green leaf manuring were found higher although soil pH remains slightly acidic than others. Increase in grain yield and soil nutrients may be due to the high and slow release of nutrients by green leaf manuring after decomposition. Green leaf manuring is a cost-effective and sustainable approach for smallholder farmers to improve maize yield and soil health. Further discussing about intercropping, greater influence might be seen on next cropping as nutrient release in soil is slow process. However, further trials are recommended to comprehensively evaluate its long-term effects on soil physical, chemical, and biological properties so, that the results obtained can be a great piece of information for Nepali farmers.

SIGNIFICATION OF THE MANUSCRIPT

The research primarily concentrates on marginal farmers intending to enhance maize production and productivity through various alternatives aimed at reducing production costs, as the availability of fertilizer is always an issue. This study investigates the effects of different legumes intercropping and green leaf manuring on soil fertility and maize crop production ultimately fostering 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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