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Forage yield and nutritive value of maize and legumes intercropping in Northwest region of Vietnam

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ABSTRACT

This study was conducted in the Northwest region of Vietnam to evaluate forage yield and nutritive value of intercropping maize with two legume species (soybean and black bean) under different row spacing arrangements. Results indicated that intercropping improved dry matter yield and particularly crude protein yield compared with sole maize, with maize–soybean intercrops outperforming maize–black bean combinations. Planting methods significantly affected growth and forage quality: Method 1 (maize 60 × 20 cm, legumes sown between two maize rows) produced the highest maize yield, while Method 3 (maize 90 × 20 cm, legumes sown between rows) increased the legume proportion and protein content in the mixture. The chemical composition and nutritive value of maize–legume mixtures were also improved, showing higher CP, TDN, and ME values and lower ADF and NDF compared with sole maize. These findings demonstrate that maize–legume intercropping is a promising solution to supply more nutritious forage for ruminants during the winter feed shortage in the Northwest region of Vietnam.

Keywords: *Maize, legumes, Northwest region, planting methods.*

Introduction

In the northwest region of Vietnam, it is usually lack of forage feed in terms of quantity and quality for cattle during winter period (October-March) (Van Moere, 2018). Almost farmers regularly use rice straw as feed for their cattle (Nguyen *et al.*, 2020), and consequently, growth performance of cattle is low, leading to longer time for fattening cattle to reach market weight, poor reproduction and easily getting infectious diseases. To reduce above limitations, finding solutions to provide forage feed in winter season are necessary.

Recently, the use of maize stalk silage has partly replaced green forage feed for cattle during winter period (Huyen *et al.*, 2011). According to Quang *et al.* (2019), biomass maize is well adapted in Dien Bien province. Although biomass maize has given high fresh and dry matter yield, a constraint of biomass maize is its lower protein content compared with legume forage (Mut *et al.*, 2017). Therefore, intercropping maize and legumes is a way to improve forage protein content (Zhu *et al.*, 2011), and thereby leading to enhance the nutritive value of silages (Heathcliffe and Kenneth, 2008; Qu *et al.*, 2013). In the northwest region of Vietnam, forage soybean was successfully intercropped with biomass maize (Quang *et al.*, 2021). However, the maize and legume intercropping benefits are closely depended on crop management, local

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conditions, sowing rate, planting distance and legume species as well as competition between legumes and maize (Mut *et al.*, 2017; Singh *et al.*, 2008; Lawson *et al.*, 2007). Due to this respect, this study aimed to test legume (black bean and soybean) - maize intercropping with different row distances for yield and nutritive value at the forage harvest stage.

Materials and methods

Materials

Hybrid corn (LCH9) and soybean (DT84) and black bean (*Vigna unguiculata*) were used in this experiment.

Experimental time and site

The experiment was implemented on farm during winter season from November 2020 to February 2021, in Sam Mun commune, Dien Bien district, Dien Bien province. The experimental area is rich in alluvial soil. Average temperature and total rainfall in the experimental time were 17.8°C and 140 mm.

Experimetal method

Experimental design

The experiment was conducted in a randomize completed block design with 2 × 3 factors (2 varieties of legumes and 3 planting methods) and 4 replications (see attached experimental layout).

Two legume varieties were soybean (SB) and black bean (BB). Three planting methods were as follows: Method 1 (M1), legumes (10 cm distance between two legume cavities) were spaced between two rows of maize growing distance of 60 cm × 20 cm, with sowing rate 75.000 plants/ha for maize and 55.000 plants for legume; Method 2 (M2), legume was grown between two maize cavities in the same maize growing row with distance of 60 × 20 cm, with sowing rate 75.000 plants/ha for maize and 27.500 plants for legume; Method 3 (M3), legume (10 cm distance between two legume cavities) was grown between two rows of maize growing distance of 90 cm × 20 cm, with sowing rate 50.000 plants/ha for maize and 55.000 plants for legume.

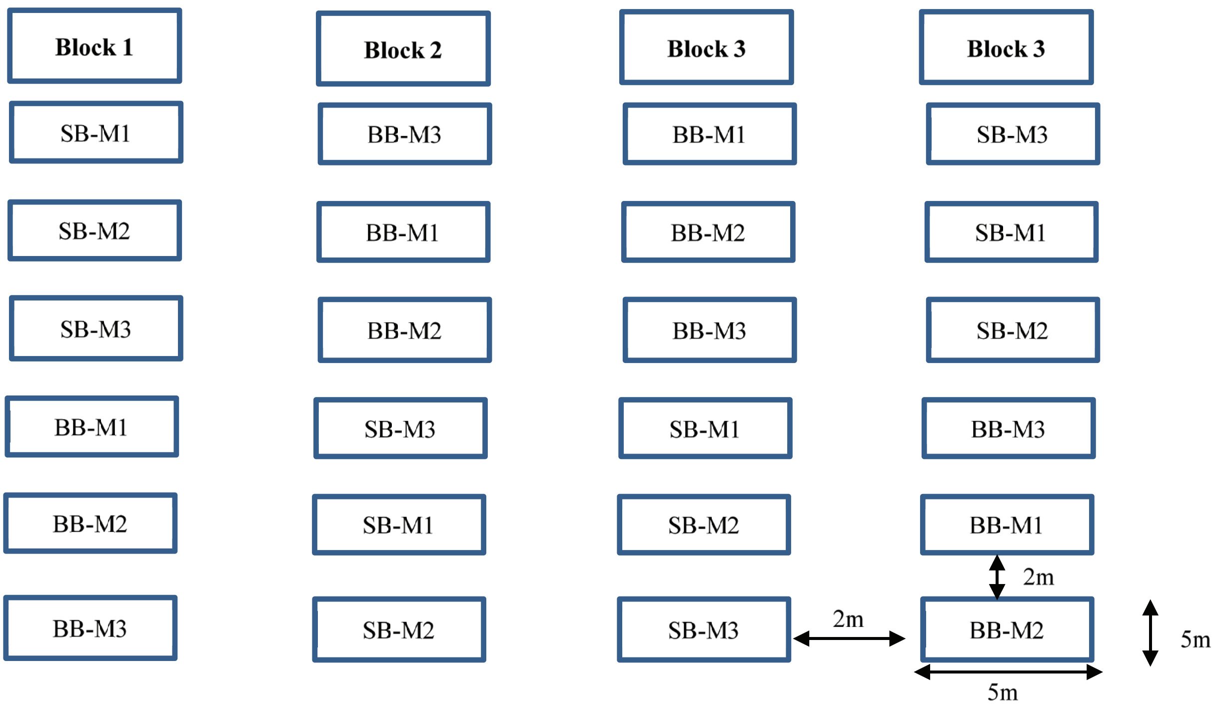

Figure 1. Experimental layout (SB, soybean; BB, black bean; M1, method 1; M2, method 2; M3, method 3)

Each plot size was a 5m × 5m. The actual plot size to be harvested was 4m × 4m (see Figure 2). Plots will be separated and surrounded by a 2m buffer of sown maize.

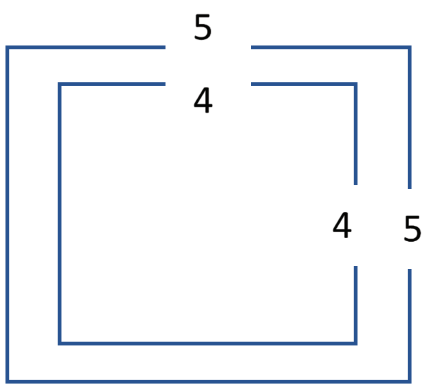

Figure 2. Experimental plot size

Fertilizer was applied to all plots at the same amount of 20 tons cattle manure and 400kg NPK/ha before sowing. Thus, each plot was fertilized with 50 kg of cattle manure and 4kg of NPK.

Measuring plant response

At harvest (when maize reached the soft dough stage, 100 days after sowing), a 4 × 4 m area of each plot was cut in the morning, and the fresh weight was recorded prior to drying. A subsample of 500 g was taken and oven-dried at 60°C for 48 hours until a constant weight was obtained. The dried samples from each treatment were bulked, and a dried subsample was sent for nutritive analysis. All forage samples were analyzed for crude protein (CP), crude fiber (CF), and ash according to AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed using the methods of Van Soest *et al.* (1991). Van Soest *et al.* (1991). Total digestible nutrients (TDN) and metabolizable energy (ME) contents were calculated as follows:

Non-fibrous carbohydrate (NFC) was calculated as NFC = 100 - (CP +NDF + EE + Ash) (Mertens, 2002). Total digestible nutrient (TDN) was estimated using equations TDN = 0.479 NDF + 0.704 NFC + 1.594 EE + 0.714 CP for forage (Jayanegara *et al.*, 2019). Metabolisable energy (ME) was calculated by converting TDN to digestible energy (DE (MJ/kg DM)) = TDN × 0.01 × 4.4 × 4.185) which was converted as ME = DE × 0.82) as per Le *et al.* (2018).

Data analysis

Version 16.2 of Minitab statistical software (2010) was used to analyse all collected data. Analysis of variance (ANOVA) was employed to analyse the data through a general linear model. Tukey's probability pairwise comparison tests were applied to identify significant differences at the P<0.05 threshold.

Results and discussion

Forage yield

The fresh, dry matter and crude protein yields of maize was similar (P>0.05) between intercrops of maize with black bean and soybean (Table 1). However, the fresh, dry matter and crude protein yields was higher for soybean than for black bean when both these legumes intercropped with maize (P<0.01). Total fresh yield was not different (P>0.05) between BB-Ma. and SB-Ma. treatments, whereas total yields of dry matter and crude protein were higher in SB-Ma. treatment than in BB-Ma. treatment (P<0.05). Intercropping method affected on the fresh, dry matter and crude protein yields of maize, legumes and total (P<0.05). The highest maize and total yields of fresh, dry matter and crude protein were for M1 method, whereas the highest legume yields of fresh, dry matter and crude protein were for M3 method.

The findings of this study are absolutely important in evaluating the yield and nutritive values of the maize and soybean forages when intercropping. The total yields of dry matter and crude protein were higher for SB-Ma. treatment than for BB-Ma. treatment, this is due to dry matter and crude protein yields of soybean were higher than black bean. Similar to previous studies (Javanmard *et al.*, 2009), dry matter forage yield was different from different legumes intercropped with maize, of which maize-vetch mixture gave largest value and maize-bitter vetch mixture gave smallest value.

Although M1 method had similar sowing rate of maize with M2 method and of legumes M3 method, M1 method had higher maize yields of fresh, DM and CP than M2 method and lower legume yields of fresh, DM and CP than M3 method. One possible explanation for the higher yields of intercrops is due to the planting distance between maize and legumes which consequently affect interplant competition, such as light and water (Htet *et al.*, 2021). These competitions may have negative effects on crop yield by reducing leaves and leaf area index (Htet *et al.*, 2016). Besides, Nkosi (2016) indicated that the shading effect of legumes by the maize plant (taller) could also be attributed to a decrease in the yield of intercropped legumes by reducing the photosynthetic rate of the lower growing plant. Eskandari (2011) pointed out that the density of mixed crops per unit area was the factor most closely correlated with the total yield of mixture. These reasons could be explained for the recent results that the total yields of fresh, dry matter and crude protein were higher for M1 and M3 treatments than M2 treatment. Furthermore, the higher total protein yield produced by M1 and M3 treatments was attributed to higher protein content than by M2 treatment (Table 4).

Forage quality

The chemical compositions and nutritive values of maize are given in Table 2. The DM, TDN and ME contents of maize were higher in SB-Ma. treatment than in BB-Ma. treatment ($P<0.05$), whereas the EE and NDF contents were lower in SB-Ma. treatment than in BB-Ma. treatment ($P<0.05$). However, the CP, ash, CF, ADF and OM contents are similar between SB-Ma. and BB-Ma. treatments ($P>0.05$). The EE, ADF, TDN and ME contents of maize were affected by intercropping method ($P<0.05$). The EE, TDN and ME values were highest for M3 method, but the highest value of ADF content was for M2 method.

Black bean had higher CP, EE, Ash, CF, ADF contents than soybean ($P<0.01$), whereas the contents of DM, NDF and OM were higher for soybean than for black bean ($P<0.01$) (Table 3). The values of TDN and ME were not different between black bean and soybean forages ($P>0.05$). Concentrations of DM, CP, TDN and ME of maize-legume forage mixture were higher for SB-Ma. treatment than for BB-Ma. treatment ($P<0.05$), whereas the reverse trend occurred with EE, CF, ADF and NDF contents ($P<0.05$) (Table 4). The intercropping method had impacts on the DM, CP, EE, CF, ADF, NDF, TDN and ME contents of legume forage and maize-legume forage mixture ($P<0.05$), with the highest values of CP, EE, TDN and ME for M3 method, but the highest values of CF, ADF, and NDF for M1 method (Table 3 and 4).

The CP, ADF and NDF concentrations are considered to be important forage quality characteristics. According to Tang *et al.* (2018), higher forage quality exhibited the high content of CP and the low content of ADF (cellulose and lignin) and NDF (hemicelluloses, cellulose, and lignin). The results of the present study showed that intercropping of maize and legumes with different distances gave significant differences in CP, ADF and NDF concentrations, with the lowest CP content and highest ADF, NDF contents in M2 pattern, followed by M1 pattern and the highest CP content and lowest ADF, NDF contents in M3 patterns. This result was due to increasing the legume ratio in the total forage yield (Table 1). Furthermore, the maize had higher content of ADF and NDF and lower content of CP compared with legumes (Table 2 and 3). Similarly, Hedayati-Firoozabadi *et al.* (2020) showed that ash, ADF and NDF contents were decreased by different intercropping ratios of sorghum (Sorghum bicolor) with kochia (Bassia indica), leading to improve forage quality. Studies by Dahmardeh *et al.* (2009) and Htet *et al.* (2016) confirmed that the values of NDF and ADF in the mixture decreased when legume seed number increased in intercrop. The TDN content was determined by formula of Jayanegara *et al.* (2019) and hence the factors most affected by CP and NDF contents, resulting in better nutritive value of maize-legume forage in terms of TDN at M3 pattern. Similarly, ME concentration had the same trend as TDN content, because ME content was calculated by 0.82 × (TDN × 0.01 × 4.4 × 4.185) (Le *et al.*, 2018).

Conclusions

Intercropping maize with legumes significantly improved both dry matter yield and nutritive value, especially crude protein yield, compared with sole maize cropping. Soybean performed better than black bean when intercropped with maize, resulting in higher dry matter and protein yields, as well as enhanced CP, TDN, and ME content of the forage mixture.

Among planting arrangements, Method 1 (sowing rate 75.000 plants/ha for maize and 55.000 plants for legume) optimized maize yield, while Method 3 (sowing rate 50.000 plants/ha for maize and 55.000 plants for legume) enhanced protein concentration and overall forage quality. The chemical composition of maize–legume mixtures showed a more balanced nutritive profile (higher CP, lower NDF and ADF), which is beneficial for digestibility and feeding value in cattle.

The findings confirm that maize–legume intercropping is an effective strategy to alleviate forage shortages during winter, thereby improving cattle feeding systems and livestock productivity in the mountainous areas of Northern Vietnam.

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ADDENDUM

Table 1. Forage yield in different cropping patterns

	Fresh yield (kg/ha)			Dry matter yield (kg/ha)			Crude protein yield (kg/ha)		
	Maize	Legume	Total	Maize	Legume	Total	Maize	Legume	Total
Legume									
BB-Ma.	58533.3	2916.7	61450.0	10731.6	473.9	11205.0	1445.3	128.2	1573.0
SB-Ma.	51633.3	13166.7	64800.0	10051.5	2933.1	12985.0	1294.5	714.8	2009.0
SEM	2547.38	955.61	2665.54	438.35	208.18	461.39	60.32	53.48	70.64
P	0.075	<0.0001	0.388	0.290	<0.0001	0.016	0.098	<0.0001	0.001
Method									
M1	63450.0[a]	7875.0[ab]	71325.0[a]	12253.7[a]	1649.8[ab]	13904.0[a]	1614.5[a]	388.3[ab]	2003.0[a]
M2	51800.0[b]	5250.0[a]	57050.0[b]	9344.8[b]	1156.1[a]	10501.0[b]	1211.0[b]	263.2[a]	1474.0[b]
M3	50000.0[b]	11000.0[b]	61000.0[ab]	9576.2[b]	2304.6[b]	11881.0[ab]	1284.3[b]	612.9[b]	1897.0[a]
SEM	3119.89	1170.38	3264.61	536.87	254.97	565.09	73.88	65.50	86.52
P	0.016	0.012	0.020	0.003	0.020	0.003	0.003	0.006	0.001

Note: BB, black bean; SB, soybean; Ma, Maize; M1, method 1; M2, method 2; M3, method 3. Means with different superscript letters within a collumn indicate significant difference (P<0.05).

Table 2. Chemical composition and nutritive value of maize in different cropping patterns

	DM	CP	EE	Ash	CF	ADF	NDF	OM	TDN	ME
Legume										
BB-Ma.	18.32	13.49	2.06	7.84	27.21	36.85	63.65	92.16	52.53	7.93
SB-Ma.	19.48	12.97	1.86	7.40	26.73	37.13	61.97	92.61	53.04	8.01
SEM	0.311	0.290	0.025	0.149	0.191	0.315	0.440	0.149	0.127	0.019
P	0.020	0.225	<0.0001	0.054	0.096	0.548	0.016	0.054	0.012	0.012
Method										
M1	19.37	13.20	1.75[a]	7.72	27.05	36.83[ab]	63.56	92.28	52.35[a]	7.91[a]
M2	18.10	12.99	1.96[b]	7.64	27.35	37.99[a]	62.66	92.36	52.79[ab]	7.97[ab]
M3	19.23	13.49	2.18[c]	7.49	26.52	36.16[b]	62.20	92.51	53.20[b]	8.03[b]
SEM	0.381	0.355	0.030	0.183	0.234	0.385	0.539	0.183	0.156	0.024
P	0.065	0.607	<0.0001	0.682	0.072	0.014	0.229	0.682	0.006	0.006

Note: BB, black bean; SB, soybean; Ma, Maize; M1, method 1; M2, method 2; M3, method 3. Means with different superscript letters within a collumn indicate significant difference (P < 0.05).

Table 3. Chemical composition and nutritive value of legume in different cropping patterns

	DM (%)	CP (%)	EE (%)	Ash (%)	CF (%)	ADF (%)	NDF (%)	OM (%)	TDN (%)	ME (MJ/kg)
Legume										
BB-Ma.	17.27	26.85	2.06	13.82	26.87	35.69	41.83	86.19	53.36	8.06
SB-Ma.	22.42	23.93	1.61	10.92	24.79	32.39	49.94	89.08	53.15	8.03
SEM	0.705	0.361	0.021	0.279	0.355	0.281	0.479	0.279	0.219	0.033
P	<0.0001	<0.0001	<0.0001	<0.0001	0.001	<0.0001	<0.0001	<0.0001	0.498	0.498
Method										
M1	19.45	24.79[a]	1.78[a]	12.09	26.58[a]	35.09[a]	48.75[a]	87.91	52.75[a]	7.97[a]
M2	21.18	24.31[a]	1.69[a]	13.10	26.09[ab]	33.62[b]	43.64[b]	86.90	53.11[ab]	8.02[ab]
M3	18.90	27.07[b]	2.03[b]	11.91	24.82[b]	33.40[b]	45.27[b]	88.09	53.91[b]	8.14[b]
SEM	0.863	0.442	0.026	0.342	0.435	0.344	0.586	0.342	0.269	0.041
P	0.183	0.001	<0.0001	0.055	0.032	0.002	<0.0001	0.055	0.023	0.023

Note: BB, black bean; SB, soybean; Ma, Maize; M1, method 1; M2, method 2; M3, method 3. Means with different superscript letters within a collumn indicate significant difference (P < 0.05).

Table 4. Chemical composition and nutritive value of maize-legume forage mixture in different cropping patterns

	DM (%)	CP (%)	EE (%)	Ash (%)	CF (%)	ADF (%)	NDF (%)	OM (%)	TDN (%)	ME (MJ/kg)
Legume										
BB-Ma.	18.22	14.06	2.06	8.10	27.19	36.81	62.74	91.90	52.55	7.94
SB-Ma.	20.06	15.56	1.80	8.13	26.31	36.08	59.20	91.87	53.12	8.02
SEM	0.256	0.299	0.022	0.149	0.191	0.300	0.462	0.149	0.130	0.020
P	<0.0001	0.003	<0.0001	0.900	0.005	0.107	<0.0001	0.900	0.008	0.008
Method										
M1	19.45[a]	14.42[b]	1.74[a]	8.16	26.81[ab]	36.32[ab]	62.26[a]	91.84	52.34[a]	7.90[a]
M2	18.42[b]	14.02[b]	1.92[b]	8.16	27.23[a]	37.54[a]	61.19[ab]	91.84	52.74[a]	7.96[a]
M3	19.55[a]	15.99[a]	2.12[c]	8.02	26.22[b]	35.48[b]	59.47[b]	91.99	53.43[b]	8.07[b]
SEM	0.313	0.366	0.027	0.183	0.234	0.367	0.566	0.183	0.159	0.024
P	0.040	0.004	<0.0001	0.809	0.025	0.004	0.010	0.809	0.001	0.001

Note: BB, black bean; SB, soybean; Ma, Maize; M1, method 1; M2, method 2; M3, method 3. Means with different superscript letters within a collumn indicate significant difference (P < 0.05).