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Intercropping of maize and climbing bean: fodder yield, quality and nutrient composition of silages

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Abstract

A study was conducted to examine fodder yield and silage quality of maize (*Zea mays* L.) and climbing bean (*Phaseolus vulgaris* L.) intercropping with different planting structure. Maize was cultivated alone and intercropped with climbing bean as follows;1 row maize to 1 row climbing bean (1M1K), 1 row maize to 2 rows climbing bean (1M2K) and 2 rows maize to 1 row climbing bean (2M1K). The experiment was laid out in randomized complete block design with four treatments and three replications. The crops were harvested when the maize reached at milk stage and climbing bean at R7 stage. The results indicated significant increase in fresh biomass and dry matter production of maize fodder alone as compared to maize intercropped with climbing bean fodder. However, no difference ($p>0.05$) was observed in ether extract (EE), and ash (%) of nutrient composition of fodder among the four treatments After 45 days of ensiling period, silage samples were analysed for pH, organic acids (lactic, acetic, and butyric), ammonia-N(NH_3-N), dry matter (DM), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF), acid detergent fibre (ADF), water soluble carbohydrate (WSC), calcium (Ca), sodium (Na) and potassium (K). All intercropped silages had higher CP values (1M1K, 12.0%; 1M2K, 12.3%; 2M1K, 11.1%) than the monocrop maize (SM, 8.9%) silage. Higher organic acids and ammonia-N ($p<0.05$) were produced in the 1M2K silages as compared to others silages. The study showed that among all intercropped silages the 1M2K (1 row maize to 2 rows climbing bean) was preferable according to nutrient composition than other intercropped silages.

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Introduction

Maize silage is a major forage source in the livestock production of many countries. It has relatively consistent nutritive value and high energy density, but relatively low crude protein content. The intercropping of maize (*Zea mays* L.) with climbing bean (*Phaseolus vulgaris* L.) may serve as a way to increase crude protein and improve the overall nutritive value of silage (Grobelnik *et al.,* 2005).

Intercropping, the simultaneous cultivation of more than one species or cultivar on the same area of land, is being advocated as a new and improved approach to farming (INTERCROP, 2006). Intercropping involves competition for light, water and nutrients. However, intercropping usually benefits from increased light interception, root contact with more soil, increased microbial activity and can act as a deterrent to pests and weeds of the other crop. There is also evidence that suggests intercropping may benefit a non-legume which needs nitrogen if the other crop is a legume, since legumes will fix nitrogen in the soil (Avcioglu *et al.,* 2003). Dawo *et al.* (2007), ensiled corn and bean (*Phaseolus vulgaris* L.) intercropped at different densities. They did not find differences in Ph with the addition of the bean compared with monoculture corn; however, CP, DM, and lactic acid concentrations did increase. Armstrong *et al.* (2008), reported that intercropping climbing beans with corn increased CP and neutral detergent fiber concentration in the mixture. Proper spatial arrangements, planting rates and the maturity dates of components in maize-grain legume intercropping enhance biodiversity and have many advantages over pure maize cropping. The intercropping advantage, its improved stability on environmental resources, recycling nutrients and enhance nitrogen fixation (Rao *et al.,* 1984; Vandermeer , 1989). It's also better for weed, pest and diseases control as well as increased CP of silage (Anil *et al.,* 2000; Anil *et al.,* 1998).

The hypothesis of present study it would provide valuable information about the contribution of intercropping maize with climbing bean for better silage; (1) the making of silage under China climate condition with both crops simultaneously sown and harvested; (2) improves the silage quality by increasing protein contents. Therefore it was conducted to evaluate the fodder biomass yield and silage nutrient quality of maize and climbing bean intercropping treatments, differing in planting and spatial arrangements, as an alternative to pure maize cropping.

Materials and methods

Plant cultivation and Fodder Production

The crops were produced during the crop growing season in summer 2015 at the North campus experimental area (34º 18' 00" N, 108º 5' 42" E) in Northwest Agriculture and Forestry University, Shaanxi, Yangling, China. The crop production was carried out with a randomized complete block design with three replicates. The experiment was established on a sandy clay loam soil with 8.3 pH (Table 1). Summer maize (*Zea mays* L. Zheng Dan 958) was seeded as monocrop (SM) and intercropped with climbing bean (*Phaseolus vulgaris* L. Jin Jia Dou) as follows: 1 row maize to 1 row climbing bean (1M1K), 1 row maize to 2 rows climbing bean (1M2K), and 2 rows maize to 1 row climbing bean (2M1K). The site of experiment was ploughed to 0.2 to 0.3 m depth after the removal of winter wheat straw, followed by harrowing prior to trial. All plots were fertilized with the same amount of fertilizer before sowing, containing 70 kg N ha^{-1}, 70 kg P_2O_5 ha^{-1} and 70 kg of K_2O ha^{-1}. Maize and climbing bean were simultaneously seeded in 14 June 2015 in a field which had previously been cropped with winter wheat. The maize and climbing bean were spaced at 70cm x 25cm and 30cm x 15cm with population of about 114,285 and 444,444 plants per hectare, respectively. None of the climbing bean seeds were inoculated with *Rhizobium*. Neither herbicides nor were insecticides used. Hand weeding by hoe was done once when the maize was approximately 30cm in height. During the experimental period, the field was irrigated 3 times with 30 days interval.

Table 1. Soil characteristics of the experiment area.

Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Lime (%)	Salt (%)	OM (%)	N (%)	P ppm	K ppm	pH
20-40	36.7	30.6	30.4	18.5	0.07	1.5	0.2	0.3	400	8.3

OM - organic matter; N – nitrogen; P (ppm) - *phosphorus (parts per million); K (ppm) - Potassium (*parts per million).

Maize and climbing bean fodders were manually harvested simultaneously in three sampling areas in a total area of a 1m² of each plot at milk stage for maize and R7 stage for climbing bean in 20 September 2015. The maximum and minimum daily air temperatures were 31˚C and 20˚C respectively, and precipitation was 640 mm during the crop production.

Silage Preparation

Fodder was manually harvested and chopped into 3 to 4 cm in length with chaff cutter (JB 400, Power chaff cutter, Gujarat, India) and ensiled without additives into the plastic bags. The plastic bags were used for each type of silage and packing was done by manual trampling on the fodder. The plastic bags were sealed airtight and kept at room temperatures to allow for anaerobic fermentation for 45 days. Before fermentation, samples of 500g were taken for nutrient composition analysis. After the ensiling period, the mature samples were taken from the centre of ensiled mass of each plastic bags for chemical analysis. The fodder and silage samples were air-dried and ground by Blender and then flour samples were stored into a refrigerator for chemical analysis.

Determination of Nutrient Composition

The pH of silages was determined on the aqueous extract of silage by pH meter. Silages samples were dried at 80˚C for 48hr and ground to pass through a 2 mm screen. The ground samples were ashed at 550˚C (AOAC, 2000; Matsoukis *et al.,* 2014) for 2 hr in a muffle furnace (Nabertherm, Lilienthal, Germany). The Crude Protein (CP) content was determined as N x 6.25 using the Kjeldahl Analyzer (RAY-K9840, Auto Kjeldahl Distiller, Shandong, China). Ether extract (EE) was analysed by a standard ether extraction method (AOAC, 2000).Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined with procedures (Van Soest *et al.,* 1991). Ash content was measured by ingestion of the dried material in muffle furnace at 600˚C for 4hrs. The water soluble carbohydrate (WSC) was determined by the anthrone method, using freeze dried samples, where the WSC was extracted with water (Thomas *et al.,* 1997). Ca, Na, and K were analysed by atomic absorption spectrophotometry (AOAC, 2000). Ammonia-N concentration was determined using the Tecator Kjeltec Auto Sampler System 1035 Analyser. Organic acids (lactic, acetic, and butyric) were analysed by high pressure liquid chromatography (Andersson *et al.,* 1983).

Statistical analysis

Data of fodder production and chemical analysis of different silages was analysed by One-way-ANOVA using SPSS (version 19) and Duncan test (α=0.05) was used to compare the treatments means.

Results and discussion

Fodder yield

Data regarding green fodder and nutrients production (tons/ha) of fodder cultivated as a maize alone and maize intercropped with climbing bean at different planting structure are presented in table 2. The fresh fodder and DM yields were ranged from 34.6 to 45.6 t/ha and 12.1 to 14.7 t/ha (Table 2). Monocrop maize had a higher fresh biomass yield (45.6 t/ha) than other intercropped fodder.

Fresh forage and DM yields were higher in SM fodder, followed by three intercropped fodder. DM yield characteristic is a very dependable parameter in agronomical studies (Herbert *et al.,* 1984; Martin *et al.,* 1990). Several researchers have reported variable results of intercropping systems.

The intercropped maize with cowpea (*Vigna unguiculata* (L.) Walp.) and bean (*Phaseolus vulgaris* L.) produced higher DM yield than SM (Geren *et al.,* 2008). On the other hand, maize in row intercropping had a marked depressing effect on legume growth because of tall and leafy structure (Maasdorp *et al.,* 1997). Competition and unequal use of environmental or underground resources, such as light and water, seem to account for problems experienced on intercropped communities. These imbalances may have negative effects (for example reduced leaves or leaf area index) on crop yield (Chui *et al.,* 1984; Esmail *et al.,* 1991). Maize mixed with climbing bean possessed better fodder CP yields (2.2-2.6 t/ha) than the SM. The results suggested that the contributions provided by legume components in the mixtures increased CP yields of fodder.

Table 2. Fresh biomass, dry matter and crude protein yield of maize and maize-climbing bean intercropped fodder.

Fodder	Yields (tons/ha)		
	Fresh biomass	Dry matter	Crude protein*
SM	45.6^{a}	14.7^{a}	1.9^{d}
1M1K	34.6^{d}	12.1^{d}	2.4^{b}
1M2K	36.5^{c}	12.4^{c}	2.6^{a}
2M1K	40.3^{b}	13.2^{b}	2.2^{c}

Note: Different letters in the column mean significant difference ($p<0.05$).

SM, monocrop maize; 1M1K, 1 row maize to 1 row climbing bean; 1M2K, 1 row maize to 2 rows climbing bean; 2M1K, 2 rows maize to 1 row climbing bean.

*On dry matter basis.

Nutrient composition of fodder

Results of nutrient composition of maize and intercropped maize and climbing bean fodder are given in table 3. Crude protein contents of maize intercropped with climbing bean at different planting structure was ($p<0.05$) higher as compared to maize fodder alone. The DM content increased ($p<0.05$) with the intercropping of maize with climbing bean at different planting structure compared to maize fodder alone. No difference ($p>0.05$) was observed in ether extract and ash contents among fodders.

The NDF and ADF contents were decreased ($p<0.05$) with the intercropping of maize with climbing bean at different planting structure compared to maize fodder alone. The values of water soluble carbohydrate were 9.4, 8.9, 9.0 and 9.2% for SM, 1M1K, 1M2K and 2M1K, respectively. The value of WSC of fodder tended to be sufficient for good fermentation required for the preservation of fodder in the form of silage (Wilkinson *et al.,* 1983).

Table 3. Nutrient composition of maize and maize climbing bean intercropped fodder (%DM).

Nutrient composition	Fodder			
	SM	1M1K	1M2K	2M1K
DM, %	30.1^{d}	31.4^{c}	33.8^{b}	35.2^{a}
CP, %	8.2^{d}	11.2^{b}	11.5^{a}	10.1^{c}
EE, %	2.1	2.1	2.2	2.1
Ash, %	6.0	6.1	6.2	6.1
NDF, %	43.1^{a}	32.1^{d}	32.9^{c}	40.2^{b}
ADF, %	24.2^{a}	20.1^{d}	21.4^{c}	22.2^{b}
WSC, %	9.4^{a}	8.9^{d}	9.0^{c}	9.2^{b}

Note: Different letters in the column mean significant difference ($p<0.05$).

SM, monocrop maize; 1M1K, 1 row maize to 1 row climbing bean; 1M2K, 1 row maize to 2 rows climbing bean; 2M1K, 2 rows maize to 1 row climbing bean.

Fermentation quality of silages

Results of fermentation quality of different silages are depicted in table 4.Desirable pH values were found in all the silages. The intercropped silages were highly effective on pH compared to monocropped maize. There were significant differences between monocrop silages (SM) and intercrop silages in pH ($p<0.05$), SM having the lowest pH (3.9). Higher organic acids (lactic, acetic, and butyric) and ammonia-N ($p<0.05$) were produced in the 1M2K silages as compared to others silages.

Nutrient composition of silages

Results of nutrient composition of different silages are depicted in table 5.The DM contents of the silages were between 29.0%to 32.3%. The 1M2K silage had the highest DM value (32.3%) than the other silages. The optimum DM range of ideal corn silage is between 28% and 32% (McDonald *et al.,* 1987). The DM level was related to the fermentation conditions of the material (Costa *et al.,* 2012).

Table 4. Fermentation quality of maize and maize-climbing bean intercropped silage (%DM).

Parameter	Silage			
	SM	1M1K	1M2K	2M1K
pH	3.9[c]	4.1[b]	4.4[a]	4.1[b]
Lactic acid	9.0[c]	11.1[b]	13.2[a]	11.2[b]
Acetic acid	9.3[d]	10.4[b]	13.2[a]	10.0[c]
Butyric acid	2.0[c]	2.1[c]	3.2[a]	2.3[b]
NH_3-N/TN	8.1[d]	10.1[b]	10.6[a]	9.0[c]

Note: Different letters in the column mean significant difference (p<0.05).

SM, monocrop maize; 1M1K, 1 row maize to 1 row climbing bean; 1M2K, 1 row maize to 2 rows climbing bean; 2M1K, 2 rows maize to 1 row climbing bean.

One of the main objectives of intercropped silage is to obtain a complementary effect of the desirable nutrient of two or more crops. In the present study it was determined that the crude protein value of intercropped silages 1M1K, 1M2K and 2M1K were (p<0.05) higher as compared to SM. Legumes are rich in protein. The intercropping of maize with a variety of protein rich forages could increase silage CP level by 3% - 5% and improve N digestibility, indicating a potential to reduce the requirement for purchased protein supplements (Anil *et al.,* 2000).

Table 5. Nutrient composition of maize and maize-climbing bean intercropped silage (%DM).

Nutrient composition	Fodder			
	SM	1M1K	1M2K	2M1K
DM, %	29.0[d]	30.0[c]	32.3[a]	31.3[b]
CP, %	8.9[d]	12.0[b]	12.3[a]	11.1[c]
Ash, %	7.6[a]	7.1[c]	7.4[b]	7.1[c]
NDF, %	40.2[a]	29.8[d]	30.9[c]	39.2[b]
ADF, %	22.2[a]	18.2[d]	18.9[c]	21.8[b]
Ca, %	0.25[d]	0.33[b]	0.36[a]	0.31[c]
Na, %	0.15[c]	0.16[b]	0.18[a]	0.16[b]
K, %	2.3	2.3	2.3	2.3

Note: Different letters in the column mean significant difference (p<0.05).

SM, monocrop maize; 1M1K, 1 row maize to 1 row climbing bean; 1M2K, 1 row maize to 2 rows climbing bean; 2M1K, 2 rows maize to 1 row climbing bean.

The NDF contents of the silages varied from 29.8% to 40.2%. The presence of leguminous plants in the ensiled mass affected NDF and ADF levels in the present study. There is usually lower concentration of fibres in the DM of legumes in relation to grasses (Costa *et al.,* 2012). In addition, NDF level is related to the maturity stage of the forage sources, because of levels of cell wall components, chiefly the cellulose, hemicellulose, and lignin (Mugweni *et al.,* 2000). However, such an effect had not been observed in other experiments as no effect of intercropping was found on the NDF and ADF levels (Costa *et al.,* 2012). When compared to SM, the maize intercropped silages increased pH, and CP contents (p<0.05), whereas decreased NDF, ADF, and ash (p<0.05) contents. No difference (p>0.05) was found in K contents of nutrient composition of silage among the four treatments. Also Ca and Na contents in the intercrop silages were higher (p<0.05) than SM. The intercropped silage 1M2K had higher nutrient composition than the others intercropped silages.

Conclusion

The findings of this study, it may be concluded that intercropping of maize with climbing bean at different planting structure proved to be an effective way to increase fresh fodder production and to enhancing nutrient quality of silage ensuring the supply of nutritionally rich silage for livestock feeding. Intercropped maize with legumes increased CP, and decreased NDF and ADF concentrations in silages. However, for high yield of fresh biomass and DM yields, SM silage is recommended. Finally, among all intercropped silages the 1M2K (1 row maize to 2 rows climbing bean) was preferable according to nutrient composition than other intercropped silages.

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