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Effect of Intercropping on Growth Parameters, Chemical and Mineral Composition on Maize-Forage Legumes

[1]Yilwatda, B.M, [1]Musa, A., [2]Ishiaku, Y.M, [3]Idachaba, C.U, [1]Zakka, T., [4]Abdullahi, U.
[1]Department of Animal Science, Ahmadu Bello University, Zaria
[2]National Animal Production Research Institute, Shika, Zaria
[3]Department of Animal Production, University of Jos, Jos
[4]Department of Animal Science, Federal University, Gashua

Correspondence: blessingmorkat@gmail.com, 08036436418

Abstract

The study investigate the growth parameters, chemical composition, and mineral concentration of sole and intercropped Maize (Zea mays L.) with Mucuna (Mucuna pruriens), and Lablab (Lablab purpureus) using planting patterns of 1:1, 1:2 and 2:1 (maize:legume). The experiment was carried out at the National Animal Production Research Institute (NAPRI), Shika, Zaria. The trial was laid out in a Randomized Complete Block Design with three (3) replicates. The result showed that intercropping significantly (P<0.05) improved agronomic characteristics. Plant height (PH), leaf dimension, and leaf area index (LAI) of maize were significantly (P<0.05) higher in 1ma:2mu (201.79 cm, 821.61cm^2 and 3.10) compared to other treatments. The vine length, leaf length, number of leaves, and LAI were highest in sole mucuna (393.78cm, 19.54, 432.33, and 11.05 cm respectively). Dry matter of maize forage was significantly highest (P<0.05) in 1ma-1lb (94.75%), and comparable in other treatments. Crude protein (CP) of maize increased significantly under all intercropping arrangements compared with sole maize (8.81%), with the highest value in 1ma:2lb (15.43%). Ca concentration of maize was significantly highest (P<0.05) in the 1ma:2mu (3108.10 mg/kg) compared to 2ma:1mu (2846.30 mg/kg) and sole maize (1527.10 mg/kg). Phosphorus concentration of maize in maize-legume combination was highest significantly (P<0.05) under 2ma:1mu (908.93 mg/kg,). For the mucuna, 1ma:2mu produced the highest Ca and P (4920.40 mg/kg and 909.12 mg/kg respectively), while sole mucuna and 2ma:1mu have lower values. The study showed that intercropping maize with forage legumes significantly improved growth parameters, chemical and mineral composition of maize. Intercropping with 1ma:2mu combination is recommended for optimal agronomic performance and nutrient quality.

KEYWORDS: Intercropping, Maize-forage legume, Growth parameters, Chemical composition, Mineral concentration.

Description of Problem

The rapid increase in population has led to rising global demand for sustainable livestock production and efficient land utilization which propelled interest in the cultivation of more than one crop on the same plot of land during a growing season - intercropping. Intercropping is now the centre of attention targeting sustainability in agriculture (1). It warrants developing an appropriate technique of growing field crops in association with each other. Intercropping systems are estimated to promote yield stability, risk reduction, and contribute up to 15-20% of the world's food supply (2). Intercropping cereal with forage legumes is promising, low-cost, ecological means of improving soil fertility (3). In general, cereal–legume intercropping has several major advantages in cropping systems, including increasing yield (4), improving soil properties (5), controlling weeds (6;7) and increasing the number of nitrogen-fixing bacteria (8). Species or cultivar selections, seeding ratios, competition capability and planting patterns within mixtures may affect the growth and yield of the species used in intercropping systems (8;9). The most common type of cereal-legume mixture is the maize (*Zea mays* L.) based intercropping systems and account for approximately 60% of maize production. Most farmers intercrop maize with lima bean *(Phaseolus lunatus* L.) or cowpea (*Vigna unguiculata* L.) due to the ability of these legumes to provide basic food supply (10). Also, when properly structured, intercropping maize with other legumes can better optimize the utilization of light, heat, water, and greater resilience to environmental stressors, resulting in increased productivity – biomass and nutrient quality of the resultant forages (11).

Mucuna (*Mucuna pruriens*) and lablab (*Lablab purpureus*) are promising forage legumes that have been successfully intercropped with maize. They have also shown to increase yields of maize crop compared to solely grown maize (12). Apart from their nitrogen-fixing ability as green manure, they also produce more dry matter about 2.13 to 6 t/ha (13;14;15). Consequently, understanding the relationship between planting patterns of maize-forage legumes and its subsequent impacts on forage quality produced is vital for improving feed quality (16). In maize-forage legume intercropping systems, the combination of maize and legumes such as mucuna, lablab, beans, clover, or alfalfa can significantly influence the chemical and mineral composition of the crops (17). This practice enhances soil nitrogen fixation by legumes, leading to improved nutrient availability for maize, while also potentially altering the concentrations of essential minerals like nitrogen, phosphorus, calcium, potassium, and micronutrients (10). The interactions between maize and legumes in intercropping systems can result in better nutrient cycling, reduced nutrient leaching, and enhanced soil fertility, contributing to more sustainable agricultural practices (13;18).

Although many scholars have analysed the chemical properties of different forages (19;3;20;21), few have worked on the contribution of legumes on the chemical composition and mineral concentration of intercropped maize-mucuna and maize-lablab. Thus, this study aims to explore the effect of maize-forage legumes intercropped at different planting patterns and its effect on the chemical and mineral composition on the forage. The study hence was carried out to determine the effect of intercropping on growth parameters, chemical and mineral composition of maize, mucuna and lablab forages

Materials and Methods

Experimental Site and Location

The study was conducted at the Experimental Farm of Feed and Nutrition Research Programme, National Animal Production Research Institute (NAPRI), Shika. The farm is located on Latitude 11^0 12^1W, Longitude 07^0 33^1E and altitude 660m above sea level, 22km North-West of Zaria in the Northern Guinea Savannah zone of Nigeria. The climate is characterized by defined wet and dry seasons. Wet season begins from late May and ends in early October while the dry season is from late October to April. The mean total annual rainfall is 1815mm with a maximum temperature of 31.7^{0}C, relative humidity of approximately 72.98%, and average sunshine of 10.63hrs during the rainy season (22).

Table 1: Meteorological Distribution of Experimental Location in 2023 Growing Season

	Months					
Parameter	May	June	July	August	September	October
Temperature max.(^{0}C)	35.4	30.1	30.0	29.1	30.5	31.7
Temperature min.(^{0}C)	24.3	22.6	22.8	22.5	23.2	21.9
Rainfall (mm)	1705	1799	1117	3219	2290	760
Relative humidity	62.0	77.8	75.5	82.2	75.5	57.9
Sunshine (Hours)	11.0	10.9	10.9	10.0	10.4	10.6

Soil Samples of the Experimental Site

Soil samples were randomly collected from the experimental site with the aid of soil auger at four corners and centre of the plots at 0cm to 30cm depth (21), to make composite samples for soil analysis. The soil sample was bulked and mixed thoroughly before collecting sub-samples for routine analysis. The sub-samples were analysed for physical and chemical properties to determine texture, particle size, total nitrogen, total carbon, phosphorus, soil pH and cation exchange capacity. The analysis was carried out at the Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria.

Land Preparation, Experimental Layout, Treatments and Source of Experimental Materials

The field was prepared by clearing of debris. It was harrowed with tractor drawn implements and ridged with two work bulls to provide a clean seedbed and to enhance early seed germination. A total land area of 11m x 98m (1,078m^2) was used. The experiment was laid in a Randomised Complete Block Design (RCBD) and replicated three times with planting patterns of 1:1, 1:2 and 2:1 for maize-mucuna and maize-lablab in all intercrop. Each block was divided into 9 plots of 3m x 10m (30m^2) having 1m between block and 0.5m within sub-plots respectively. Maize (SAMMAZ 51) seed was sourced at the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. Lablab and mucuna were sourced from National Animal Production Research Institute (NAPRI), Shika. Fertilizer was procured from the local market in Samaru, Zaria. The seeds of maize (SAMMAZ 51), mucuna and lablab were planted on ridges at 2cm depth and 30cm intra row spacing. Weeding was carried out manually using hoe at four (4) and eight (8) weeks after planting for effective weed control. A blanket dose of 220kg/ha NPK (20:10:10) fertilizer was applied to the maize at four (4) and eight (8) weeks after sowing, while single super phosphate was applied to mucuna and lablab at 120kg P_2O_5/ha four weeks after sowing.

Data Collection on Growth Parameters

After crop establishment, data on crop phenology of the treatment combinations were measured at 8, 10 and 12 weeks after sowing (WAS). Three (3) plants were randomly selected and tagged per plot for the measurements of various agronomic parameters using the standard procedure as reported by (23).

Plant Height

Plant height, in cm, was measured from base of the plant to the tip of the flag leave with the aid of a 200cm tape rule on the three randomly selected plants per plot and the average was computed.

Leaf Length

Leaf length was estimated by measuring from the tip of the lamina to the base of the ligules with the aid of tape rule from the three randomly tagged plants per plot.

Leaf Width

Leaf width was determined by placing the 30cm meter rule perpendicular to the lamina at the widest point on the leaf, value obtained was recorded.

Number of Leaves per Plant

The number of leaves on the three (3) randomly selected and tagged plants were counted and the mean of leaves per plant was determined from each plot at 8,10 and 12 weeks after sowing.

Leaf area index

Leaf area index was determined using the method described by (23). LAI is the ratio of leaf area multiply by a factor (0.75) to the unit ground area covered by each plant.

$$\textbf{LAI} = \frac{leaf area per plant (cm) \times 0.75}{area of ground per plant (cm)}$$

Chemical Analysis

Forages of maize, mucuna and lablab harvested were analysed for their chemical composition using the standard procedure of (24). Mineral analysis of Calcium (Ca) and Phosphorus (P) were carried out to determine the mineral content by (24) methods using the Atomic Absorption Spectrum Photometer.

Statistical Analyses and Models: Data collected from the agronomic components were analyzed using the Repeated Measure Analysis of Variance (ANOVA) using the General Linear Procedure of (25). Significant differences at 5% ($P \leq 0.05$) among treatment means were separated using (26).

Experimental model:

$Y_{ij} = \mu + A_i + E_{ij}$

Where:

Y_{ij} = is the record of observations for dependent variables

μ= is the overall mean

A_i = effect of intercropping/planting patterns (ma, mu, lb, 1ma:1mu, 1ma:2mu, 2ma:1mu, 1ma:1lb, 1ma:2lb, and 2ma:1lb)

E_{ij}= random error assumed to be normally and independently distributed.

Results and Discussion

Effect of Intercropping/Planting Pattern on the Growth Components of Maize-Mucuna and Maize-Lablab Forages (12 WAS)

Planting patterns have significant ($P < 0.05$) effect on growth components (Table 2). Plant height (PH) of maize, in maize+legumes combination, ranged from 162.52 cm in 2ma:1lb to 201.79 cm in 1ma:2mu. Leaf length (LL) and leaf width (LW) were highest in 1ma:2mu (88.25 cm and 9.31 cm, respectively). Number of leaves (NL) was highest in 1ma:2mu (12.55) and lowest in 1ma:2lb (11.44). Stem diameter (SD) was higher ($P<0.05$) in sole maize (3.67 cm) and in 1ma:1mu (3.91 cm). Leaf area index (LAI) was highest under 1ma:2mu (3.10) and lowest under 2ma:1lb (2.13). The vine length, LL, NL, NB, and LAI were highest in sole mucuna (393.78cm, 19.54, 432.33, 13.40, 110.57cm respectively). Vine length in 1ma+2m is 357.78 cm, and comparable in other treatments. The lowest LAI was observed in 2ma:1mu (77.26 cm). Similarly, sole lablab has the highest vine length, 347.67 cm; LL, 15.34 cm; NL, 355.67 cm; and LAI, 7.84cm.

The tallest maize plants under 1ma:2mu indicate a positive nitrogen-enhancing ability of mucuna, which improves soil nitrogen availability and stimulates vegetative growth. This agrees with findings by (27), who reported increased maize height from 191–215 cm when intercropped with mucuna. Conversely, the depressed height in 1ma:1lb (162.52 cm) suggests higher interspecific competition for resources. This is similar to the findings by (28), who observed reduced maize height (155–168 cm) when competing with lablab. Leaf length (LL) and leaf width (LW) were highest in 1ma:2mu (88.25 cm and 9.31 cm, respectively), reflecting improved soil nitrogen that promotes leaf area development.

Table 2: Effect of Intercropping/Planting Pattern on the Growth Components of Maize-Mucuna and Maize-Lablab Forages (12 WAS)

	Parameters (cm)					
Treatments	PH	LL	LW	NL	SD	LAI
Sole maize	198.99[a]	81.03[ab]	8.33[b]	12.77[a]	3.67[ab]	2.61[b]
1ma:1mu	195.82[a]	75.62[ab]	7.94[c]	12.00[a]	3.91[a]	2.16[b]
1ma:2mu	201.79[a]	88.25[a]	9.31[a]	12.55[a]	3.82[a]	3.10[a]
2ma:1mu	180.54[ab]	73.35[ab]	7.91[c]	11.88[b]	3.58[ab]	2.08[b]
1ma:1lb	187.97[ab]	71.03	8.32[b]	12.33[a]	3.44[b]	2.22[b]
1ma:2lb	180.46[ab]	73.43[ab]	8.19[b]	11.44[b]	3.69[a]	2.07[b]
2ma:1lb	162.52[b]	68.15[b]	8.38[b]	12.44[a]	3.73[ab]	2.13[b]
SEM	9.18	4.65	0.47	0.41	0.315	0.24
P. value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sole mucuna	393.78[a]	19.54[a]	13.40[a]	432.33[a]	43.89[b]	11.05[a]
1ma:1mu	346.89[c]	18.57[b]	12.36[b]	290.89[b]	61.44[a]	10.42[b]
1ma:2mu	357.78[b]	19.44[a]	13.28[a]	414.44[ab]	38.33[c]	9.29[c]
2ma:1mu	342.57[d]	18.15[b]	13.43[a]	357.67[ab]	39.55[bc]	7.72[d]
SEM	26.64	0.64	0.86	40.29	15.56	0.30
P. value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sole lablab	347.67[a]	15.34[a]	11.86[ab]	355.67[a]	40.89[b]	7.84[a]
1ma:1lb	299.78[c]	12.61[c]	10.85[b]	240.11[d]	43.55[a]	7.62[a]
1ma:2lb	333.32[b]	15.63[a]	12.74[a]	316.00[b]	37.55[c]	6.18[b]
2ma:1lb	252.78[d]	13.30[b]	10.69[b]	243.89[c]	34.11[d]	3.48[c]
SEM	36.12	2.44	0.55	40.88	9.91	21.53
P. value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

[abcd]Means with different superscript along the same row are significantly ($P<0.05$) different, SEM: standard error of means, PH= plant height, LL= leaf length, LW= leaf width, NL= number of leaf, SD= stem diameter, LAI= leaf area index, Ma = maize, Mu= mucuna, Lb =lablab, Ma:Mu = maize+mucuna, Ma:Lb= maize+lablab

Treatments with lablab, especially 1ma:1lb (LL = 68.15 cm; LW = 7.91 cm), showed reduced leaf size due to competition, as similarly reported by (29), where leaf width declined from 8.9 cm to 7.2 cm under closer spacing. Number of leaves (NL) was highest in 1ma:2mu (12.55) and lowest in 1ma:2lb (11.44). Increased NL under mucuna may be attributed to enhanced photosynthetic efficiency. This is comparable to the study by (30), who observed NL values of 12.3–13.1 in maize–mucuna systems. Stem diameter (SD) was higher (P<0.05) in sole maize (3.67 cm) and in 1ma:1mu (3.91 cm), further indicating mucuna's contribution to structural growth. Lower SD under lablab intercrops agrees with (31), who reported 12–18% reductions in competitive systems. Leaf area index (LAI) was highest under 1ma:2mu (3.10) and lowest under 1ma:1lb (2.13). High LAI under mucuna suggests better canopy development due to improved nitrogen, similar to values (2.8–3.4) reported by (32). Lower LAI under lablab reflects competitive shading effects (10).

Mucuna growth was depressed by maize, with plant height reducing from 393.78 cm in sole crop to 342.57 cm under intercropping. LAI dropped from 11.05 to 7.72 in 2ma:1mu, indicating shading. This is consistent with (33), who recorded a 15–28% reduction in mucuna growth under maize canopy. Lablab also experienced notable suppression, with plant height declining from 347.67 cm (sole) to 252.78 cm (2ma:1lb) and LAI dropping from 7.04 to 3.48. These trends agree with (34), who found lablab height decreasing from 345 cm to 260 cm in maize intercrop. Lablab's slower early growth makes it more vulnerable (35).

Effect of Intercropping/Planting Pattern on Chemical Composition of Maize-Mucuna and Maize-Lablab Forages

There was significant (P<0.05) different on the chemical composition in all the intercrop (Table 3). Dry matter was highest (P<0.05) in 1ma-1lb (94.75%), and comparable in other treatments. The lowest value was recorded in 2ma-1mu (90.9%). Crude protein (CP) increased significantly under all intercropping arrangements compared with sole maize (8.81%). For maize in the maize–mucuna mixture planted at 1ma:1mu produced the highest CP among the mucuna intercrops (13.60%), followed by 1ma:2mu and 2ma:1mu with values of 11.82% and 11.67%, respectively. Crude fibre content declined under intercropping relative to sole maize (57.55%), and sole maize recorded NDF of 58.28% and ADF of 49.88%, whereas the maize+mucuna arrangement produced lower ADF values, particularly the 1ma:2mu (31.17%) and 1ma:2lb (29.01%) combinations.

The chemical composition of maize intercropped with mucuna and lablab showed clear and consistent responses to legume species and planting patterns. Crude protein (CP) increased significantly (P<0.05) under all intercropping arrangements compared with sole maize (8.81%), reflecting the contribution of biologically fixed nitrogen from the legumes. The maize in maize+mucuna mixture planted at 1ma:1mu produced the highest CP (13.60%), followed by 1ma:2mu and 2ma:1mu with values of 11.82% and 11.67%, respectively. These results align with reports that mucuna enhances nitrogen availability and improves forage CP due to its vigorous N-fixation and canopy development (3;8). Similarly, maize–lablab mixtures maintained higher CP than sole maize, with values ranging from 15.43% in the 1ma:2lb pattern to 9.99% in the 1ma:1lb arrangement. The superiority of lablab in boosting forage protein has been well documented, with studies showing that lablab contributes higher-quality foliage and more readily available nitrogen to companion cereals (4;12). Crude fibre (CF) and acid detergent fibre (ADF) declined under intercropping relative to sole maize, indicating improved forage quality due to the dilution of maize structural carbohydrates. Sole maize recorded the highest CF (47.08%), and ADF (49.88%), whereas the maize–mucuna mixtures produced lower ADF values, particularly the 1ma:1mu (31.17%) and 2ma:1mu (40.00%) patterns. Also, maize–lablab combinations recorded reduced structural fibre, especially in the 1ma:2lb treatment (ADF 29.01%) compared with sole maize. These reductions are consistent with previous findings by (13;12), that combining maize with legumes typically lower lignin and structural fibre, resulting in improved digestibility. The relatively lower ADF values in lablab intercrops compared with mucuna also correspond with the species' morphological differences, as lablab tends to retain a higher proportion of tender foliage at the growth stages commonly used for forage (36).

Table 3: Effect of Intercropping/Planting Pattern on Chemical Composition of Maize-Mucuna and Maize-Lablab Forages

	Parameters (%)							
Treatment	DM	ASH	EE	CF	CP	NFE	NDF	ADF
Sole maize	92.71[ab]	6.98[b]	0.60[a]	47.08[a]	8.81[d]	36.53[b]	58.28[c]	49.88[a]
1ma:1mu	92.34[ab]	6.01[b]	0.63[a]	46.96[a]	13.6[b]	32.8[c]	57.9[c]	49.16[a]
1ma:2mu	93.18[ab]	5.83[b]	0.33[c]	45.95[b]	11.82[c]	36.07[b]	68.04[a]	31.17[d]
2ma:1mu	90.9[b]	6.44[b]	0.58[b]	45.82[b]	11.67[c]	35.49[b]	63.65[b]	40.00[b]
1ma:1lb	94.75[a]	7.77[b]	0.34[c]	42.38[c]	9.99[d]	39.52[a]	66.93[a]	37.71[c]
1ma:2lb	94.04[a]	15.00[a]	0.62[a]	41.8[d]	15.43[a]	27.15[d]	52.08[d]	29.01[e]
2ma:1lb	92.47[ab]	4.95[b]	0.44[b]	41.78[d]	12.11[c]	40.72[a]	67.04[a]	36.48[c]
SEM	0.829	0.922	0.187	0.163	0.408	0.620	0.906	0.122
P. value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sole mucuna	93.06[ab]	6.30[ab]	0.34[b]	36.3[c]	19.32[a]	37.74[a]	81.99[a]	54.92[a]
1ma:1mu	91.32[b]	5.56[b]	0.39[b]	37.09[b]	18.69[a]	38.27[a]	57.31[c]	42.99[d]
1ma:2mu	90.51[b]	8.75[a]	0.57[a]	40.96[a]	14.69[b]	35.03[b]	62.84[b]	44.62[b]
2ma:1mu	94.66[a]	8.00[ab]	0.19[c]	37.71[b]	18.19[a]	35.91[b]	58.35c	43.84[c]
SEM	0.829	0.922	0.18	0.163	0.408	0.620	0.906	0.122
P. value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Sole lablab	92.24[ab]	9.24[c]	0.51[a]	39.77[a]	16.16[c]	34.32[a]	52.56[c]	41.82[c]
1ma:1lb	93.53[a]	9.90[c]	0.57[a]	40.2[a]	18.34[b]	30.99[b]	58.14[ab]	44.19[b]
1ma:2lb	94.31[a]	12.87[b]	0.44[b]	34.17[b]	24.30[a]	28.22[c]	56.02[b]	45.08[a]
2ma:1lb	90.08[b]	22.19[a]	0.35[c]	30.8c	24.45[a]	22.21[d]	60.03[a]	39.11[d]
SEM	0.829	0.922	0.187	0.163	0.408	0.620	0.906	0.122
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

[abcde]Means with different superscript along the same row are significantly ($P<0.05$) different, SEM: standard error of means, DM=dry matter, EE=ether extract, CF=crude fibre, CP=crude protein, NFE=nitrogen free extract, NDF=neutral detergent fibre, ADF=acid detergent fibre, Ma = maize, Mu= mucuna, Lb =lablab, Ma:Mu = maize+mucuna, Ma:Lb= maize+lablab

Ash content values increased from 6.90% in sole maize to as high as 15.00% in the 1ma:2lb, indicating greater mineral contribution from legumes. Previous research has shown that legume foliage contains higher concentrations of key minerals such as calcium, and phosphorus, which may explain the elevated ash contents in some intercrops (3;11). From the chemical composition values obtained in this study, it was shown that intercropping significantly improves forage nutritive quality, with the level of improvement dependent on both legume species and planting arrangement. The consistently higher CP and lower fibre fractions in maize+mucuna and maize+lablab mixtures agree with the report of (4;7) that cereal-legume intercrop can enhance both soil fertility and nutrient of companion crop.

Effect of Intercropping/Planting Patterns on Mineral Composition of Maize-Mucuna and Maize-Lablab Forages

There were highly significant ($P<0.05$) effects of intercropping pattern on both calcium and phosphorus concentrations (Table 4). It showed that Ca concentration in maize was highest ($P<0.05$) in the 1ma:2mu (3108.10 mg kg^{-1}) and 2ma:1mu (2846.30 mg kg^{-1}) combinations than sole maize (1527.10 mg kg^{-1}). Phosphorus concentration in maize was highest under 2ma:1mu (908.93 mg kg^{-1},) and 568 mg kg^{-1} in both 1ma:1mu and 1ma:2mu. For the mucuna, 1ma:2mu produced the highest Ca and P (4920.40 mg kg^{-1} and 909.12 mg kg^{-1} respectively), while sole mucuna and 2ma:1mu have lower values. A comparable pattern was observed in lablab where 1ma:1lb and 1ma:2lb showed higher mineral concentrations than sole lablab.

The observed increase of calcium composition in maize-legume combination were consistent with the reports of Chamkhi (37) and Moreira (38), that integration of legumes in cereals can enhance nutrient availability and mineral concentration through improved nitrogen supply and altered mineral dynamics. Legume-based intercropping systems often promote root-microbe interactions and increased nutrient cycling, leading to improved soil fertility and crop mineral composition. This aligns with the findings of Moreira (37), which reported higher calcium and phosphorus contents in maize+lablab intercrops compared with sole cropping. Similarly, Tchapga (39) found that Mucuna improved nutrient uptake in companion crops under different intercrop ratios, confirming the positive influence of mucuna observed in this study. However, other studies have reported non-significant ($P>0.05$) effects of legume intercropping on mineral composition, which may arise from competition for nutrients or biomass dilution effects when total yield increases (40). Such discrepancies among studies are often attributed to variations in soil fertility, environmental conditions, crop species, and harvest stage (18). In this study, the higher calcium values in maize+mucuna and maize+lablab arrangements may reflect enhanced nutrient availability and uptake efficiency resulting from biological nitrogen fixation and improved mineral mobilization in legume root systems. These findings showed the importance of optimizing planting patterns to achieve both yield and mineral concentration in both maize and companion legumes.

Conclusion

The study has shown that the Plant height (PH), leaf dimension, and leaf area index (LAI) of maize were higher in 1ma:2mu compared to other treatments. Dry matter of the forage was highest in 1ma-1lb, and comparable in other treatments. Crude protein (CP) increased under all intercropping arrangements compared with sole maize, with the highest value in 1ma:1mu. Ca concentration was highest in the 1ma:2mu compared to 2ma:1mu and sole maize. Phosphorus concentration in maize was highest under 2ma:1mu. For the mucuna, 1ma:2mu produced the highest Ca and P, while sole mucuna and 2ma:1mu have lower values.

Recommendations

1. Planting pattern with 1ma:2mu combination is recommended for optimal agronomic performance and nutritional quality.
2. The results suggest that 1ma:2mu and 2ma:1mu intercropping patterns are most effective for maximizing mineral concentration in maize-legume systems under the present experimental conditions.
3. Intercropping maize with legumes can improve hay crude protein content by 8–25%, thereby enhancing the nutrient content of maize stover for livestock production.

Table 4: Effect of Intercropping/Planting Pattern on Mineral Composition of Maize-Mucuna and Maize-Lablab Forages

Treatment	Ca(mg/kg)	P(mg/kg)
Sole maize	1527.10[bc]	686.29[c]
1ma:1mu	1392.90[c]	568.65[d]
1ma:2mu	3108.10[a]	568.12[d]
2ma:1mu	2846.30[a]	908.93[a]
1ma:1lb	1780.20[bc]	568.16[d]
1ma:2lb	1980.80[b]	568.69[d]
2ma:1lb	1549.20[bc]	797.23[b]
SE±	163.02	3.890
P. value	0.0001	0.0001
Sole mucuna	3813.40[b]	795.56[b]
1ma:1mu	1030.60[c]	681.61[c]
1ma:2mu	4920.40[a]	909.12[a]
2ma:1mu	3974.50[b]	681.49[c]
SE±	146.99	4.146
P. value	0.0001	0.0001
Sole lablab	1802.60[d]	681.73[c]
1ma:1lb	2996.70[a]	795.57[b]
1ma:2lb	2540.50[c]	909.21[a]
2ma:1lb	2799.70[b]	568.69[d]
SE±	3.891	4.764
P-value	0.0001	0.0001

[abcde]Means with different superscript along the same row are significantly (P<0.05) different, SEM: standard error of means, Ca= calcium, P= phosphorus, Ma = maize, Mc = mucuna, Lb =lablab, Ma:Mc = maize-mucuna, Ma:Ll = maize-lablab

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