

Mitigating Plant and Soil Health Options Through Climate Resilient Maize-Mungbean Based Intercropping for Rainfed Agriculture

ABSTRACT

An experiment was conducted at National Agricultural Research Council (NARC), Islamabad to evaluate the response of intercropping in maize and cowpea with implementation of farm yard manure and chemical fertilizer. The experiment was laid down in RCBD with split plot arrangement having three replications. The data was recorded for plant parameters of chlorophyll content ($\mu\text{mol}/\text{m}^2$), rate of photosynthesis ($\mu\text{mol}/\text{s}$), intercellular CO_2 (ppm), protein content (%) and grain yield (kg/ha) while soil parameters that were estimated included are: soil pH, electric conductivity (dS/m), cation exchange capacity (cmol/kg), exchangeable Ca (cmol/kg), exchangeable Mg (cmol/kg), soil organic matter content (%), available N (ppm), available P (ppm), available K (ppm). The analysis of the data revealed that all of the studied traits were significantly affected by the intercropping. The increased value of chlorophyll content (67.12 and 61.07 $\mu\text{mol}/\text{m}^2$) was obtained in intercropped maize-mungbean (M-Mb) and farm yard manure (FYM) treatments, maximum rate of photosynthesis (25.33 and 20.76 $\mu\text{mol}/\text{s}$) was obtained by maize and mungbean in maize-mungbean (M-Mb) intercropping along with farm yard manure (FYM) treatments. Correspondingly, protein content (28.15 and 16.43 %) and grain yield (9246.1 and 1610.71 kg/ha) for maize and mungbean were improved by the application of maize-mungbean (M-Mb) and farm yard manure (FYM) treatments. There was also increased in the values of soil pH (6.44), CEC (44.31 cmol/kg), exchangeable Ca (6.42 cmol/kg), exchangeable Mg (2.21 cmol/kg), SOM content (0.78%), available N (2.98 ppm), available P (18.67 ppm) and available K (198.76 ppm) with the implementation of farm yard manure (FYM) and maize-mungbean intercropping treatments. Overall, the study revealed that intercropping is a best way of increasing crop yield and quality with bringing positive changes in the soil properties and health.

INTRODUCTION

Intercropping as "the technique of planting two or more crops on the same plot of land in the same year to foster interaction and increase production by avoiding reliance on a single crop" [1]. Many tropical agricultural systems rely on various intercropping arrangements for legumes and non-legumes [2,3]. Intercropping is most typically used on small-scale farms with limited space, necessitating the growth of many plants on the same plot of agricultural land at one time. Reduced rainfall and/or unpredictable distribution of rainfall may drive farmers to intercrop in order to maximize water use, but this could end in competition for scarce resources in the extreme [4]. The primary advantages of intercropping are decreased failure of growth risk and agricultural diversification- nutritive crops are typically intercropped with commercial crops to help offer both nourishment and additional money [5]. The intercrop is more efficient at utilizing resources such as light, water, and nutrients [6].

Increasing plant variety, in an intercrop setting, is also recommended as a way to increased robust and sustainable agricultural methods [7]. One element that drives production variations between mixes and pure crops is crop competing for soil obtainable sunlight, nutrients, and water [8]. Multiple standards are employed to assess the prospective benefits of intercropping and interactions between species. Their choices, usage, and significance are critical for interpreting scientific information as well as enabling us to evaluate results from other studies [9].

Globally, maize (*Zea mays*), a primary cereal food, is extensively farmed. Due to a roughage scarcity, substantial emphasis has been dedicated to its feeding value in recent years. Maize can produce massive amounts of energy-rich forage for animal diets, and its fodder may be fed safely at all phases of growth without the risk of oxalic acid or prussic acid toxicity that sorghum does [10]. But its greatest disadvantage is clearly its minimum crude protein content, ranging normally between 70 and 80 g/kg dry matter (DM) [11].

Mungbean (*Vigna radiata*) is an herbaceous annual crop produced mostly in the tropics' dry agro-ecologies in Latin America, Africa, and South Asia [12]. It is a legume of the Fabaceae family, tribe Phaseoleae, genus *Vigna*, and section *Catiang*. Maize belongs to the poaceae family and is a grain crop, whereas mungbean belongs to the fabaceae family and is produced for its edible legumes. As a result, intercropping cereals and legumes helps to preserve soil fertility. Legumes assist to fix atmospheric nitrogen, which might benefit the host plant or be utilized by

another nearby plant [13]. Mungbean (*Vigna radiata*), an annual legume with high levels of protein (about twice that of maize), can be combined with maize to increase the protein content of diets and, as a consequence, reduce the cost of producing high-quality feed [14]. Several studies have also revealed that intercropping mungbean and maize increased biomass production (20-40%) [15] and protein (11-15%) [16].

MATERIALS AND METHODS

Experimental Site and Material Collection

Maize and mungbean varieties were evaluated for different yield and quality related parameters along with soil attributes through intercropping at National Agricultural Research Center (NARC), Islamabad, Pakistan. The experimental material was provided by Fodder and Forage Research Program, Crop Sciences Institute, NARC Islamabad.

Crops Plantation

The seeds were sown in randomized full blocks with split plot arrangement with three replications. The main treatments included the 3 cropping practices, sole maize (SM), sole mungbean (SMb), intercropped maize mungbean (M-Mb) while sub treatments that were used are 2 nutrient management approaches, farm yard manure (FYM) and chemical fertilizer (CF). Every replication had been produced in a plot containing four rows where length of row was kept at 3 meters along with 6m × 3 m plot size. Row to row spacing of 75 cm were kept for sole maize and mungbean whereas intercropped treatment had row to row distance of 100 cm.

Experimental Set-up

Plot Size: 6m×3m= 18m²

Design: RCBD with split plot arrangement

Replications: 3

Number of Rows: 4

Row Spacing: 75cm for both maize and mungbean, 100 cm for intercropped treatments

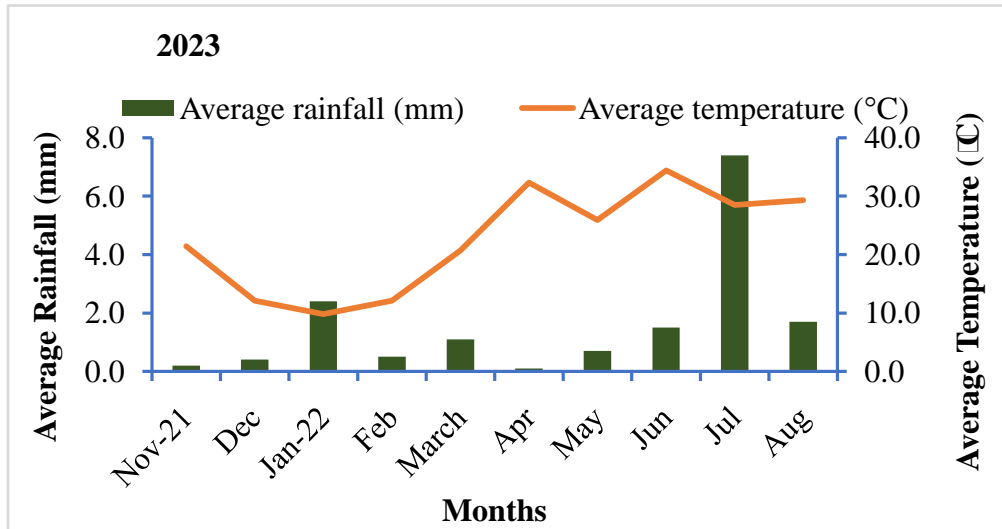


Figure 1. Average temperature and rainfall in the experimental site (NARC, Islamabad) in 2023. (Source: Climate Observatory at NARC, 250 m away from experimental location)

Crop Husbandry

The experimental area received 10 cm of pre-soaking irrigation during the season. For the preparation of seedbed, soil had to achieve field capacity. Table 1 shows the crops that were grown according to the suggested production technology for the area. With a hand drill, all the crops were manually seeded in lines. The irrigation was completely dependent on precipitation. Urea (nitrogen-based fertilizer) were used as chemical fertilizers and 1/3rd portion of urea was applied at sowing time. The rest of the chemical fertilizer was applied during the first and second irrigations, respectively. Farm yard manure (FYM) was applied and intermixed properly in soil before sowing. In the cropping season, diseases, insects, and pests were managed by implementing the necessary agronomic and crop protection methods. The plant and soil samples from every plot of both crops were estimated after the harvest of maize and mungbean.

Table 1: Details of crops sown to estimate the effect of intercropping practice on plant and soil growth.

Crops	Sowing Time	Varieties	Seed Rate (kg/ha)	P-P (cm)	R-R (cm)	Harvesting Time	Harvest Method
Maize	24 March	DS-2003	35	15	75	08 September	Manual
Mungbean	24 March	NM-2011	75	10	30	08 September	Manual

Plant Parameters

Chlorophyll is an important photosynthetic pigment for the plant, which gives help in determining the photosynthetic capacity as well as plant growth so it is very important to measure chlorophyll content of plant. Leaf chlorophyll content was reliably determined by extracting chlorophyll in a solvent and then measuring it in vitro with a spectrophotometer. Non-destructive, in-situ optical approaches, on the other hand, have become frequently employed to offer a relative estimate of leaf chlorophyll content. The concentration of chlorophyll in plant leaves is commonly represented in terms of amount per area of leaf surface, micromoles per square meter ($\mu\text{mol}/\text{m}^2$), or mass per area of leaf surface, milligrams per square meter (mg/m^2). Photosynthetic rate was measured with the help of infrared gas analyzer CI-340 handheld photosynthesis system (IRGA). Stomatal conductance was measured by infrared gas analyzer CI-340 (CID Inc. USA) handheld photosynthesis system (IRGA). Transpiration rate ($\text{mmol}/\text{m}^2/\text{s}$) data was measured by the infrared gas analyzer CI-340 handheld photosynthesis system (IRGA). CO_2 uptake was evaluated using an IRGA (Infrared-Red Gas Analyzer), which can compare the amount of carbon dioxide (CO_2) in gas entering into a chamber around a leaf per plant to the CO_2 concentration exiting the chamber. Plant specimen protein concentration had been assessed using Kjeldahl technique and traditional nitrogen to protein (N:P) transformation value 6.25, as well as the sum of residues of amino acids. The grain yield was measured by estimating the weight of samples taken from 1 m^2 area through quadrant and then the resulted value was multiplied with 10000 to figure out the amount from 1 hectare.

Soil Parameters

Composite soil samples (0–15 cm depth) were obtained from each experimental unit for post-harvest soil analysis of pH, electric conductivity (EC), cation exchange capacity (CEC), exchangeable Ca, exchangeable Mg, soil organic content (SOM), available nitrogen, available phosphorus and available potassium. To find out the value of soil organic matter content we will multiply organic carbon (OC) by 1.73 while Walkley and Black method was followed to determine OC titrimetrically. To find out the value of available phosphorus soil was shaken with 0.03 M NH_4F —0.025 M HCl solution at $\text{pH} < 7.0$. To find out the exchangeable calcium (Ca) and magnesium (Mg) contents we have used acetate extracted method and then ethylene-diamine tetra acetic was applied to find value of Ca and Mg. Glass electrode pH meter was used to measure the pH value. CEC was calculated by mean of NH_4OH extraction method. Available nitrogen was determined by Kjeldahl method. To evaluate the value of available K was determined by using the ammonium bicarbonate-DTPA technique (AB-DTPA).

RESULTS

Plant Parameters

Chlorophyll is a vital photosynthetic pigment in plants, influencing photosynthetic capability and hence plant development. A significant variation was noticed for chlorophyll content ($\mu\text{mol}/\text{m}^2$) as a result of nutrient treatments on both maize and mungbean (Figure 2 & Figure 3). The means for various treatments for maize ranged from 48.21 to 67.12 $\mu\text{mol}/\text{m}^2$ (Figure 2). Maize genotype under intercropped treatment maize-mungbean (M-Mb) had maximum chlorophyll content (67.12 $\mu\text{mol}/\text{m}^2$) while minimum chlorophyll content (48.21 $\mu\text{mol}/\text{m}^2$) was obtained in sole treatment (SM). It is also observed that the farm yard manure (FYM) is suitable for obtaining increased chlorophyll content in maize-mungbean (M-Mb) intercropping. On the other hand, the means for various treatments for mungbean ranged from 48.21 to 67.12 $\mu\text{mol}/\text{m}^2$ (Figure 3). Mungbean has observed better chlorophyll content of 67.12 $\mu\text{mol}/\text{m}^2$ in intercropped treatment with addition of farm yard manure (FYM) though diminished value of chlorophyll content (48.21 $\mu\text{mol}/\text{m}^2$) was shown by sole mungbean (SMb) with application chemical fertilizer (CF). It shows that the intercropped maize-mungbean (M-Mb) with farm yard manure (FYM) is suitable for maximizing the chlorophyll content.

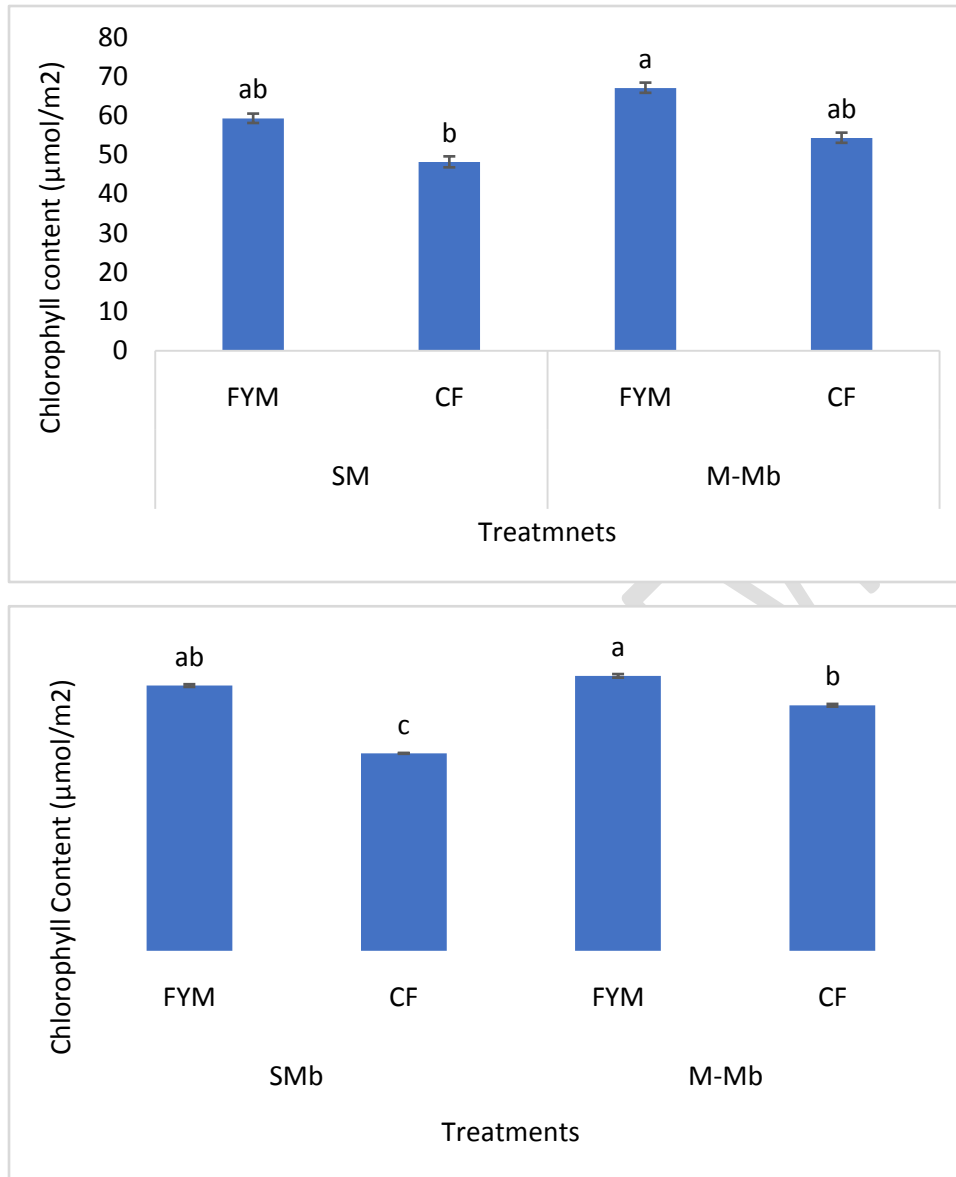


Figure 2 & 3: Effect of different cropping practices and nutrient management approaches on chlorophyll content ($\mu\text{mol}/\text{m}^2$) of maize and mungbean, respectively.

The rate of photosynthesis influences agricultural crop productivity. It guarantees that all living things in the atmosphere have access to oxygen. It regulates the quantities of oxygen and carbon dioxide in the ecosystem. A significant variation was noticed for photosynthesis rate ($\mu\text{mol}/\text{s}$) as a result of different nutrient treatments and cropping practices on both maize and mungbean (Figure 4&Figure 5). The means for various treatments for maize ranged from 18.38 to 25.33 $\mu\text{mol}/\text{s}$ (Figure 4). The rate of photosynthesis improved (25.33 $\mu\text{mol}/\text{s}$) which is followed by sole maize (SM) treatment with farm yard manure (FYM) having photosynthetic rate of 21.65 $\mu\text{mol}/\text{s}$

whereas photosynthesis rate ($18.38 \mu\text{mol/s}$) was observed lowest in sole maize (SM) treatment with application of chemical fertilizer (CF). Conversely, the means for various treatments for mungbean ranged from 14.24 to $20.76 \mu\text{mol/s}$ (Figure 5). Mungbean genotype under farm yard manure treatment with intercropped maize-mungbean (M-Mb) exhibited maximum photosynthesis rate ($20.76 \mu\text{mol/s}$) while least photosynthesis rate ($14.24 \mu\text{mol/s}$) was present in chemical fertilizer treatment in sole mungbean (SMb) followed by intercropping maize-mungbean ($17.33 \mu\text{mol/s}$). It is illustrated that the intercropped treatment of maize-mungbean with farm yard manure is appropriate for obtaining minimizing rate of photosynthesis.

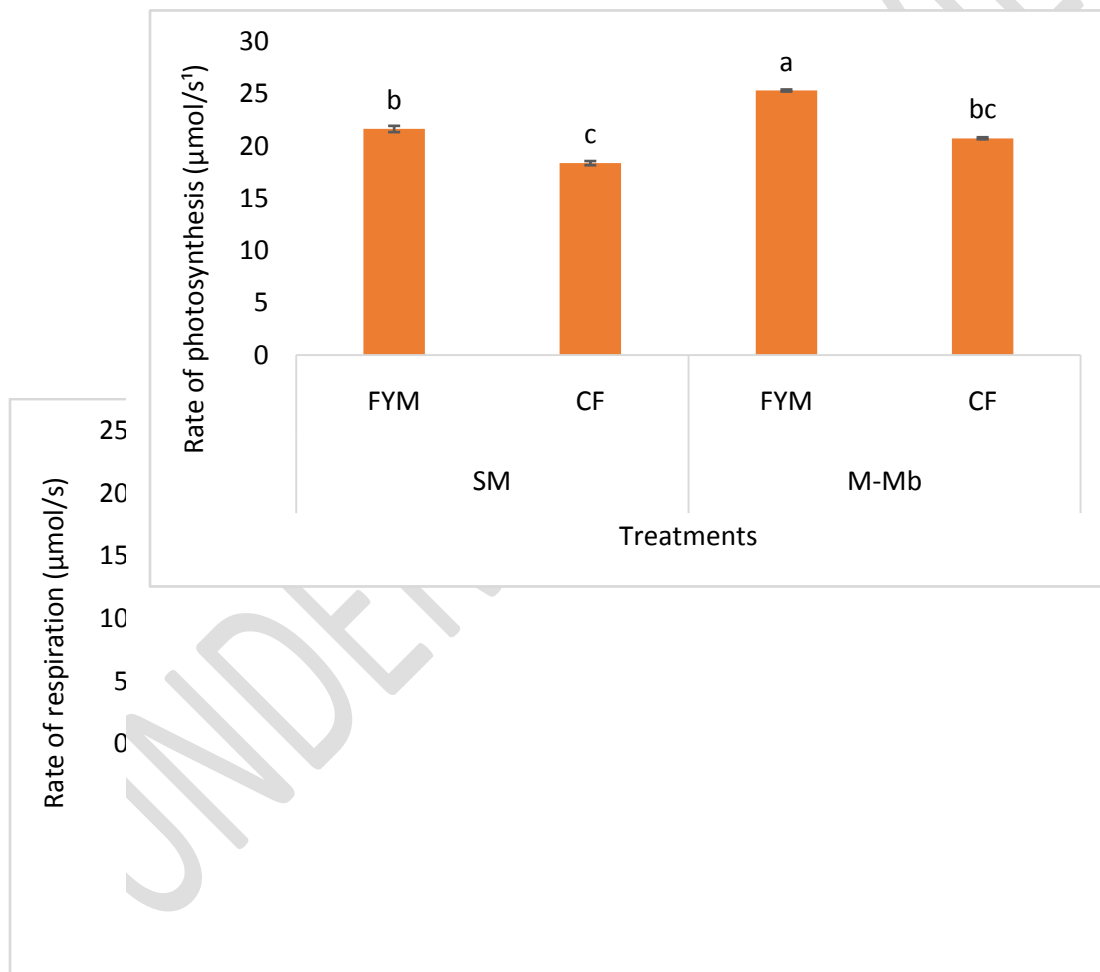


Figure 4 & 5: Effect of different cropping practices and nutrient management approaches on rate of photosynthesis ($\mu\text{mol/s}$) of maize and mungbean, respectively.

If stomatal apertures and external concentration stay constant throughout photosynthesis, the concentration of carbon dioxide in a leaf's intercellular spaces dictates the flow of carbon dioxide into the leaf. In the present experiment mean square values for intercellular CO_2 (ppm) showed significant variations in both maize and mungbean under the effect of cropping and nutrient management practices. The means for various treatments for cropping practices ranged from 216.35 to 331.36 ppm (Figure 6 & 7). Sole cropping of maize (SM) with amendment of farmyard manure (FYM) had given maximum intercellular CO_2 value (331.36 ppm) for maize while minimum intercellular CO_2 (216.35 ppm) was obtained for maize in intercropped maize-mungbean (M-Mb) treatment with accumulation of chemical fertilizer (CF). Apart from this, the means for various treatments for mungbean ranged from 123.29 to 238.86 ppm (Figure 7). Increase in the value of intercellular CO_2 for mungbean was observed in sole mungbean (SMb) with treatment of farm yard manure (FYM) (238.86 ppm) followed by intercropped maize-mungbean (M-Mb) (198.77 ppm) despite this, minimum intercellular CO_2 (113.75 ppm) was experienced in maize-mungbean (M-Mb) and chemical fertilizer (CF) treatment.

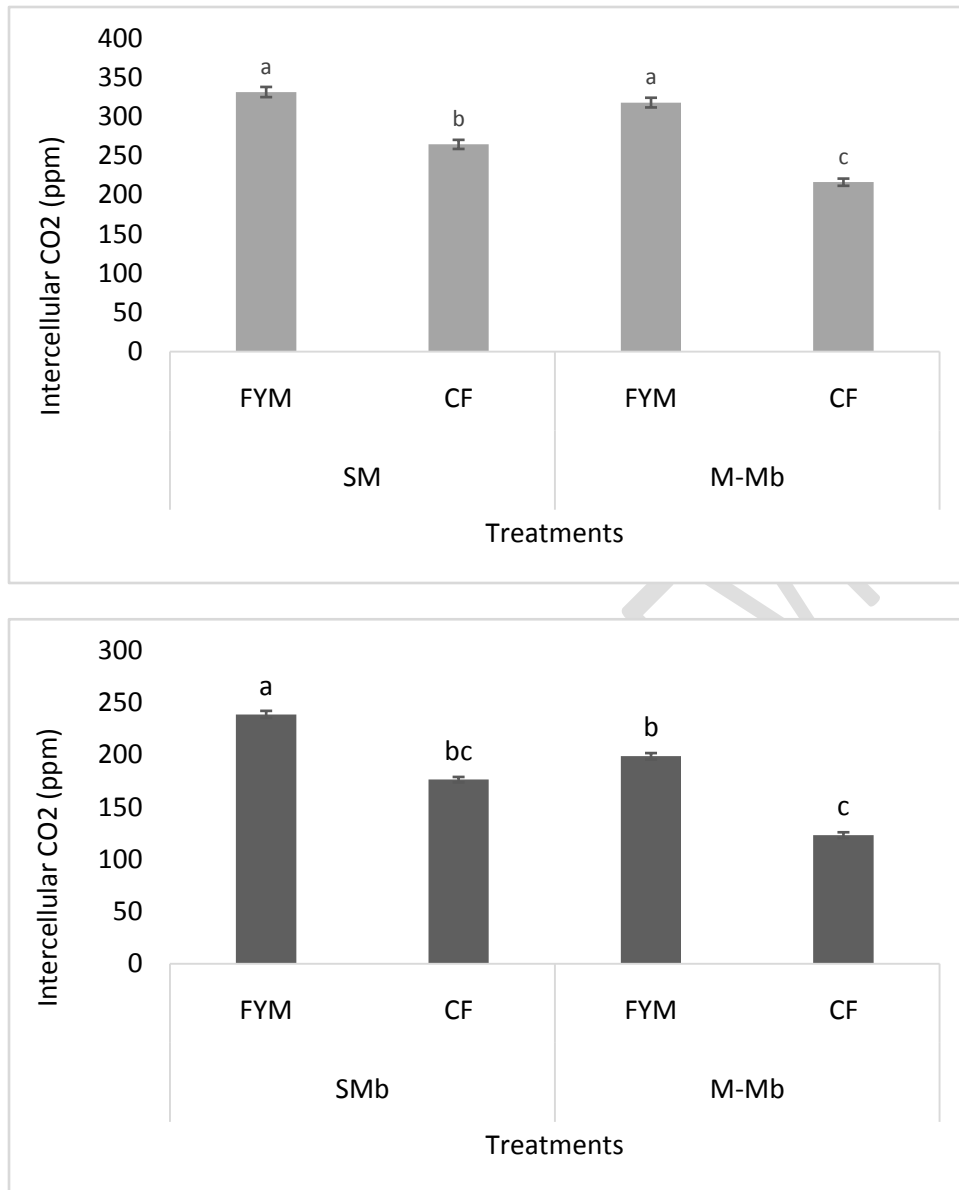


Figure 6 & 7: Effect of different cropping practices and nutrient management approaches on intercellular CO₂ (ppm) of maize and mungbean, respectively.

Mean square values for protein content (%) showed significant variability among both maize and mungbean genotype under the effect of intercropping (Figure 8&9). The means for various treatments for maize ranged from 8.95 to 16.43 % (Figure 8). Maize genotype under maize-mungbean (M-Mb) and farm yard manure (FYM) treatments had highest protein content (8.95 %) while lowest protein content (15.78 %) was obtained by sole maize (SM) and chemical fertilizer (CF). On the other hand, the means for various treatments for protein content in mungbean ranged from 15.42 to 28.15 % (Figure 9). Maximum protein content (28.15 %) was

observed in maize-mungbean (M-Mb) treatment with accrual of farm yard manure (FYM) while minimum protein content (15.42 %) was present in sole treatment (SMb) and chemical fertilizer (CF).

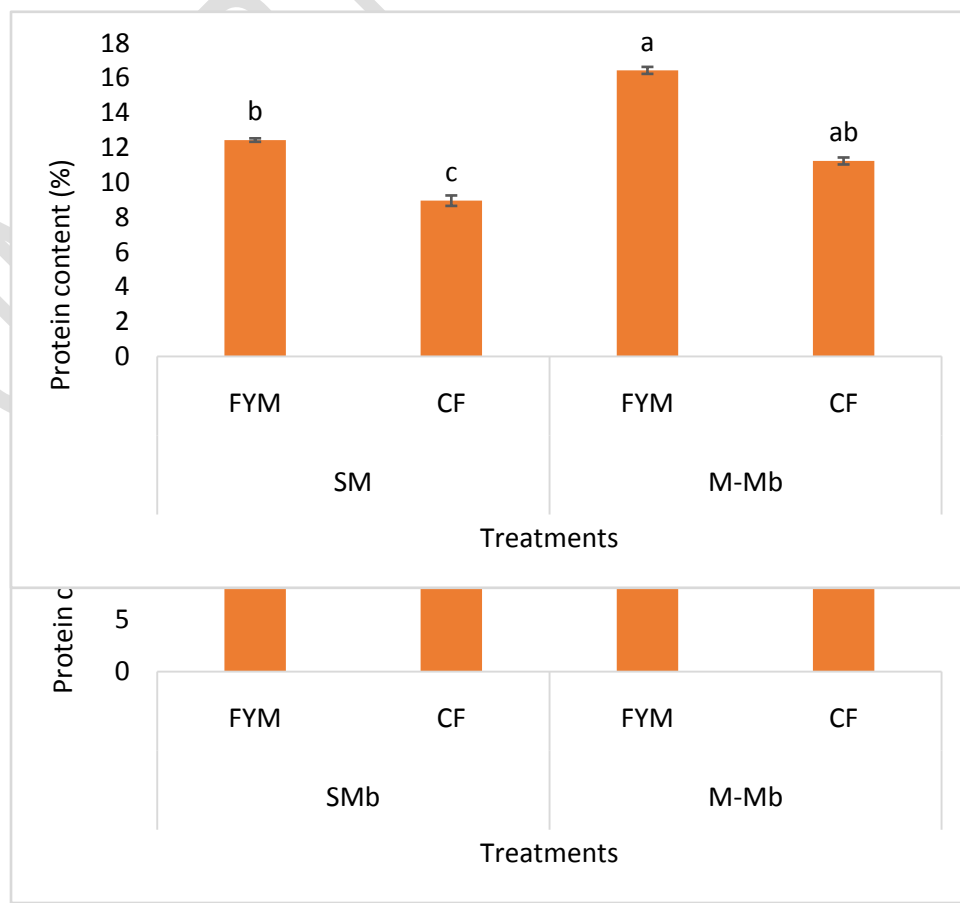


Figure 8 & 9: Effect of different cropping practices and nutrient management approaches on protein content (&) of maize and mungbean, respectively.

Grain yield is an important plant feature because it provides a more accurate evaluation of production by excluding the fluctuations induced by water content. The grain yield of crops is intimately related to plant performance as a result of photosynthetic aptitude, nutrition, environmental conditions, and other variables. The analysis of variance for dry weight (g) showed significant variability among both maize and cowpea mixed by various nutrient management treatments (Figure 10 & 11). The means for various treatments for maize ranged from 7467.4 to 9246.1 kg/ha (Figure 10). Maize under intercropped maize-mungbean (M-Mb) and farm yard manure (FYM) treatments displayed maximum grain yield (7467.2 kg/ha) followed by sole maize (SM) treatment with farm yard manure (FYM) (8754.1 kg/ha), maximum grain yield (9246.1 kg/ha) was seen in sole maize (SM) and chemical fertilizer (CF) treatments. On the other hand, the means for various treatments for mungbean ranged from 810.27 to 1610.71 kg/ha (Figure 11). Mungbean genotype under intercropped treatment (M-Mb) and farm yard manure demonstrated maximum grain yield (1610.71 kg/ha) whereas minimum grain yield (810.27 kg/ha) was produced in sole mungbean (SMb) treatment with application of chemical fertilizer.

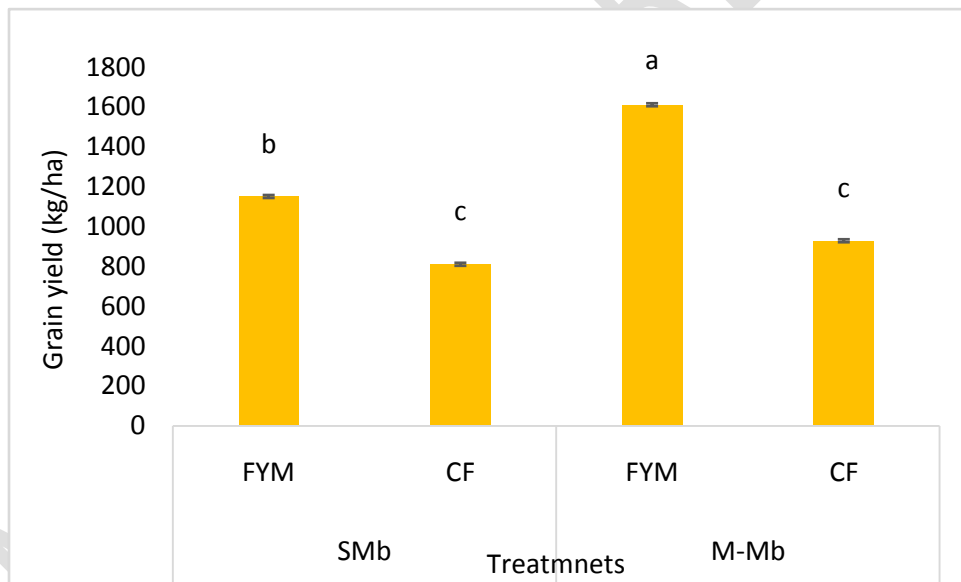
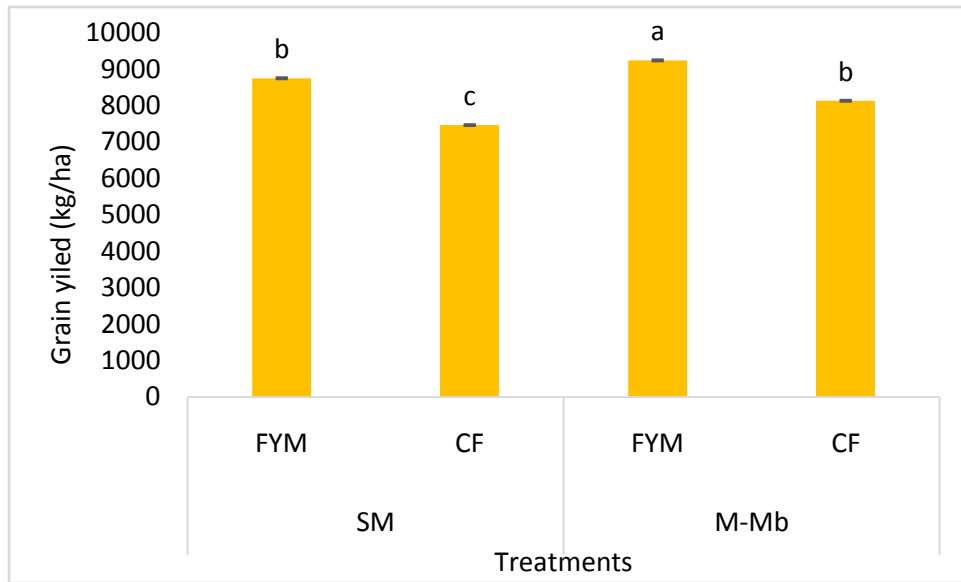


Figure 10 & 11: Effect of different cropping practices and nutrient management approaches on grain yield (kg/ha) of maize and mungbean, respectively.

Soil Parameters

Application of nutrient management strategies with the implementation of different cropping practices has meaningfully improved the soil properties and soil fertility as shown in Table 2.

SOM content has been significantly altered by the applications of these approaches in all cropping practices, it ranged from 0.14 to 0.78%. Intercropped maize-mungbean (M-Mb) with farm yard manure (FYM) has observed highest SOM content (0.78%) while lowest value, 0.22% was in sole maize (SM) of chemical fertilizer (CF) followed by sole mungbean (SMb) of chemical fertilizer (CF) (0.21%) (Table 2). Likewise, the value of available N fluctuated between 0.09 to 2.98 ppm in all the cropping practices and nutrient management practices in this experiment. In sole maize (SM) and chemical fertilizer (CF) treatments, the value of available N has diminished to 0.09, however there was significant increase of available N to 2.98 ppm in intercropped maize-mungbean (M-Mb) by implementing farm yard manure (FYM). Also, intercropped maize-mungbean (M-Mb) with chemical fertilizer (CF) has given better and improved results of available N with value of 2.11 ppm (Table 2).

pH in soil was 4.50 to 6.44 by the application of nutrient management and cropping practices. pH decreased to 4.50 in the sole maize (SMb) treatment of farm yard manure (FYM) followed by sole maize (SM) of chemical fertilizer (CF) (4.54) while intercropped maize-mungbean (M-Mb) with farm yard manure (FYM) increased available P content to 6.44 (Table 2). Available P has been significantly improved by the applications of these management approaches with both cropping practices, it ranged from 5.98 to 18.67 ppm. Maize-mungbean (M-Mb) has observed highest available P, 18.67 along with the addition of farm yard manure (FYM) and while lowest value, 5.98 ppm was in sole maize (SM) of chemical fertilizer (CF) followed by sole maize (SM) of farm yard manure (FYM) with 7.12 ppm, which were statistically similar to each other (Table 2).

Available K ranged from 121.53 to 198.76 ppm in both farm yard manure (FYM) and chemical fertilizer (CF) along with cropping practices, sole maize (SM), sole mungbean (SMb) and intercropped maize-mungbean (M-Mb), showing the highest value (198.76 ppm) in maize-mungbean intercropped treatment (M-Mb) with addition of farm yard manure (FYM) in it followed by M-Mb with chemical fertilizer (CF) (178.87 ppm). The lowest value 121.53 ppm was observed by sole maize (SM) with amendment chemical fertilizer (CF) (Table 2).

In CEC of the soil there was significant change was observed from 32.41 to 44.31 cmol/kg in both cropping and nutrient management practices in this experiment. In farm yard manure (FYM) and intercropped maize-mungbean (M-Mb) treatments, soil CEC increased to 44.31

cmol/kg in contrast to the chemical fertilizer (CF) of intercropped maize-mungbean (M-Mb) having CEC with 41.33 cmol/kg (Table 2). On the other hand, minimum increase (32.41 cmol/kg) was assessed in sole maize (SM) with chemical fertilizer (CF) (Table 3). Exchangeable Ca has been significantly changed by the application of nutrient management strategies with implementing different cropping practices, it ranged from 3.98 to 6.42 cmol/kg in this experiment. Intercropped maize-mungbean (M-Mb) has observed optimal value of exchangeable Ca (6.42cmol/kg)with implementing of farm yard manure (FYM) while lowest value, 3.98cmol/kg was in sole maize (SM) and chemical fertilizer (CF) (Table 2). Similarly, the exchangeable Mg varied between 1.02 to 2.21cmol/kg in farm yard manure (FYM) and chemical fertilizers (CF) along with sole maize (SM), sole mungbean (SMb) and maize-mungbean (M-Mb) used as cropping practices. In chemical fertilizer (CF) of sole maize (SM), the exchangeable Mg has reduced to 1.02 cmol/kg, however there was significant increase to value of 2.21 cmol/kg in farm yard manure (FYM) of maize-mungbean (M-Mb) followed by chemical fertilizer (CF) of intercropped maize-mungbean (M-Mb) with exchangeable Mg of 1.97 cmol/kg (Table 2).

CP	Ph		EC (dS/m)		CEC (cmol/kg)		Exchangeable Ca (cmol/kg)		Exchangeable Mg (cmol/kg)	
	FYM	CF	FYM	CF	FYM	CF	FYM	CF	FYM	CF
SM	4.54c	4.50d	0.29c	0.21c	35.60b	32.42c	4.21c	3.98d	1.19	1.02c
				d	c				c	
SM	5.66b	5.13b	0.41b	0.24c	39.41a	38.11b	5.86bc	5.14bc	1.77	1.54b
b	c				b				b	c
M-Mb	6.44 a	5.96a	0.51a	0.33b	44.31a	41.33a	6.42a	5.91b	2.21	1.97a
		b		c		b			a	b
SE	0.21		0.14		1.15		0.19		0.16	
CV	1.64		3.72		1.58		0.95		0.73	
(%)										
CP	SOM Content (%)		Available N (ppm)		Available P (ppm)		Available K (ppm)			

	FYM	CF	FYM	CF	FYM	CF	FYM	CF
SM	0.45b	0.14c	0.21c	0.09c	7.12bc	5.98c	156.92c	121.53
							d	d
SM	0.64a	0.29b	1.64b	1.23b	15.95a	10.43b	182.65b	161.21
b	b	c	c	c	b		c	c
M-	0.78a	0.69a	2.98a	2.11b	18.67a	17.15a	198.76°	178.87
Mb		b				b		b
SE		0.05		0.16		0.15		5.63
CV		0.79		1.99		2.14		1.78
(%)								

Table 2: Effect of different nutrient management approaches and cropping practices on the soil properties.

Figures in a column having common letters do not differ significantly at 5% level of significance. SE = Standard error of means; CV (%) = Coefficient of variation; SM = Sole Maize; SMb = Sole Mungbean; M-Mb = Intercropped Maize-Mungbean; FYM = Farm Yard Manure; CF = Chemical Fertilizer.

DISCUSSION

Nasar et al., [17] performed maize-mungbean intercropping at optimal N fertilization boosts maize crop N absorption, yield, and N usage efficiency through modulating N assimilatory enzymes and recorded similar results for chlorophyll content. Adding to this, Roet al., [18] led research to check impact of intercropping in maize and mungbean yield and quality parameters and found similar results that mungbean and maize is boosted as intercropping plays its pivot role. Meanwhile, Song et al., [19] assessed yield and nutritive value of maize-legume intercropping systems in paddy fields during summer by sowing maize with soybean and obtained same increased intercellular CO₂ as a result of intercropping. The amount of CO₂ raises as nutrient level is maximized to optimum with the intercropping of cereal legume practices [20]. Plant proteins provide a variety of enzymatic, structural, and functional functions

(photosynthesis, biosynthesis, transport, immunology, and so on). They also serve as storage media to suit the nutritional and development requirements of growing seedlings [21]. Tamta et al., [22] findings on the nutritional profile of mungbean and maize utilizing diverse intercropping ratios and balanced fertilization of nitrogen are consistent with present protein content findings. Moreover, Ibrahim et al., [23] also investigated fodder nutrition of mungbean and maize as solo crops as well as mixtures at different seed ratios and noticed similar results for protein content in both maize and mungbean. Kumari et al., [24] investigated the impacts of intercropping on crop and livestock profitability, health of the soil growth, and insect dynamics in a rainfed region of India and discovered comparable results for grain yield. Similarly, farm yard manure heightens up the grain yield with intercropped cereal legume practice and this is the result of increased nutrient output to soil and equally provided to plant which is efficiently taken up by both crops [22]. Geren et al., [25] intercropped maize with cowpea to find yield output and quality of grain and reported improvement in grain yield for both crops.

One of the most important and effective cropping practice for improving crop yield and soil is farm yard manure [26]. The amount of farm yard manure [27] as well as the essential initial chemical and physical properties, such as pH buffering capability and soil organic matter [28], have a significant impact on how farm yard manure affect soil pH.

The impact of intercropped cereal legume with farm yard manure incorporation appeared to be larger when the initial soil SOM was high because high SOM typically leads in high soil CEC and pH buffer capacity [29]. This is a result of the complex interactions between soil, plants, and the environment as well as the variety of soil's physical and chemical characteristics [27]. This whole changing behavior in the soil leads to the betterment of plant growth and in end result is provided with improved protein content [21]. In accordance with Wangiyana [30], our findings showed that the application of farm yard manure with sole maize (SM) and sole mungbean (SMb) elevated the pH by roughly 23.49% and 23.70%, respectively after the experiment, but increased soil acidity by 32.45% in maize mungbean intercropped plot (M-Mb) (Table 2). The addition of FYM in M-Mb treatment could have increased the pH of the soil through any of the following processes or combinations of processes: consumption of proton by functional groups linked to organic materials [31], decarboxylation of organic acid anions during decomposition,

specific adsorption of organic molecules by ligand exchange with the release of OH [32], and the release of OH ions during reduction reactions linked to localized anaerobic microsites.

According to prior research by Diatta [33], the application of farm yard manure together with the maize-mungbean cropping practice improved the soil's available N, P, and K content due to a rise in soil pH. Because of the maize-mungbean intercropping practice, the use of farm yard manure, and the use of chemical fertilizer, the availability of exchangeable Ca and Mg increased as soil pH increased, which was also reported by Mosharof et al. [30] and Kunhikrishnan et al. [7]. According to Lyngdoh et al. [34] and Amanullah et al. [35], increasing soil pH due to farm yard manure amendment with maize-mungbean intercropped treatment also raised soil EC and CEC. The M-Mb cropping practice is best suited for areas where weed growth is intense [36] because it enhanced the soil's characteristics by making more nitrogen available and bringing the pH level closer to that of growth [37]. This also improves the plant photosynthetic rate which leads to the improvement of respiration [31].

The efficiency of nutrient usage can also be influenced by management techniques [34] in addition to the transformation and uptake of nutrients by plants [12, 38]. It is generally acknowledged that cereal legume intercropping can deliver basic cations like Ca and Mg to the root zones while also neutralizing excess acidic ions in the soil like proton ions and other acidic mineral cations (like Al ion) [39].

According to Ajio et al. [40], raising the pH of the soil boosted soil microbial activity and had a significant impact on the rate of soil C and N cycling. The optimal P nutrition for arable crops depends on the connection between soil pH and P availability [41]. The ideal soil pH for P absorption needs to be reevaluated, according to Frida et al. [42]. However, organic matter concentration significantly affects yield response to P and should be taken into account in addition to pH [43]. Recent studies in Ethiopia and Germany, Wanget al. [44] and von Nasar et al. [45], have shown the influence of P status on yield response to pH for barley especially where it was intercropped with legume.

CONCLUSION

In conclusion, the study suggests that intercropping maize and mungbean, particularly when combined with farm yard manure, can lead to improved plant parameters (chlorophyll content,

photosynthesis rate, protein content, and grain yield) and positively influence soil parameters (SOM, nutrient availability, pH, CEC, and exchangeable Ca and Mg). These findings are consistent with existing research on the benefits of intercropping and the use of organic amendments like farm yard manure to enhance crop productivity and soil fertility.

The use of farm yard manure in intercropped systems appears to have multiple benefits, including improved soil fertility, better nutrient availability, and increased plant performance. The higher chlorophyll content and photosynthesis rate in intercropped treatments suggest that this approach can enhance the photosynthetic capacity of the plants, which is crucial for crop growth and yield. Additionally, the increased protein content in crops is beneficial for both livestock feed and human nutrition.

Overall, the study supports the idea that intercropping, in combination with appropriate nutrient management practices, can be an effective strategy for maximizing agricultural productivity and improving soil health. It is also important to note that soil parameters, such as pH, SOM, and nutrient availability, play a crucial role in crop performance, and proper management of these factors can lead to significant benefits for farmers and the environment.

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