Effect of intercropping of corn and soybean on dry matter yield and nutritive value of forage corn

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ABSTRACT

Cereal-based forage production could be considered to have potential to supply great deal of energy-rich feed in animal diets. Experiment was conducted to evaluate effect of corn-soybean combinations of 75:25, 50:50 and 25:75 in addition to monocrops of corn and soybean to determine forage dry matter (DM) yield and quality in corn-soybean intercropping. The crop combination ratio had significant effects on dry matter yield and nutritive quality of forage. The ratio of 75:25 and 50:50 recorded DM yields similar to those of monocropped corn (14.77 t/ha). Forage quality in terms of crude protein (CP) (75:25 ratio 12.75%, 50:50 ratio 13.73% and 25:75 ratio 14.68%) was improved by intercropping due to higher nitrogen availability for corn in intercropping compared with its sole crop (10.83% CP). Increase ratio of corn in corn-soybean mixture, negatively affected neutral detergent fiber (NDF), acid detergent fiber (ADF) of forage and declined with increasing ratio of soybean plants. Combination ratio of 50:50 gave higher protein yield (1886.45 kg/ha) than other crop combination ratio. Among all the combination ratios, the 50:50 corn-soybean ratio was the optimum giving highest forage yield, protein content as well as protein yield.

Key words: Corn-legume forage, Intercropping, Nutritive quality, NIRS, Protein yield.

INTRODUCTION

Feed related products from corn (Zea mays L.) provide high-energy content, but its crude protein (CP) content and biological value are relatively low (Mlynár et al., 2004). The low protein concentration in forage corn can be augmented by incorporating protein-rich ingredients such as soybean (Glycine max) (Choukan, 1997). Corn-legume intercrops could noticeably increase forage quantity and enhance its quality as well and also decrease requirements for protein supplements compared with the corn monocultures (Liu et al., 2006; Javanmard et al., 2009). High quality of forage has been informed as a vital feature of forage crop production. Legumes have a high quality forage, but low dry matter production (Lithourgidis et al., 2006). Therefore, legume-cereal composition is deliberated as a management strategy in generating both high quantity and quality forage. Determination of proper crop combination ratio can help balance rivalry among species in intercropping systems. Generally, species can be planted as mixed, alternate and cross-seeding patterns in mixtures (Acikgoz, 2001). Different crop combination ratio affects forage yields (Kumar et al., 2003; Chen et al., 2004) and crude protein (CP) yield (Altin, 1982). In addition, results showed that CP yields per hectare increased with corn-legume intercrop than that of monocropped corn (Javanmard et al., 2009; Sánchez et al., 2010; Baghdadi et al., 2014). The proportion of seed of intercropping components is one of factor that affects forage yield and CP content. For instance, Ibrahim et al. (2006) reported that seed combinations of corn affected the production of CP and cowpea in various ratios. Thus, increased CP contents is a function of an increased proportion of cowpea in seed mixture. The CP content increased in intercrop when corn amount decreased by corn and mixture of bean (Dawo et al., 2007).

However the forage acid detergent fiber (ADF) content responded inversely to the protein content of forage ADF showed increased tendency as dry matter yield increased with prolonged harvest days (Foster and malhi, 2013). Dry matter yield and CP of forages were improved using legume intercrops in comparison with the corn sole crop. In addition, a significant decrease in neutral detergent fiber (NDF) and ADF content was observed during the corn/legume intercrop. This caused improved digestibility of feed. Generally, corn intercropping with legume increased CP content, decreased concentrations of NDF and ADF, and subsequently enhanced forage nutritive value (Eskandari, 2012).
Corn provides high dry matter yield and low protein content forage. However, livestock need a good protein source for their growth and milk production. Protein is also essential for rumen bacteria, which digest the feed for ruminant animals (Ghanbari-Bonjar, 2000). Therefore, it seems essential to support livestock with protein increments when forage quality is low. The objective of this study was to use different crop combination ratios of corn and soybean to evaluate dry matter yield and nutritive value of forage corn intercropped with soybean.

**MATERIALS AND METHODS**

An experiment was conducted at research field, Universiti Putra Malaysia (UPM). Total annual rainfall in the year 2013 was approximately 1623.5 mm. Mean annual minimum and maximum temperatures were 24.5°C and 32.2°C, respectively, while the mean relative humidity was 78.9%. A composite soil sample was collected at random in the entire plot before the experiment to determine the physical and chemical characteristics. Details of soil physical and chemical properties of the experimental site are given in Table 1.

The experiment was established using a randomized complete block design with four replications. Corn (variety 926) was intercropped with soybean. The treatments consisted of five-crop combination ratio of corn and soybean as follows: 100:0, 75:25, 50:50, 25:75, and 0:100. The intercrop composition was based on replacement design. One plot comprised of corn monocrop and one plot comprised of soybean monocrop.

The previous crop on this field was corn. Corn and soybean intercrops were planted at the same time. The sowing date of the field experiment was on 25 November 2013. Two seeds were hand planted per point and plants were thinned to the target population just prior to the six-leaf stage (60000 plant/ha for corn and soybean respectively). The rest of N fertilizer was applied at 8-leaf stage of corn. All agronomic practices except those under study were kept uniform for all treatments.

Corn and soybean intercrops were harvested at the same time. Corn was harvested when the kernel milk-line was between 50 and 75% and soybean at seed fill stage. They were weighed fresh to determine fresh forage yield. The sampled area was 5 m² for the monoculture corn and intercropping treatments at the center of each plot and fresh biomass weight was determined as g DM m⁻² and above plant parts were harvested by hand cutting the plant 2 cm above the soil surface. Samples were oven-dried at 70°C for at least 72 hours. In addition, whole plant weight was measured fresh and after oven drying. Forage DM yield was calculated from the fresh and dry weights of respective components listed above.

Sample plants of each plot were chopped and mixed mechanically, and a 500 g sub-sample of each weighed forage sample were dried for 7 days in a 70°C forced-air oven to constant moisture to determine forage quality characteristics. Dried sub-samples were retained for forage quality assays. All dried samples were ground using a hammer mill to pass a 1-mm screen and analyzed for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), dry matter digestibility (DMD), water soluble carbohydrates (WSC) and acid detergent fiber (ADL). Near infrared reflectance spectroscopy (NIRS) technology, using a global calibration equation was used to estimate the nutritive quality of forage corn (Jafari et al., 2003). NIRS analyses requires a sample (0.5–1.0 g) which is exposed to an electro-magnetic scan over a spectral wavelength range of 1100 to 2500 nm (near infrared). Energy in this spectral range is directed onto the sample and reflected energy (R) is measured by the instrument. The diffuse reflection carries information, which identifies chemical bonds within the sample, such as -CH, -OH, -NH and -SH. The reflected energy is stored as the reciprocal logarithm (log 1/R) and the spectra are transformed to provide information about the chemical composition of the sample (Shenk and Westerhaus, 1991).

All data were were subjected to analysis of variance (ANOVA). The least significant difference (LSD) was used to compare treatment means at the 0.01 and 0.05% probability levels. The mixed linear model in SAS statistical software package (Version 9.1) (SAS, 2003) was used to perform an analysis of variance appropriate for a RCBD.

**RESULTS AND DISCUSSION**

Results showed crop combination ratio significantly affected the total DM yield of corn-soybean forage. Among the corn and soybean monocrop and corn-soybean intercropping, the total DM yield of corn monocrop (14.77 t/ha), 75:25 (14.68 t/ha) and 50:50 (14.59 t/ha) corn-soybean combination ratio were not significantly different, but they

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**Table 1:** Soil physical and chemical properties of the experimental site (0-30 cm depth)

<table>
<thead>
<tr>
<th>Soil characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon (%)</td>
<td>1.55</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>18.77</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>18.41</td>
</tr>
<tr>
<td>Sand (%)</td>
<td>62.61</td>
</tr>
<tr>
<td>Texture</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>pH</td>
<td>6.18</td>
</tr>
<tr>
<td>EC (ds/m)</td>
<td>3.16</td>
</tr>
<tr>
<td>K (ppm)</td>
<td>19.7</td>
</tr>
<tr>
<td>N (%)</td>
<td>0.11</td>
</tr>
<tr>
<td>P (ppm)</td>
<td>18.7</td>
</tr>
</tbody>
</table>
were significantly greater than total DM yield of 25:75 (12.38 t/ha) ratio and soybean sole crop (10.44 t/ha) (Table 2).

The summary of the ANOVA tables shows the significance of the main effects of different crop combination ratio on all nutritive quality parameters of corn-soybean forage in corn-soybean intercrops (Table 3). All the corn-soybean combination treatments resulted in substantially higher total CP content than corn monocrop. The CP content was significantly affected by crop combination ratio. The CP content declined with decrease in proportion of soybean from 17.27% to 10.83% (Table 4). Combination ratio of corn-soybean had significant effect on DMD of forage. Combination of corn-soybean in all ratios gave significantly higher DMD than corn monocrop. The results showed that crude protein and dry matter digestibility increased with increasing ratio of soybean in mixture with corn (Fig. 1).

The NDF was significantly affected by crop combination ratio (Table 3). The highest NDF content was for the corn monocrop (57.65%) and 75:25 (57.62%) corn-soybean ratio. There was no significant difference between 50:50 (54.12%) and 25:75 (53.92%) and soybean sole crop (53.74%). Corn-soybean combination had a significant effect on ADF content of forage. Corn sole crop and 75:25 corn-soybean ratios produced significantly higher concentration of ADF (36.26 and 36.48%, respectively) than the other treatments. Results indicated that increase ratio of corn in corn-soybean mixture, negatively affectd ADF and NDF of forage and declined with increasing ratio of soybean plants (Fig. 2).

Crop combination ratio had a significant effect on WSC content of forage. Increase ratio of soybean resulted in reduction of WSC in the mixed forage. The WSC content was similar for sole crop corn up to 50:50 corn-soybean combinations. Crop combination ratio had a significant effect on ADL concentration. The ADL content increased when soybean ratio increased in mixed forage. The ADL content was similar for sole crop corn up to 50:50 corn-soybean combinations (Table 4).

Protein yield of forage varied significantly with crop combination ratio treatments. The highest forage protein yield produced by intercropping at 50:50 corn-soybean ratio (2003.40 kg/ha) which was significantly different with the other intercrop combination ratio of 1871.05 and 1815.50 kg/ha for 75:25 and 25:75 corn-soybean intercropping combination ratio, respectively. Protein yield was lowest in the corn monoculture treatment (1598.84 kg/ha) (Table 4).

The mixed corn-soybean gave similar DM yield as monocrop corn but increasing soybean more than 50% resulted in lower dry matter yield. This implies that to get good quality silage without a reduction in yield the soybean component should not exceed 50% of the combination. These results were in accordance with Hulet et al. (1986) who recommended that farmer could increase the ratio of the

<table>
<thead>
<tr>
<th>Corn-soybean ratios</th>
<th>Corn Dry Matter Yield (t/ha)</th>
<th>Soybean Dry Matter Yield (t/ha)</th>
<th>Total Dry Matter Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 : 100</td>
<td>14.77a</td>
<td>-</td>
<td>14.77a</td>
</tr>
<tr>
<td>75 : 25</td>
<td>11.68b</td>
<td>3.00d</td>
<td>14.68a</td>
</tr>
<tr>
<td>50 : 50</td>
<td>8.83c</td>
<td>5.76c</td>
<td>14.59a</td>
</tr>
<tr>
<td>25 : 75</td>
<td>4.24d</td>
<td>8.14ab</td>
<td>12.38b</td>
</tr>
<tr>
<td>0 : 100</td>
<td>-</td>
<td>5.76c</td>
<td>10.44a</td>
</tr>
</tbody>
</table>

Mean values followed by the same letter in the same column are not significantly different at P<0.05, based on least significant difference test (LSD).

Fig 1: Effect of corn-soybean combination ratio on crude protein and dry matter digestibility.

Table 2: Dry matter yield of sole and intercropped corn and soybean as influenced by crop combination ratio.
Higher forage DM is considered desirable when forage protein content is high (Lithourgidis et al., 2006; Lithourgidis et al., 2007). The outcome of that study indicated an increased ratio of soybean in intercrops increased the CP contents. There was a report by Dawo et al. (2007) in which CP concentration increased by 22% in the mixture when corn proportion in the mixture decreased by 50%. Results in the present study were in agreement with other studies where legumes also increased CP concentration when in a mixture with corn (Ibrahim et al., 2006; Dawo et al., 2007; Ayub et al., 2008; Dahmardeh et al., 2009). Higher forage DM yield with considerable protein content is the ultimate goal of a smallholder farmer when intercropping is practiced (Sadeghpour et al., 2013). The highest CP yield was for the intercropping corn with soybean at 50:50 corn-soybean ratio, which was significantly higher than sole crop of corn. The CP per hectare was lowest for sole corn crops. The higher total protein yield recorded by intercropping was due to the higher protein content of intercrops. Other studies have reported similar results where in legumes included in the intercropping systems significantly increased the CP per hectare (Ghanbari-Bonjar, 2000; Lithourgidis et al., 2006; Javanmard et al., 2009; Eskandari, 2012; Eskandari et al., 2009). Strydhorst et al. (2008) also reported that intercrops such as alfalfa, clover, and vetch recorded 64, 27, and 55% higher protein yields as compared to the sole barley crop, respectively.

The increase in the soybean ratio in the mixture reduces ADF and NDF significantly. Generally, NDF concentration is greater for grasses than for legumes (NRC, 2001) and the magnitude of this difference and the proportions of legume in these mixtures seemed sufficient to have a significant impact on the mixtures. These results were in accordance with other study outcome stated by Dahmardeh et al. (2009) who reported that corn-legumes intercropping treatments had lower values of NDF and ADF compared to sole corn crop. Dahmardeh et al. (2009) reported that higher value of ADF (31.85%) was recorded by sowing corn alone while increasing the proportion of cowpea seeds to 50% in intercropping with corn, resulted in the lowest ADF (25-89%). Similarly, Laurita and Kirksey (2004) noted that intercropping of cereal with winter pea reduced NDF in all cereal forage-legume intercrops compared to corn monoculture. On the other hand, Armstrong et al. (2008) reported that intercropping climbing beans with corn increased NDF concentration and decreased digestibility compared to monoculture corn.

The positive effect of intercropping on DM digestibility may be attributed to the higher protein concentration

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**Table 3:** Mean Squares from analysis of variance nutritive quality of corn-soybean forage under different crop combination ratios in corn-soybean intercrops

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>Crude Protein</th>
<th>Neutral Detergent</th>
<th>Acid Detergent</th>
<th>Dry Matter</th>
<th>Water Soluble</th>
<th>Acid Detergent</th>
<th>Protein yield (Kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>3</td>
<td>2.65</td>
<td>16.56**</td>
<td>1.37**</td>
<td>5.03</td>
<td>0.04</td>
<td>79.26</td>
</tr>
<tr>
<td>combination ratio</td>
<td>4</td>
<td>3.73**</td>
<td>13.96**</td>
<td>1.87*</td>
<td>5.47</td>
<td>0.10</td>
<td>68.86**</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td>0.04</td>
<td>5.03</td>
<td>0.74</td>
<td>2.08</td>
<td>0.07</td>
<td>44.99</td>
</tr>
<tr>
<td>cv</td>
<td>0.46</td>
<td>4.04</td>
<td>3.05</td>
<td>6.10</td>
<td>1.17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*, ** significant at P<0.05, 0.01, respectively

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**Table 4:** Forage nutritive quality of sole and intercropped corn and soybean as influenced by crop combination ratio

<table>
<thead>
<tr>
<th>Corn-soybean ratios</th>
<th>Crude Protein (%)</th>
<th>Neutral Detergent (%)</th>
<th>Acid Detergent (%)</th>
<th>Dry Matter (%)</th>
<th>Water Soluble (%)</th>
<th>Acid Detergent (%)</th>
<th>Protein yield (Kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100:0</td>
<td>7.5-15</td>
<td>57.65a</td>
<td>57.62a</td>
<td>5.42b</td>
<td>66.66ab</td>
<td>3.64b</td>
<td>26.96a</td>
</tr>
<tr>
<td>75:25</td>
<td>12.75d</td>
<td>57.62a</td>
<td>57.62a</td>
<td>5.42b</td>
<td>66.66ab</td>
<td>3.64b</td>
<td>26.96a</td>
</tr>
<tr>
<td>50:50</td>
<td>13.73c</td>
<td>54.12b</td>
<td>54.12b</td>
<td>5.42b</td>
<td>68.66bc</td>
<td>3.64b</td>
<td>27.00d</td>
</tr>
<tr>
<td>25:75</td>
<td>14.68b</td>
<td>53.92b</td>
<td>53.92b</td>
<td>5.42b</td>
<td>70.66bc</td>
<td>3.64b</td>
<td>24.63b</td>
</tr>
<tr>
<td>0:100</td>
<td>17.27a</td>
<td>53.74b</td>
<td>53.74b</td>
<td>5.42b</td>
<td>70.66bc</td>
<td>3.64b</td>
<td>18.03c</td>
</tr>
</tbody>
</table>

LSD(0.05) 0.10        3.44 1.61 2.18 2.22 0.40 32.68

P value <.0001 0.0479 0.0003 0.0438 0.0476 <.0001 <.0001 <.0001

Mean values followed by the same letter in the same column are not significantly different at P<0.05, based on least significant difference test (LSD).
when corn was sown in the mixture with soybean. These results were in the line with Javanmard et al. (2009) who found that intercropping of legumes with corn significantly increased digestibility of the forages.

For this experiment, WSC concentration increased in intercrops compared with that in sole soybean, and in agreement with Kristensen (1992) for barley-bean compared with sole bean.

Intercropping of corn-soybean under different combination ratio enhanced the forage quality in terms of CP yield, CP content, NDF, ADF concentrations as compared to the sole cropping of corn. DM yield of the corn-soybean with 50:50 combination ratio was not different from monoculture corn, but had a higher protein yield and good quality of forage and silage than monoculture corn. Inclusion of corn with soybean improves forage quality, as soybean are rich in protein. The best ratio of corn-soybean to obtain high quality silage with good yield is 50:50.

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