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Potential Benefits of Intercropping Corn with Runner Bean for Small-sized Farming System

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ABSTRACT : The objectives of this study were to evaluate potential benefits of intercropping of corn with runner bean for a small-sized farming system, based on land equivalent ratio (LER) and silage yield and quality of corn intercropped with runner bean (*Phaseolus vulgaris L.*), in arid conditions of Turkey under an irrigation system. This experiment was established as a split-plot design in a randomized complete block, with three replications and carried out over two (consecutive) years in 2006 and 2007. Seven different mixtures (runner bean, B and silage corn sole crop, C, 10% B+90% C, 20% B+80% C, 30% B+70% C, 40% B+60%C, and 50% B+50%C) of silage corn-runner bean were intercropped. All of the mixtures were grown under irrigation. The corn-runner bean fields were planted in the second week of May and harvested in the first week of September in both years. Green beans were harvested three times each year and green bean yields were recorded each time. After the 3rd harvest of green bean, residues of bean and corn together were randomly harvested from a 1 m^2 area by hand using a clipper when the bean started to dry and corn was at the dough stage. Green mass yields of each plot were recorded. Silages were prepared from each plot (triplicate) in 1 L mini-silos. After 60 d ensiling, sub-samples were taken from this material for determination of dry matter (DM), pH, organic acids, chemical composition, and *in vitro* DM digestibility of silages. The LER index was also calculated to evaluate intercrop efficiencies with respect to sole crops. Average pH, acetic, propionic and butyric acid concentrations were similar but lactic acid and ammonia-N levels were significantly different ($p<0.05$) among different mixtures of bean intercropped with corn. Ammonia-N levels linearly increased from 0.90% to 2.218 as the percentage of bean increased in the mixtures up to a 50:50 seeding ratio. While average CP content increased linearly from 6.47 to 12.45%, and average NDF and ADF contents decreased linearly from 56.17 to 44.88 and from 34.92 to 33.51%, respectively, ($p<0.05$) as the percentage of bean increased in the mixtures up to a 50:50 seeding ratio, but DM and OM contents did not differ among different mixtures of bean intercropped with corn ($p>0.05$). *In vitro* OM digestibility values differed significantly among bean-corn mixture silages ($p<0.05$). Fresh bean, herbage DM, IVOMD, ME yields, and LER index were significantly influenced by percentage of bean in the mixtures ($p<0.01$). As the percentage of bean increased in the mixtures up to a 50:50 seeding ratio, yields of fresh bean (from 0 to 24,380 kg/ha) and CP (from 1,258.0 to 1,563.0 kg/ha) and LER values (from 1.0 to 1.775) linearly increased, but yields of herbage DM (from 19,670 to 12,550 kg/ha), IVOMD (from 12,790 to 8,020 kg/ha) and ME (46,230 to 29,000 Mcal/ha) yields decreased ($p<0.05$). In conclusion, all of the bean-corn mixtures provided a good silage and better CP concentrations. Even though forage yields decreased, the LER index linearly increased as the percentage of bean increased in the mixture up to a 50:50 seeding ratio, which indicates a greater utilization of land. Therefore, a 50:50 seeding ratio seemed to be best for optimal utilization of land in this study and to provide greater financial stability for labor-intensive, small farmers. (**Key Words :** Intercropping, Runner Bean, Corn, Silage, Digestibility, LER Value)

INTRODUCTION

Feed cost comprises from 50 to 70% of total farming expenses in Turkey (Ergün et al., 2002). Crops and livestock are interdependent elements, thus, income of farmers can be improved by utilizing the production factors for the combination of crops and dairying (Widodo et al., 1994). In order to reduce feed costs and create more sustainable management systems for moderate-sized, family operations, value-promoted livestock enterprises must be integrated with existing cropping enterprises.

One of the most important factors affecting Turkish farming systems is the lack of cheap, abundant and high quality feedstuff. The feeding of low-quality forages such as crop residues (wheat, barley straw) and low-quality hays

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with protein (meal) or energy supplementation (grain barley) to wintering ruminants is a common practice in Turkey. However, these low-quality forages may limit performance of dairy and fast-growing beef cows due to their high gut-filling capacity (Minson and Wilson, 1994). Dairy cows can only produce high milk yields and beef cows can only reach their maximum potential if their intermediary metabolism is supplied with sufficient nutrients (Ergün et al., 2002). Thus, high-quality forages have to be produced.

Corn silage has become more popular as a high-quality forage for ruminant animals in many parts of world as well as in Turkey. Corn silage has become a major constituent of ruminant, especially dairy, rations in recent years (Anil et al., 2000). Cereal forages are mainly used as an energy source in ruminant rations, possessing mainly carbohydrates but often with inadequate protein for high levels of production (Anil and Phipps, 1998). Thus, cereal forages often require additional protein supplementation for high milk and meat production. Protein-rich forages such as legumes can be ensiled and utilized to complement high energy corn silage.

Intercropping has been traditionally practiced in many parts of world (Anil et al., 2000; Karadag, 2004) as well as in Turkey (Karadag, 2004) and has some advantages over monocultures (Anil and Phipps, 1998; Karadag, 2004). One of its obvious advantages may be to increase forage protein, the principle being improvement of forage quality through the complementary effects of two or more crops grown simultaneously on the same area of land (Anil et al., 2000). Intercropping supplies efficient resource utilization, reduces risk to the environment and production costs, and provides greater financial stability, making the system more suitable particularly for labor-intensive, small farmers (Anil and Phipps, 1998).

Therefore, the objectives of this study were to evaluate potential benefits of intercropping of corn with runner bean for a small-sized farming system, based on LER and silage yield and quality of corn intercropped with runner bean, in arid conditions of Turkey under an irrigation system.

MATERIALS AND METHODS

Place of experiment

This experiment was carried out in the Van-Gevaş region, at the border of Turkey and Iran (38°18'N, 43°07'E, altitude of experimental field 1,720 m, mean temperature 8.8°C and average rainfall 516.9 mm). Soil of the experimental field was slightly alkaline, and poor in terms of organic matter, nitrogen and phosphorous contents.

Experimental design and treatments

This experiment was established as a split-plot design in a randomized complete block, with three replications. A silage corn (C) cultivar (Rx-788) and a local runner bean (B; (*Phaseolus vulgaris L.*) cultivar were utilized in this study and the experiment was carried out over two consecutive years in 2006 and 2007. Seven different mixtures (runner bean and silage corn sole crop, 10% B+90% C, 20% B+80% C, 30% B+70% C, 40% B+60% C, and 50% B+50% C) of silage corn-runner bean were intercropped. All of the mixtures were grown under irrigation. The corn-runner bean fields were planted in the second week of May and harvested in the first week of September in both years. Rows were 5 m long and with 60 cm spacing. Each plot consisted of 6 rows. The bean and corn were seeded on the same row. All of the bean-corn fields were watered every other week, hoed twice throughout the experiment, and were fertilized with 150 kg diammonium phosphate per hectare (ha) at seeding. Sole corn and the mixtures were additionally fertilized with 53 kg ammonium nitrate per hectare (ha).

Harvesting

Green beans were harvested three times each year and green bean yields were recorded each time. After the 3rd harvest of green bean, residues of bean and corn together were randomly harvested from a 1 m^2 area by hand using a clipper when the bean started to dry and corn was at the dough stage. To eliminate side effect, all plants from each side of each plot were excluded and then the remaining plants were sampled for determination of yield and other analysis. Green mass yields of each plot were recorded.

Silage-making

All forages were chopped by a one-row forage harvester. Silage was made from each plot (triplicate) in a 1 L mini-silo. Ensiling was performed by stamping as much chopped plant material as possible into the mini-silo. By this action most of the air was excluded. After ensiling, each mini-silo was sealed off tightly with a screw lid. The lids were poked with a pin to eliminate the gas pressure that built up during the initial phase of ensiling and then the holes were sealed with tape after the first week of ensiling. The mini-silos were then stored for 60 d in a dark room with a temperature ranging from 20 to 25°C. After 60 d ensiling, sampling was accomplished by complete emptying of the silo, after discarding upper part of silage, into a container. Then, sub-samples were taken from this material for determination of dry matter (DM), pH, organic acids, chemical composition, and *in vitro* DM digestibility of silages.

Determination of yields, energy and chemical contents of silages

Dry matter of samples was determined by oven drying of triplicate sub-samples at 65°C for 72-h, after an air-

Table 1. Effects of intercropping corn with runner bean at differing rates on fermentation characteristics of silages (All values except pH expressed as % DM)

Item	pH			Acetic acid			Propionic acid			Butyric acid			Lactic acid			Ammonia-N		
	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave.
Corn (Sole)	3.58^{c}	3.70^{b}	3.64^{b}	0.33^{b}	1.11	0.72	0.06^{bc}	0.09	0.08^{ab}	0	0	0	4.21^{bc}	3.38	3.80^{b}	0.79^{c}	1.01^{b}	0.90^{c}
Runner bean (Sole)	3.77^{bc}	4.13^{a}	3.95^{a}	0.99^{a}	1.14	1.07	0^{c}	0	0^{b}	0.22	0	0.11	2.80^{d}	2.96	2.88^{b}	2.96^{a}	2.95^{a}	2.96^{a}
Corn 90%	4.22^{a}	3.81^{b}	4.02^{a}	1.13^{a}	1.06	1.09	0.23^{a}	0	0.12^{a}	0.25	0	0.13	3.25^{d}	3.18	3.21^{b}	1.09^{bc}	1.09^{b}	1.09^{c}
Corn 80%	3.85^{abc}	3.83^{ab}	3.84^{ab}	0.74^{ab}	0.93	0.83	0.05^{bc}	0.17	0.11^{a}	0	0	0	6.49^{ab}	3.01	4.75^{ab}	1.26^{b}	0.99^{b}	1.12^{c}
Corn 70%	4.17^{ab}	3.78^{b}	3.97^{a}	0.81^{ab}	1.01	1.91	0.15^{ab}	0	0.07^{ab}	0.38	0	0.19	3.72^{d}	2.97	3.34^{ab}	1.42^{b}	1.09^{b}	1.25^{c}
Corn 60%	3.89^{abc}	3.96^{ab}	3.93^{a}	0.86^{a}	1.14	1.00	0.10^{ab}	0	0.05^{ab}	0.04	0	0.02	5.06^{bc}	3.73	4.39^{b}	1.32^{b}	1.21^{b}	1.27^{c}
Corn 50%	4.09^{ab}	3.86^{ab}	3.98^{a}	1.08^{a}	1.13	1.10	0.11^{ab}	0.13	0.12^{a}	0.21	0	0.11	6.75^{a}	5.86	6.30^{a}	2.68^{a}	1.69^{b}	2.18^{b}
SEM	0.13	0.09	0.08	0.16	0.37	0.20	0.04	0.05	0.03	0.12	0	0.06	0.52	1.32	0.70	0.11	0.23	0.13
Year			0.28			0.79			0.09			0.24			0.63			0.05
Bean	0.04	0.09	0.01	0.05	0.99	0.15	0.04	0.17	0.20	0.27	0	0.25	0.01	0.70	0.03	0.01	0.01	0.01
Year×Bean			0.04			0.84			0.02			0.02			0.06			0.03

a-c Means with different superscripts within a column are significantly different ($p<0.05$).

drying (AOAC, 1980). DM yield was calculated by multiplying the DM content of the mixtures by their green mass yield.

The pH of each sample was determined in triplicate using approximately 25 g wet ensilage added to 100 ml of distilled water. After hydration for 10 min using a blender, the pH was determined using a digital pH meter (Polan et al., 1998). The filtrate was filtered through filter paper, centrifuged and stored for organic acid analysis. Organic acid analysis were accomplished by gas chromatography (Shimadzu, GC-14B) as described by Leventini et al. (1990).

All analyses except CP were performed on dried samples. Dried samples were ground to pass through a 1 mm screen before analysis. Ash concentration of samples was determined in a muffle furnace at 550°C for 8 h. All samples were analyzed for CP by the Kjeldahl procedure (AOAC, 1980), neutral detergent fiber (NDF) (Van Soest and Robertson, 1979), and acid detergent fiber (ADF) (Goering and Van Soest, 1970) concentrations. *In vitro* dry matter digestibility (IVDMD) of samples was determined as described by Tilley and Terry (1963) and modified by Marten and Barnes (1980). Ruminal ingesta from an alfalfa-fed, ruminally-fistulated ram was hand-collected and strained through 4 layers of cheesecloth to provide innocula for the IVDMD determination. Metabolizable energy (ME, Mcal/kg) was calculated using the following equation (NRC, 1989):

$$\text{ME (Mcal/kg)} = \text{Digestible energy} \times 0.82$$

Determination of the land equivalent ratio

The Land Equivalent Ratio (LER) index was utilized to evaluate intercrop efficiencies with respect to sole crops (Çiftçi and Ülker, 2005). The LER defines yield as a function of area:

$$LER = I_a/S_a + I_b/S_b$$

Where, I and S refer to intercrop and sole crop yields, respectively. The subscripts a and b indicate the crop components of the mixture.

Statistical analysis

All data were subjected to analysis of variance for a completely randomized design using the GLM procedure of SAS and means were separated by Duncan's t-test (SAS, 1985).

RESULTS AND DISCUSSION

Effect on chemical contents

The main objective of this study was to evaluate potential benefits of intercropping of corn with runner bean for small-sized farming systems in Turkey. Runner bean was preferred in the intercropping system because runner bean is used as one of the major summer meals and extensively consumed by Turkish people. Secondly, runner bean contains considerable amounts of crude protein because it is a legume. Therefore, it was thought that ensiling bean together with corn might increase CP content of silage as well.

Table 1 presents fermentation characteristics of the silages. Average pH, and acetic, propionic and butyric acid concentrations were similar, but lactic acid and ammonia-N levels were significantly different ($p<0.05$) among the different mixtures of beans intercropped with corn. Average pH values of mixtures were in the ideal range of 3.8-4.2 (Table 1). All intercrop silages were low in butyric acid and well fermented, indicating a good conservation, which was supported by earlier studies of Valdez et al. (1988) and Anil et al. (2000).

Table 2 shows the chemical composition of corn and bean as sole crop, and different mixtures of beans intercropped with corn conserved as silage. While average DM and OM contents did not differ, average CP, NDF and ADF contents were significantly different among different

Table 2. Effects of intercropping corn with runner bean at differing rates on chemical compositions of silages (Values expressed as % DM)

Item	DM			OM			CP			NDF			ADF		
	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave.
Corn (Sole)	28.35^{ab}	26.95^{a}	27.65^{a}	93.25^{a}	94.33^{a}	93.79^{a}	6.42^{f}	6.52^{d}	6.47^{e}	56.99^{a}	51.35^{a}	54.17^{a}	36.71^{ab}	33.13	34.92^{ab}
Runner bean (Sole)	25.58^{b}	23.00^{b}	24.29^{b}	89.86^{b}	89.69^{b}	89.77^{c}	14.66^{a}	17.30^{a}	15.98^{a}	42.86^{b}	38.25^{c}	40.55^{b}	38.71^{ab}	33.81	36.26^{a}
Corn 90%	28.18^{ab}	27.14^{a}	27.66^{a}	91.83^{ab}	93.12^{a}	92.47^{ab}	7.82^{e}	9.22^{c}	8.52^{d}	52.95^{a}	48.84^{ab}	50.90^{ab}	36.46^{b}	33.28	34.87^{ab}
Corn 80%	27.67^{ab}	28.00^{a}	27.83^{a}	91.72^{ab}	94.83^{a}	93.72^{ab}	8.67^{de}	8.02^{de}	8.34^{d}	50.14^{ab}	49.80^{ab}	49.97^{ab}	35.50^{b}	29.97	32.74^{b}
Corn 70%	26.20^{b}	27.61^{a}	26.90^{a}	90.74^{b}	94.24^{a}	92.49^{ab}	10.28^{c}	9.44^{c}	9.86^{c}	54.40^{a}	48.70^{ab}	51.55^{ab}	41.06^{a}	31.82	36.44^{a}
Corn 60%	30.40^{a}	28.34^{a}	29.37^{a}	91.64^{ab}	93.48^{a}	92.56^{ab}	9.66^{de}	9.99^{c}	9.83^{c}	51.19^{ab}	46.86^{b}	49.03^{ab}	36.80^{b}	33.24	35.02^{ab}
Corn 50%	27.06^{ab}	27.95^{a}	27.50^{a}	90.43^{b}	93.17^{a}	91.80^{b}	12.45^{b}	12.45^{b}	12.45^{b}	43.57^{b}	46.18^{b}	44.88^{c}	36.44^{b}	30.58	33.51^{b}
SEM	1.11	1.12	0.79	0.62	0.69	0.46	0.41	0.68	0.39	2.69	1.15	1.46	1.35	1.33	0.95
Year			0.31			0.01			0.16			0.01			0.01
Bean	0.12	0.06	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.13	0.30	0.10
Year×Bean			0.49			0.11			0.05			0.37			0.32

$^{a\text{-}f}$ Means with different superscripts within a column are significantly different ($p<0.05$).

mixtures of beans intercropped with corn ($p<0.05$). Average DM, OM, CP, and NDF contents were significantly different between sole bean and sole corn silages ($p<0.05$). Crude protein content of bean-corn silages ranged from 8.52 to 12.45% and increased in a linear fashion as the percentage of bean increased in the mixture ($p<0.05$). Sole bean silage had a significantly greater CP concentration than the other silages ($p<0.01$). Sole corn silage had a significantly higher average NDF content compared with sole bean silage ($p<0.05$). Increasing the percentage of bean linearly decreased NDF content of bean-corn mixture silages ($p<0.05$). The contents of OM, NDF, and ADF were significantly affected by planting year ($p<0.01$). Average DM concentrations of silage were between 24.29 and 29.37%. Average DM content of mixtures were close to the lower optimal DM content (30%) suggested for ideal silage making (Ergün et al., 2002). DM content of beans was significantly lower than that of corn, which was in agreement with the results of Anil et al. (2000). Average OM matter contents of bean-corn mixtures were similar and ranged from 91.80 to 92.47%. OM level of bean was significantly lower than that of corn, which resulted in a linear decrease of OM in the mixtures. It is well-known that mineral content of legumes is higher than that of cereals (NRC, 1989; Smith, 1990). Similarly, CP content of legumes is considerably greater compared with that of cereals (NRC, 1989; Tuna and Orak, 2007). Average crude protein concentrations of bean-corn mixtures were between 8.34 and 12.45%. Similarly, intercropping corn with runner bean increased silage CP content from 8.1% to 12.0% (Anil et al., 2000). Armstrong et al. (2005) also noted that beans increased the CP concentration of all mixtures when intercropped with corn. NDF and ADF concentrations were significantly different among mixtures and sole crops ($p<0.05$). NDF concentration of bean was significantly lower than that of corn and increasing the percentage of bean in the mixtures reduced NDF concentration. Al-Masri (1998) reported that NDF content of vetch was lower but ADF content was similar to that of barley and intercropping reduced NDF content of the mixture, which supports the result of the current study. However, Anil et al. (2000) noted that the NDF and ADF contents of corn silage tended to be lower than those recorded for corn-runner bean silage.

Effect on energy values

In vitro DM digestibility and ME values ranged from

Table 3. Effects of intercropping corn with runner bean at differing rates on IVOMD (% OM) and ME (Mcal/kg)

Item	IVOMD (% OM)			ME (Mcal/kg)		
	Year I	Year II	Ave.	Year I	Year II	Ave.
Corn (Sole)	66.33^{a}	64.68^{ab}	65.50^{ab}	2.40^{a}	2.34^{ab}	2.37^{ab}
Runner bean (Sole)	62.09^{ab}	62.49^{b}	62.29^{bc}	2.24^{ab}	2.26^{b}	2.25^{bc}
Corn 90%	58.87^{b}	62.04^{b}	60.46^{c}	2.13^{b}	2.24^{b}	2.19^{c}
Corn 80%	67.13^{a}	69.76^{a}	68.45^{a}	2.43^{a}	2.52^{a}	2.47^{a}
Corn 70%	56.91^{b}	66.56^{ab}	61.74^{bc}	2.06^{b}	2.41^{ab}	2.23^{bc}
Corn 60%	59.68^{b}	64.80^{ab}	62.25^{bc}	2.16^{b}	2.34^{ab}	2.25^{bc}
Corn 50%	62.40^{ab}	65.65^{ab}	64.03^{bc}	2.26^{ab}	2.37^{ab}	2.31^{bc}
SEM	1.89	2.04	1.39	0.07	0.07	0.05
Year			0.01			0.01
Bean	0.02	0.21	0.01	0.02	0.21	0.01
Year×Bean			0.17			0.17

$^{a\text{-}c}$ Means with different superscripts within a column are significantly different ($p<0.05$).

Table 4. Effects of intercropping corn with runner bean at differing rates on fresh bean, herbage DM, digestible DM, ME and CP yields (kg/ha)

Item	Fresh bean yield			Herbage DM yield			Digestible DM yield			ME yield			CP yield		
	Year I	Year II	Ave	Year I	Year II	Ave.	Year I	Year II	Ave.	Year I	Year II	Ave	Year I	Year II	Ave
Corn (Sole)	0^{f}	0^{g}	0^{g}	23,220^{a}	15,720^{a}	19,670^{a}	15,400^{a}	10,170^{a}	12,790^{a}	55,690^{a}	36,780^{a}	46,230^{a}	1,489^{b}	1,027^{b}	1,258^{b}
Runner bean (Sole)	19,340^{c}	24,330^{c}	21,830^{b}	5.880^{e}	6.760^{e}	6.320^{d}	3.650^{e}	4.210^{d}	3.930^{e}	13.180^{e}	15.230^{d}	14.210^{e}	862^{c}	1,156^{ab}	1,010^{c}
Corn 90%	14,070^{f}	8,200^{f}	11.130^{f}	22.120^{ab}	14.520^{ab}	18.310^{a}	12.970^{b}	9.010^{ab}	10.990^{bc}	46.900^{bc}	32.580^{ab}	3,974^{bc}	1,711^{ab}	1,340^{ab}	1,525^{a}
Corn 80%	16,720^{e}	10,850^{e}	13,780^{e}	20,380^{bc}	13,250^{bc}	16,810^{b}	13,650^{b}	9,240^{ab}	11,450^{b}	49,360^{b}	34,410^{ab}	4,138^{b}	1,772^{a}	1,062^{b}	1,417^{ab}
Corn 70%	18,740^{c}	14,530^{d}	16,630^{d}	15.430^{d}	12.140^{de}	13.780^{c}	8.750^{d}	8.070^{bc}	8.410^{d}	31.650^{d}	29.190^{bc}	3,042^{d}	1.582^{ab}	1,149^{ab}	1,366^{ab}
Corn 60%	19,450^{b}	16,200^{c}	17,830^{c}	18,580^{c}	12,370^{de}	15,470^{b}	11,080^{c}	8,040^{bc}	9,560^{c}	40,060^{c}	29,060^{bc}	3,456^{c}	1,794^{a}	1,242^{ab}	1,518^{a}
Corn 50%	22,380^{a}	26,370^{a}	24.380^{a}	13,600^{d}	11.490^{e}	12.550^{c}	8.490^{d}	7.560^{c}	8.020^{d}	30.690^{bc}	27.330^{c}	2.900^{d}	1.693^{ab}	1,433^{a}	1,563^{a}
SEM	469.3	271.6	270.7	839.6	474.7	481.6	447.4	429.1	309.5	1,617.6	1,551.1	111.90	73.2	107.3	64.9
Year			0.01			0.01			0.16			0.01			0.01
Bean	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.10
Year×Bean			0.01			0.85			0.83			0.77			0.82

a-f Means with different superscripts within a column are significantly different ($p<0.05$).

58.47 to 69.20% DM and from 2.19 to 2.47 Mcal/kg, respectively, (Table 3) which are in agreement with the values reported in the literature (Anil et al., 2000). Lithourgidis et al. (2006) have reported that as ADF increases there is a decline in TDN which means that animals are not able to utilize the nutrients that are present in the forage. They also speculated that the lowest values for TDN in common vetch are attributable to the high amount of ADF and also to the high lignin content. *In vitro* DM digestibility of bean-corn silages seemed to be highly related to cell wall components of the bean-corn mixture. The highest digestibility values were observed for bean-corn mixtures with the lowest cell wall components. This finding is supported by the observation of Al-Masri (1998).

Effect on yields

Fresh bean, DM, digestible DM and ME yields decreased linearly with increasing percentages of bean in the mixtures (Table 4; $p<0.01$). Fresh bean yield increased linearly as percentage of bean increased in the mixtures; however, fresh bean yield of the sole bean crop was statistically less than that of the bean-corn mixture with a 50:50 seeding ratio. As percentage of bean increased in the mixtures, fresh bean and CP yields linearly increased but herbage DM, IVOMD and ME yields decreased ($p<0.05$). As plant density increased in the mixtures fresh bean yields also naturally increased. Corn provided a better standing for bean so that bean in the mixture got a higher light intensity for photosynthesis and opportunity for fertilization compared with the sole bean crop. This may cause greater fresh bean yield in the mixture compared with a sole crop (Tsubo and Walker, 2004). There was a more than 3 fold difference in DM yield between sole bean (3,930 kg/ha) and sole corn (12,790 kg/ha) herbage. Average herbage DM matter yield of the mixtures ranged from 8,020 to 10,990 kg/ha and a similar pattern was also observed for digestible DM and ME yields. These differences were caused by the linear decreases in DM, digestible DM and ME yields with increasing percentage of bean in the mixture. Ross et al. (2004) have reported that DM yields were lowest for intercrops with cereal densities of 30 plants m^{2} and exhibited linear or quadratic increases in response to increasing cereal density in the mixture. Qamar et al. (1999) have also noted that mixture rates affected the DDM and ME yields of vetch-barley mixtures. These results support the result of the current study. A similar pattern for CP yields was observed, but the magnitude of the difference was less compared with DM yield because the considerably higher CP content of bean compensated for the difference. All of the yields were significantly affected by year, being greater in the first year compared with the second year. These differences mainly resulted from utilizing the same land for the same crop for two consecutive years. It is well-established that plant rotation is necessary for optimal plant production (Drury and Tan, 1995; Temu and Aune, 1995; Adetunji, 1996).

Average crude protein yields were significantly higher for the mixtures compared with sole crops ($p<0.05$), but similar among the mixtures. Crude protein yield ranged from 1,010.0 to 1,563.0 kg/ha. The highest CP yield was observed with the mixture of bean–corn planted as a 50:50 seeding ratio, followed by the mixture of bean-corn planted as a 90:10 seeding ratio. Although, these bean-corn mixtures did not have the highest CP content among treatments, they gave the highest CP per ha of all crops because of either their higher forage yield or their higher CP content compared with the other treatments.

Effect on the LER

Average LER index, which provides an indication of maximum income from a given land, linearly increased with increasing percentage of bean in the mixtures (Table 5). The highest LER index (1.775) was obtained with a 50:50 seeding ratio, indicating strong evidence that these two

Table 5. Effects of intercropping corn with runner bean at differing rates on LER values

Item	Year I	Year II	Ave.
Corn (Sole)	1.00	1.00	1.00
Runner bean (Sole)	1.00	1.00	1.00
Corn 90%	1.69	1.26	1.475
Corn 80%	1.77	1.26	1.515
Corn 70%	1.69	1.35	1.52
Corn 60%	1.76	1.42	1.59
Corn 50%	1.77	1.78	1.775

crops can provide much higher income when intercropped together rather than when planted as sole crops (Çiftçi et al., 2006).

CONCLUSION

In conclusion, all of the bean-corn mixtures provided a good silage and better CP concentration. Even though forage yields decreased, the LER index linearly increased as the percentage of bean increased in the mixture up to a 50:50 seeding ratio, which indicates a greater utilization of land. Therefore in this study, 50:50 seemed to be the best seeding ratio for optimal utilization of land to provide greater financial stability for labor-intensive, small farmers.

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