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Intercropping maize *(Zea mays* L.*)* and cow pea *(Vigna unguiculata L.)* as a whole–crop forage: Effects of planting ratio and harvest time on forage yield and quality

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Abstract

Sole crops and intercrops of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) at eight planting ratios of maize:cowpea (100:100, 50:100, 100:50, 25:75, 75:25, 50:50, 0:100 and 100:0) and two harvest times (milky stage and doughty stage) were evaluated for quality characteristics of dry matter digestibility (DMD), crude protein (CP), neutral–detergent fiber (NDF), acid–detergent fiber (ADF) and water–soluble carbohydrate (WSC) concentrations and ash content. This experiment was carried during over two years (2007 and 2008) on Research Center, University of Zabol, Iran. Results indicated that optimum forage quality from milky stage was obtained. Maize and cowpea intercrops were higher in total forage dry matter digestibility (DMD) than maize or cowpea grown as sole crops. Cowpea intercropped with maize led to increased forage quality (CP and DMD concentration) compared with sole-maize, and higher WSC concentrations compared with sole cowpea. The highest crude protein content was obtained by harvest time in milky stage (15.2%). It is suggested that maize–cowpea intercrops may have considerable potential as a high quality.

Key words: Maize-cowpea, intercrop, harvest time, planting ratio, forage.

Introduction

Intercropping of legumes and cereals is an old practice in tropical agriculture that dates back to ancient civilization. The main objective of intercropping has been to maximize use of resources such as space, light and nutrients [26], as well as to improve forage quality and quantity [5, 18, 29, 30]. The current trend in global agriculture is to search for highly productive, sustainable and environmentally friendly cropping systems [11]. When two crops are planted together, inter specific competition or facilitation between plants may occur[39]. Intercropping is being advocated as a new and improved approach to farming. However, it has been avoided because of the complications of planting and harvesting. 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 [4]. Production of good quality fodder is of a great importance for the economical ruminant production. Both quality and quantity of fodder are influenced due to plant species [18, 21], stage of growth [18, 23] and agronomic practices [17, 31]. The growing of fodder crops in mixture with legumes enhanced fodder palatability and digestibility [8]. Intercropping of cereals and legumes produce higher grain yields than either sole crop [12, 30]. In such intercropping, the yield increases were due to improved resources of intercrops compared to sole crops [16]. Mixing of legumes in cereals is a better choice to increase the quality of forage. It has been reported that dry matter yields of maize sown as sole crops were greater than soybean intercropping. However, intercropping gave higher crude protein yields than maize as sole crop [22]. The highest dry matter yield was obtained when maize and soybean were intercropped in a ratio of 1:1. Mixing of legumes in cereals is a better choice to increase the quality of cereal fodders[22]. Lower yield of green fodder was harvested by growing cowpea alone as compared to pure stand of maize [28].

Intercropping offers to farmers the opportunity to engage nature's principle of diversity at their farms. Spatial arrangements of plants, planting rates and maturity dates must be considered when planning intercrops [19].Therefore, it is necessary value to carry out an experiment on green fodder yield and fodder quality of maize in relation to different planting ratio and harvest time. For obtaining a good fodder of improved quality, an accurate balance of legumes and non-legumes in a mixture is very essential. The objectives of the research reported here were: (i) to asses the potential of maize-cowpea intercrops to enhance forage yield and quality when compared with maize sole crops and (ii) to determine the effect to planting ratios and harvest time on forage yield and quality.

Materials and Methods

Site: The field experiment was carried out on the University of Zabol farm, Iran (61°41´E, 30°54´N, altitude 483 m above sea level). Average 30 years rainfall was 49 mm. The experiment was carried out during 2007 and 2008 growing season (Table 1) on a sandy-loam soil (Table 2).

All phosphorus (150 kg/ha) and potassium (100 kg/ha) and half

Table 1. Monthly average temperature, relative humidity and wind speed recorded at Zabol, Iran, during the 2007 and 2008 growing seasons.

	Temperature (°C)			Precipitation (mm)			Wind speed (m/s)		
Month	2007	2008	1980-2005	2007	2008	1980-2005	2007	2008	1980-2005
March	14.1	10.8	14.5	0.3	0.2	14.1	1.4	4.5	3.3
April	24.1	24.2	20.5	0	0	7.3	3.5	3.3	3.7
May	28.1	34.3	27.1	0	0	1.7	4.5	7.2	5.7
June	31.9	34.7	31.8	0.01	0	0.2	4.3	8.5	8.1
July	34.5	37.2	34.5	0.1	0	0	8.5	10.2	9.6

Table 2. Soil characteristics of the experiment area during the 2007 and 2008 growing seasons.

Year	Depth (cm)	pH	EC (mmohs/cm)	N(%)	P (ppm)	K (ppm)	Sand (%)	Silt (%)	Clay (%)
2007	0-20	8.0	7.8	0.053	7.8	190	63	20	17
2008	0-20	7.9	5.4	0.022	3.4	210	52	28	20

of nitrogen (50 kg/ha) were applied at sowing while rest of nitrogen was applied at stem elongation stage. All other cultural practices including irrigation, thinning and weeding were kept normal and uniform for all the treatments.

Experimental design and treatments: The treatments were compared in a factorial design with eight levels of planting ratios 100:100 (M:C), 50:100 (m:C), 100:50 (M:c), 50:50 (m:c), 75:25 (M':c'), 25:75 (m':C'), 0:100 (C) and 100:0 (M) and two levels of maturity stages (milky stage and doughy stage) in four replications. The treatments used for this experiment are summarized in Table 3. The treatment comprising the individual plot size was 7 m × 4 m. Maize variety Ksc 704 and cowpea variety cv29005 were sown in two years (2007-2008) by hand. For this experiment, the recommended density of maize and cowpea were used, sole crop densities being 20 and 8 plants m^{-2} for maize and bean, respectively. Inter-row spacing was 25 and 10 cm in the sole crops of maize and bean and with a between–row spacing of 50 cm. Initially 2-3 seeds were sown per hole. Twenty five days after sowing (25 March) seedlings were thinned to retain one healthy seedling per hole. Three hand weedings were done 20, 30 and 40 DAS. Quality parameters crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), water-soluble carbohydrate (WSC), dry matter digestibility (DMD) and ash were determined using NIR (Near Infra-red Spectrophotometer) Model 8600, Pertec Co.

Statistical analysis: The data on growth, yield and quality parameters were analyzed by Fisher's analysis of variance technique and Duncan test at 0.05 probability level to compare the treatment means [37]. Data analyses were conducted using of SAS [33] as a factorial experiment 8 × 2 with four replicates.

Table 3. The description of experiment treatments.

Factor A	Description
M	Sole maize (100% maize + 0% cowpea)
C	Sole cow pea (100% cowpea + 0% maize)
MC	Intercrop of maize 100% + cowpea 100%
Mc	Intercrop of maize 100% + cowpea 50%
mC	Intercrop of maize 50% + cowpea 100%
mc	Intercrop of maize 50% + cowpea 50 %
M´c´	Intercrop of maize 75% + cowpea 25%
m′C′	Intercrop of maize 25% + cowpea 75%
Factor B	
H_1	Harvest at milky stage
H_2	Harvest at doughy stage

Results

Experiment 1 (Spring 2007): Dry matter digestibility (DMD) was greatly ($p<0.01$) affected by harvest time. The mean DMD over milky stage (H_1) was 61.5%. The intercrop Mc (100% maize + 50% cowpea) produced the highest of DMD (62.5%) and the intercrop m´C´(maize 25% + cowpea 75%) produced the lowest DMD (Table 4).

Crude protein (CP) was greatly ($p<0.01$) affected by harvest time and planting ratios. The mean CP concentration of sole cowpea (19.6%) was considerably greater than that of sole maize (12.1%). The CP concentration averaged over all intercrop treatments was also greater than that of sole maize (Table 4).

Acid detergent fiber (ADF) concentration of forage declined ($p<0.01$) between H_1 and H_2. ADF concentration was significantly ($p<0.05$) affected by planting ratios, with that for sole cowpea being greater than that for sole maize.

Neutral detergent fiber (NDF) concentration showed a significant ($p<0.01$) effect by harvest time. NDF concentration decreased with harvest time, the highest NDF was at H_1 harvest time (Table 4). NDF concentration of the intercrops and sole crops were not significantly affected.

Water-soluble carbohydrate (WSC) concentration at H_2 was greater than at H_1. WSC concentration of sole maize was significantly ($p<0.01$) greater than that for sole bean and intercrops (Table 4). WSC concentration for all intercrops was greater than that for sole cowpea.

The mean ash concentration decreased ($p<0.01$) with harvest time. Ash concentration of intercrops and sole cowpea was higher ($p<0.01$) than that of sole maize, sole cowpea had higher ash concentration (10.1%) compared to other intercrops and sole maize (Table 4).

Green fodder yield (GFY) was greatly ($p<0.01$) affected by harvest time and planting ratios. The mean GF yield at H_2 (46.2 t/ha) was greater than at H_1 (21.6 t/ha). The GF yield was also affected by planting ratio, and the highest DF yield (46.7t/ha) was recorded for MC ratio (Table 4).

Dry fodder yield (DFY) was greatly ($p<0.01$) affected by harvest time and planting ratio. The mean DF yield at H_2 (9.3 t/ha) was greater than at H_1 (7.6 t/ha). The DF yield was also affected by planting ratio, and the highest DF yield (11.4 t/ha) was recorded for MC ratio (Table 4).

Experiment 2 (Spring 2008): Dry matter digestibility was significantly ($p<0.01$) affected by harvest time. The highest DMD was achieved at H_1 (70.6%) that was greater than at H_2. DMD was affected ($p<0.01$) by planting ratio. The intercrops Mc (100% maize + 50% cowpea) produced the highest DMD (70.9%), and the intercrop m´C´(maize 25% + cowpea 75%) produced the lowest DMD (Table 4). The DMD of the intercrop was between the sole maize and higher than that for sole cowpea (Table 4).

Crude protein (CP) concentration of forage was affected by harvest time. CP was greatly ($p<0.01$) affected by harvest time and planting ratio. CP concentration at H_1 (14.4%) was greater than at H_2 (Table 4). The mean CP concentration of sole cowpea (15.5%) was considerably greater than that of sole maize (12.2%). The CP concentration averaged over all intercrop treatments was also greater than that of sole maize (Table 4).

ADF concentration of forage decreased at late harvest time (Table 4). ADF concentration was significantly ($p<0.01$) affected by harvest time and planting ratio. The ADF concentration of sole cowpea was greater than that of sole maize and the intercrops. The comparison of intercropping ratios indicated that ratio maize 25% + cowpea 75% gave highest ADF concentration (Table 4).

The NDF concentration was significantly ($p<0.05$) affected by planting ratio and ($p<0.01$) harvest time. The highest NDF concentration of forage at H_1 (50.0%) and the highest NDF concentration was recorded at sole cowpea (49.7%). Planting ratio had a significant effect on NDF concentration, with NDF concentration of the intercrop being less than that of sole maize (Table 4).

WSC concentration was significantly ($p<0.01$) affected by both harvest time and planting ratio. WSC concentration of sole maize was significantly higher than that of sole cowpea and the intercrops. WSC at H_2 was greater than at H_1 (Table 4).

Ash concentration was significantly ($p<0.01$) affected by both harvest time and planting ratio. Ash concentration of the intercrop and sole maize was less than that of sole cowpea. Ash concentration at H_1 was greater than at H_2 (Table 4).

Green (GFY) was greatly ($p<0.01$) affected by harvest time and planting ratio. The mean GF yield at H_2 (37.3 t/ha) was greater than that of H_1 (17.6 t/ha). The GF yield was also affected by planting ratio, and the highest GF yield (38.1 t/ha) was recorded of MC ratio (Table 4).

Dry fodder yield (DFY) was greatly ($p<0.01$) affected by harvest time and planting ratios. The mean DF yield at H_2 (7.0 t/ha) was greater than that at H_1 (5.1 t/ha). The DF yield was also affected by planting ratio, and the highest DF yield (9.3 t/ha) was recorded of M (sole maize) ratio (Table 4).

Discussion

The results showed that an increased proportion of bean in intercrops increased the crude protein contents. These results are supported by some earlier researches [28]. Effect of legume intercrops on protein concentration of main crop has also been reported [5, 30]. The mean intercrop CP concentration, across H_1 and H_2, were 15.2 and 12.3% for Experiment 1 and 14.4 and 12.4% for Experiment 2. These were greater than in maize but less than in cowpea. Similar results have been obtained for maize [20]. Maximum crude protein (15.2%) was obtained in milky stage, and minimum crude protein (12.3%) was obtained in doughty stage. A decrease of CP content with maturity was also reported by other workers [18, 38]. Crude protein has previously been shown to decline with increasing maturity [34]. Armstrong *et al.* [2] reported that

Table 4. Means of green fodder yield and quality parameters as influenced by different planting ratios and harvest time of intercropping maize and bean based on Duncan Test.

Maize: cowpea planting ratio	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	DMD (%)	NDF (%)	ADF (%)	WSC (%)	Ash (%)	CP (%)
				2007				
100:100	46.7 a	11.4 a	60.26ab	55.55 a	27.11bc	18.15bc	7.25bc	13.22bc
100:50	40.0 bc	10.7 ab	62.52 a	54.25 a	25.89c	20.04ab	7.29b	13.04bc
50:100	23.6 d	7.6 d	57.84ab	57.95a	29.88ab	18.16bc	7.35b	13.62b
50:50	26.4 d	6.3 e	60.66ab	55.34a	26.33bc	20.58a	6.82c	12.23c
25:75	16.0e	3.6 f	56.30b	54.44a	31.04a	18.25bc	7.44b	13.94b
75:25	38.7 c	9.5 c	60.50ab	55.39a	26.87bc	20.46a	7.04bc	12.22c
100:0	41.9 b	10.8 ab	61.17ab	55.86a	26.53bc	20.69a	7.00bc	12.11c
0:100	37.9 c	10.3 bc	57.46b	54.46a	29.35abc	16.65c	10.10a	19.65a
Harvest time								
Milk stage	21.06 b	7.6 b	61.50a	57.09a	29.58a	18.42b	7.75a	15.20a
Doughty stage	46.2 a	9.3 a	57.67b	53.72b	26.17b	19.83a	7.32b	12.31b
S.E.	3008	831	4.35	4.40	3.43	1.75	0.40	1.14
CV(%)	8.85	9.76	7.31	7.95	12.3	9.2	5.38	8.33
				2008				
100:100	38.1a	8.4b	68.16 ab	47.28ab	18.97c	24.19abc	5.85cd	13.53b
100:50	34.6a	8.6ab	70.97a	44.10b	17.75c	26.20a	5.53d	12.48b
50:100	20.0c	5.2d	69.20ab	46.94ab	18.62c	25.30ab	5.96bc	12.75b
50:50	21.3c	4.9d	67.90ab	49.30a	19.07c	22.89bc	6.27b	13.21b
25:75	13.8d	2.2e	66.20b	49.60a	21.53b	22.41c	6.06bc	13.33b
75:25	30.8b	7.3c	70.45a	45.07ab	17.03c	25.92a	5.82cd	12.94b
100:0	37.7a	9.3a	69.35ab	43.95b	18.30c	26.21a	5.77cd	12.22b
0:100	23.1c	2.5e	56.35c	49.75a	32.23a	18.62d	9.83a	15.59a
Harvest time								
Milk stage	17.6b	5.1b	70.16a	50.09a	22.89a	22.12b	6.26a	14.14a
Doughty stage	37.3a	7.0a	64.48b	43.89b	17.98b	25.87a	6.11b	12.49b
S.E.	3373	684	3.22	4.03	2.10	2.52	0.35	1.08
CV(%)	12.2	10.75	4.79	8.58	10.27	10.51	5.58	8.18

Any two means not sharing a common letter differ significantly from each other at 5% probability.

intercropping climbing beans with corn increased neutral detergent fiber concentration and decreased digestibility compared to monoculture corn. Dawo *et al.* [13], reported that CP concentration increased 22% in the mixture when corn proportion in the mixture decreased by 50%. Our results are in agreement with studies where legumes also increased CP concentration when in mixture with corn [1, 13].

Quality measured indicated an advantage for cowpea, which exhibited lower NDF and higher CP content than maize. These results are in accordance with Boxton [6] and Caballero *et al.* [7], who stated that NDF and CP contents of legumes were usually less and greater, respectively, than those for cereals. For both Experiment 1 and 2, reduction in NDF and ADF concentration of forage from H_2 compared with H_1 can be attributed to increasing of grain to whole biomass ratio. Similar results have been reported by others working with sorghum-soybean [14] and maize [32]. Harvest time also affected significantly ADF; maximum ADF was recorded by milk stage. A decline in fiber concentration with increasing maturity can be attributed to the dilution effect created by the increasing content of grain as corn matures [10].

A reduction in WSC concentration with harvest time is in accordance with results of Kristensen [24] and Leaver and Hill [25]. For both experiments, WSC concentration increased in intercrops compared with that in sole cowpea, and agrees with Kristensen [24] for barley–bean compared with sole bean. The highest WSC was recorded for sole maize and sole crop of cowpea produced the lowest WSC and dry matter digestibility. These results agree with the findings of Kristensen [24] and Evans *et al.* [15]. In maize WSC content increased as crop matured from milk to doughty stage. An increase in WSC with increasing maturity can be attributed to the dilution effect created by the increasing content ratio of grain to fodder as corn matures [36]. Johnson and McClure [27] reported increased soluble carbohydrate in stalks from tasseling to the milk stage and a decline thereafter. Plots were established at the University of Wisconsin, with advancing maturity. Contreras-Govea *et al.* [9] reported that intercropping clover (*Trifolium ambiguum* M. Bieb.) with winter wheat (*Triticum aestivum* L.) for silage increased water-soluble carbohydrates compared with clover and CP concentration compared with monoculture winter wheat.

Decrease in ash concentration with maturity could result from dilution of minerals as crop mature and agree with Esmail *et al.* [14] and Ghanbari-Bonjar *et al.* [18]. Esmail *et al.* [14] reported that ash content of grain sorghum–soybean at early to mid growth stages (milky stage) was significantly greater than for sole sorghum. Also in our study the sole cowpea produced the lowest green fodder as well as dry matter. Similar results have been reported earlier [3]. Fresh biomass production in mixtures was higher than in sole crop cowpea due to the contributions by legumes in the mixtures. Some researchers reported that legume contribution to corn in mixtures was significant and increased the total biomass yields of mixtures [35].

Conclusions

This study clearly brought out the beneficial effects of maize-cowpea intercropping for forage yield and quality. Intercropping is more productive than sole cropping. Maize-cowpea intercropping increased green fodder yield and forage quality of maize. Therefore, this initial investigation shows that results of maize/climbing cowpea mixture were advantageous compared to both sole crops of maize and cowpea.

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