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Forage Quality of Cow Pea (*Vigna sinensis)* Intercropped with Corn (*Zea mays*) as Affected by Nutrient Uptake and Light Interception

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Abstract

An experiment was carried out in 2003 to investigate the effect of intercropping on light interception, nutrient uptake and forage quality of cow pea. A randomized complete block design (RCB) with three replications was employed to compare the treatments, including cow pea sole crop (Cp), corn sole crop (C), alternate-row intercropping (M_1), within-row intercropping (M_2) and mixed intercropping (M_3). The intercrop composition was based on replacement design, where one corn was replaced by three cow pea plants. The results indicated that PAR (photosyntheticaly active radiation) interception and nutrient uptake were improved by intercropping. Cow pea was more competitive than corn in absorbing divalent cations (Ca and Mg) for its high root cation exchange capacity. However, corn was more competitive than cow pea for phosphorus and potassium. Forage quality of cow pea in terms of crude protein was decreased in intercropping compared to its sole crop. It was related to reduction of biological nitrogen fixation induced by low PAR and phosphorus availability for cow pea in intercropping.

Keywords: competitive ratio, crude protein, intercropping, resource consumption

Introduction

Although cereals are widespread used in livestock nutrition for their high dry matter production and low cost (Ghanbari-Bonjar, 2000), they have low nutrition value due to their poor protein content. High quality of forage has been noticified as an important aspect of forage crop production. Thus, legume-cereal composition is considered as a management strategy in producing both high quality and quantity forage. Legumes, which are good source of protein, intercropped with cereals to compensate their protein shortage (Gebrehiwot *et al*., 1996). Cow pea (*Vigna sinensis*), which is also used for farm animal nutrition, can improved the forage quality in intercropping with corn (*Zea mays*), because of low protein content of corn (less than 100 $g.kg^{-1}$ dry matter) (Anil *et al*., 1998). It has been reported that legume-cereal intercropping increased forage quality. In this connection, Murphy *et al* (1984) concluded that corn-soybean intercropping produced more digestible dry matter compared to corn sole crop. Droushiotis (1998) showed that forage quality in terms of crude protein was improved by vetch-oat intercropping. According to Chellaiah and Ernest (1994) growing of corn in mixture with soybean produced more crude protein than its sole crop.

Physiological and morphological differences between intercrop components affect their ability of using environmental resources, especially light and nutrients. For example, atmospheric nitrogen fixation by legumes can reduce the competition for nitrogen in legume-cereal intercropping system, allowing the cereals to use more soil nitrogen. This can affect forage quality of intercrop components, because protein content is directly related to nitrogen content of forage (Putnam *et al*., 1985).

Since the quality of forage produced in intercropping is mostly depended on legumes quality, this research was aimed to evaluate the variation of cow pea forage quality under different cropping system.

Materials and methods

The experiment was carried out during the year 2003 on a field in Ramhormoz, Iran (46º 36′ N, 31º 16′ E, altitude 150 m a.s.l). The soil texture of experimental site was silt loam. The research filed is located in a semi-arid region, where the summer is hot and dry and winter is cool and rainy.

Five treatments (Cp: sole cow pea, C: sole corn, M_1: alternate-row intercrop, M_2: within-row intercrop and M_3: mixed intercrop) were compared in a complete randomized block design (RCB) in three replications, giving a total of 15 plots. Each plot was 15 m^2 consist of six rows of 5m long. The rows located 50cm apart. All plots were fertilized with the same amount of fertilizer. The fertilizers containing 70 kg of N ha^{-1}, 70 kg of P_2O_5 ha^{-1} and 70 kg of K_2O were broadcasted before sowing. Corn and cow pea seeds were simultaneously sown in July 26, 2003. The seeds were sown at high density to ensure adequate emergence. After seedling establishment, the plots of corn and cow pea sole crop were thinned to 6.7 and 20 plants/m^2, respectively. The intercrop composition was based on the replacement design (Snaydon 1991), where one corn was replaced by three cow pea plants. Total population of intercrop components was half of their sole crops. Photosyntheticaly active radiation (PAR) was measured two times during the growing season (55 and 70 days after sowing) between 12-14 hours on occasions. A Sun fleck ceptometer (model SF-80T) was used to measure above the plant canopy and the soil surface at 5 randomly selected locations within each plot. Mean values for each plot were then used to calculate the percentage of PAR intercepted by the plant canopy.

At harvest time, above plant parts were harvested by hand cutting the plant 2cm above the soil surface from a 1m^2 quadrat. After the harvest, intercrops were separated into corn and cow pea. Crude protein (CP) was used to determine cow pea forage quality which measured by Kjeldhal's method (N×6.25). Nutrients uptake were determined by measuring the Ca, Mg, K and P amount of corn and cow pea tissues using atomic absorption spectrophotometer (model AA100).

The competitive ability of cow pea for nutrients to corn was evaluated by calculating the competitive ratio of cow pea with respect to corn (RC_{cp}) or competitive ratio of corn with respect to cow pea (RC_c) (Willey 1979):

$$CR_{cp} = (Y_{ab} / Y_{aa} \div Y_{ba} / Y_{bb)} \times Z_{ab} / Z_{ba}$$

In which:

CR_{cp}: competitive ratio of cow pea with respect to corn

Y_{ab}: Nutrient uptake by cow pea in intercropping

Y_{aa}: nutrient uptake by cow pea in sole crop

Y_{ba}: nutrient uptake by corn in intercropping

Y_{bb}: nutrient uptake by corn in sole crop

Z_{ab}: part of intercropping allocated to cow pea

Z_{ba}: part of intercropping allocated to corn

Since the CR values of the two crops will in fact the reciprocal of each other, it will often be sufficient to consider the values of only one (Willey 1990). This ratio value gives the exact degree of competition, by indicating the number of times in which the dominant species is more competitive than the recessive species.

The analysis of variance of the data and the comparison of means on the basis of the least significant difference (LSD) were carried out, using MSTATC software.

Results and discussions

Percentage of PAR interception was significantly (P≤ 0/05) affected by cropping system over sampling dates (Tab. 1). At 55 days after sowing (DAS) the percentage of PAR interception by sole cropped cow pea and intercrops plants were not significantly different, with the lowest PAR reception being recorded by sole cropped corn (Tab. 2). At 70 DAS, the percentage of PAR interception by intercrops treatments were significantly (P≤ 0/05) greater than either sole crop. PAR interception by sole cropped cow pea was significantly greater than that of sole cropped corn at 70 DAS (Tab. 2).

Nutrition (Ca, Mg, K and P) uptake were significantly (P≤ 0/05) affected by cropping system (Tab. 1). Ca and Mg uptake by intercrops was significantly greater than that of sole cow pea and corn (Tab. 2). There was no significant difference between intercrops for Ca and Mg uptake. Sole cow pea showed greater Ca and Mg uptake than sole corn. Intercrops and sole corn treatments absorbed more K and P than cow pea sole cropped. While there was no significant difference between intercrops and cow pea sole crop for K uptake, they showed significant difference for P uptake (Tab. 2).

The competitive ratio of cow pea with respect to corn (CR_{cp}) for Ca and Mg was significantly (P≤ 0/05) greater than 1.0 (Tab. 3). The mean CR_{cp} for Ca and Mg averaged over three intercrops for Ca and Mg was 1.5 and 1.3 respectively, indicating that concerning Ca and Mg uptake cow pea was 1.5 and 1.3 times more competitive than corn (Tab. 3). The competitive ability of corn with respect to cow pea (CR_c) for K and P was significantly (P≤ 0/05) greater than 1.0 which was 1.2 and 1.4 averaged over three intercrops, indicating that corn was 1.2 and 1.4 times more competitive than cow pea in terms of K and P uptake, respectively (Tab. 3).

The forage quality of cow pea in terms of crude protein content (g.kg^{-1} dry matter) was significantly P≤ 0.05 affected by cropping systems, where cow pea sole crop had higher crude protein content than intercropped cow pea. Thus, the forage quality of cow pea was decreased by intercropping. There was no significant difference between intercrops for cow pea crude protein content.

Tab. 1. Degree of freedom and mean squares for light interception and nutrient uptake of five cropping system

Source of variance	df	PAR interception (%)		Nutrient uptake (kg.ha^{-1})			
		55DAS	70 DAS		Ca	Mg	K	P
Replication	2	16.67	0.55	5.74	1.1	13.95	20.21
Cropping system	4	644.75*	711.03*	1360.2*	1628.83*	428.6*	816.85*
Error	8	2.39	15	1	29.27	65.91	65.91
CV (%)		2.61	4.45	2.27	6.52	17.46	9.254

* indicates significance at P≤ 0.05 DAS: days after sowing

Tab. 2. Effect of different cropping system on PAR interception (%) and nutrient uptake (kg.ha^{-1})

Cropping system	PAR interception		Nutrient uptake			
	55 DAS	70 DAS	Ca	Mg	K	P
C_P	63.8a	71.3b	24.4b	83.85b	24.59b	56.58c
M_1	69.4a	98.2a	59.5a	95.1a	50.65a	96.76a
M_2	66.4a	97.5a	65.2a	98.7a	51.48a	97.31a
M_3	64.2a	97.1a	58.6a	96.01a	56.7a	99.85a
C	32.3b	62.1c	12.2c	41.2c	49.14a	88.66b

Different letters indicating significance at P≤ 0.05
Cp: sole cow pea M1: alternate-row intercrop M2: within row intercrop M3: mixed intercrop

Tab. 3. Effect of different cropping system on intercrop competition for nutrients.

Cropping system	M_1	M_2	M_3	Mean	LAD at 5 %
CR_{cp} for Mg	1.6	1.6	1.3	1.5	0.2
CR_{cp} for Ca	1.3	1.3	1.3	1.3	ns
CR_c for K	1.3	1.1	1.2	1.2	ns
CR_c for P	1.2	1.6	1.4	1.4	0.3

CR_{cp}: competitive ability of cow pea with respect to corn
CR_c: competitive ability of corn with respect to cow pea
M_1: alternate-row intercrop M_2: within-row intercrop M_3: mixed intercrop

Tab. 4. Degree of freedom and mean squares for cow pea crude protein (g.kg^{-1} dry matter)

Source of variance	df	Crude protein
Replication	2	5.53
Cropping system	3	266.75*
Error	6	1.58
CV (%)		1.06

* indicates significance at P≤ 0.05

Because of differences in their arrangement of foliage and canopy architecture, corn and cow pea can differ in PAR interception and can, therefore, intercept more PAR compared to sole crops. In other words, solar radiation which would be wasted due to poor growth of corn early in the season and cow pea leaf senescence at the end of the season can be utilized more efficiently by cow pea-corn intercropping. So as concluded by Watiki *et al* (1993) and Chand (1997), intercropping leads to an increase in the total amount of PAR.

Tab. 5. Effect of cropping system on cow pea crude protein (g.kg^{-1})

Cropping system	Crude protein
C_P	131.8a
M_1	112.8b
M_2	116.6b
M_3	111.2b

Different letters indicating significance at P≤ 0.05
Cp: sole corn M_1: alternate-row intercrop M_2: within-row intercrop M_3: mixed intercrop

There is an increasing requirement that nutrient uptake and utilization by crop plants should be as efficient as possible. Greater nutrient uptake is usually presumed to be possible, because of some complementary exploration of the soil profile by intercrop components (Ahlawat *et al*., 1985) of fuller use of resources over time (Willey, 1990). In some instances greater uptake might be due to the use of nutrients unavailable to sole crops (Willey, 1990). High total nutrient uptake in intercropping has been reported (Bulson *et al.* 1997; Choudhury and Rosario, 1997).

Cow pea was more competitive than corn for Ca and Mg. The roots of legumes generally have a root cation exchange capacity (CEC) about twice that of cereal roots

(Ghanbari-Bonjar, 2000). A plant root surface having a high CEC might absorb relatively more divalent cations, such as Ca and Mg, than a plant root from cereal with a low root CEC (Haynes, 1980; Caradus, 1990). However, corn was more competitive than cow pea for P and K absorption. This was a line with expectation, since legumes are known to be poor competitors for P and K when intercropped with cereals, because of their root morphology and cation exchange capacity of root surface (Choudhury and Rosario 1997).

Photosynthetically active radiation and phosphorus are essential factors for legumes to fix atmospheric nitrogen (Keating and Carbery, 1993). Thus, decreasing that availability of these environmental resources results in reduction of biological nitrogen fixation. Corn is more competitive than cow pea for phosphorus (Tab. 3), so phosphorus supply for cow pea in intercropping was less than its sole crop. Furthermore, in intercropping the taller corn was able to compete with the shorter cow pea for light, because cow pea plants were shaded by corn canopy. In the other words, light interception by cow pea in intercropping was reduced compared to sole crop, resulted in decreasing of fixed nitrogen assimilation in nodules. Since biological fixation is the main source for cow pea to cover its nitrogen requirement (Jenson, 1996; Keating *et al*., 1995), reducing light and phosphorus supply for cowpea in intercropping resulted in decreasing its nitrogen and, therefore, crude protein content. Thus, the forage quality of cow pea was decreased in intercropping compared to its sole crop.

Conclusion

In general, it can be concluded that forage quality of cow pea in intercropping is positively related with the availability of environmental resources especially light and nutrients, where reduction of PAR and phosphorus supply resulted in decreasing of forage quality of intercropped cow pea induced by less biological nitrogen fixation in intercropping compared to sole crop.

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