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Full Length Research Paper

The role of intercropping maize (*Zea mays* L.) and Cowpea (*Vigna unguiculata* L.) on yield and soil chemical properties

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Farmers in Sistan region experience low crop yields of crops due to low soil fertility. Sole crops and intercrops of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) were studied 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 doughy stage). This experiment was carried during two years (2007 and 2008) on Research Center, University of Zabol, Iran, to investigate the influence of cowpea on the soil fertility and sole maize (SM) as control. Measurements of nitrogen, phosphorous, potassium soil and crop yield were carried out to study the effects of intercropping on crop yield in a cowpea-maize intercropping system in Sistan at southeast of Iran. We found that intercropping increased the amount nitrogen (N), phosphorous (P) and potassium (K) contents compared to sole crop of maize. The highest amount of N, P, and K in soil was obtained at sole cowpea and 100% cowpea + 100% maize with no significant difference to 100% cowpea + 50% maize. The lowest amount of N, P, and K was obtained at sole maize and 75% maize + 25% cowpea. Intercropping system had significant effects on soil fertility and crop yield. LER (land equivalent ratio) values were greater in all intercropping systems with different planting ratios which indicated yield advantage of intercropping over sole cropping of maize. Results indicate that intercropping can increase nutrient elements of soil compared to sole maize and improve conservation of soil fertility. Based on high grain and improve soil fertility intercrop productivity compared to sole crop could be selected for improving the productivity of maize/cowpea mixture in the Southeast of Iran.

Key words*:* Intercropping system, maize - cowpea, soil fertility, land equivalent ratio.

INTRODUCTION

Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources (Tsubo et al., 2005). Yields of Intercropping are often higher than in sole cropping systems (Lithourgidis et al., 2006). The reasons are mainly that resources such as water, light and nutrients can be utilized more effectively than in the respective sole cropping systems (Li et al., 2006). Intercropping of cereal and legume crops helps maintain and improve soil fertility. Legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be excreted from the nodules into the soil and be used by other plants growing nearby (Andrew, 1979). Legumes can transfer fixed N to intercropped cereals during their joint growing period and this N is an important resource for the cereals (Shen and Chu, 2004). Soil mineral N contents are often higher after grain legumes than after cereals (Chalk, 1998). Nair et al. (1979) observed that when wheat was planted after maize + cowpeas, maize + soybeans and maize + groundnuts, the yields were increased by 34, 27 and 19%, respectively. Crops such as cowpea, mung bean, soybeans and groundnuts commonly accumulate 80 - 250 kg N ha^{-1} (Norman, 1996). Studies have indicated

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Abbreviation: LER, Land equivalent ratio.

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

Month	Temperature (°C)			Precipitation (mm)			Wind speed (m/s)		
	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

that legumes accumulated greater amounts of soil microbial C in the soil than cereals (Walker et al., 2003). Phosphates enzymes in the soil serve several important functions, and are good indicators of soil fertility (Dick et al., 2000). Under conditions of P deficiency, an acid phosphate secreted from roots is increased (Hayes et al., 1999; Li et al., 1997).

The amount of acid phosphates secreted by plants is genetically controlled, and differs with crop species and varieties (Izaguirre-Mayoral and Carballo, 2002). Some studies have shown that the amount of enzymes secreted by legumes were 72% higher than those from cereals (Yadav and Tarafdar, 2001). Li et al. (2004) found that, chickpea roots were also able to secrete greater amounts of acid phosphates than maize.

The activity of acid phosphates is expected to be higher in biologically managed systems because of higher quantity of organic C found in those systems. Intercropping legumes, especially maize with cowpea in the arid regions of southeastern Iran is gaining increased attention because cowpea fixes atmospheric nitrogen and produces proteins, while maize depletes the soil nitrogen and produces carbohydrates. Maize and cowpea mixtures improve the diets as well as the soil fertility and productivity. The objectives of the present study were (i) to estimate the effect of maize-cowpea intercropping systems on soil fertility (ii) to evaluate the systems for higher yields.

MATERIALS AND METHODS

Site

A factorial field experiment at randomized complete block design with four replications was carried out over two cropping seasons (2007 and 2008) on Research Center of University of Zabol, Iran (61° 41'E, 30° 54'N, altitude 483 m above sea level). Average of 30 years rainfall was 49 mm (Table 1).

Crop management

Maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) were planted in an intercropping arrangement with 8 and 20 (plants.m^{-2}), respectively. Planting dates for the cropping seasons 2007 and 2008 were March 5. The experiment was carried out during 2007 and 2008 growing season on a sandy loam soil (Table 2a).half of nitrogen (50 $kg.ha^{-1}$) 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. The treatment comprising the individual plot size was 7 × 4 m. Maize variety K.s.c 704 and cowpea variety cv29005 were sown on two years (2007 - 2008) by hand. Inter-row spacing was 25 and 10 cm in the sole crop of maize and cowpea with a between row spacing of 50 cm. Initially 2 - 3 seeds were sown per hole. Twenty five days after sowing, seedlings were thinned to retain one healthy seedling per hole. Three hand weeding were done 20, 30 and 40 DAP (day after planting).

Experimental design

The treatments were compared in a factorial experiment at RCBD design with eight levels of planting ratios of cowpea and maize at, 100:100 (M_1), 50:100 (M_2), 50:50 (M_3), 100:50 (M_4), 75:25 (M_5), 25:75 (M_6), 0: 100 (M_7) and 100:0 (M_8), and two levels of maturity stages (milky stage and doughy stage) in four replication.

Statistical analyses

The data on growth, yield and other parameters were analyzed by Fisher's analysis of variance technique and Duncan test at 0.05 probability levels to compare the treatment means (Steel and Torrie, 1984). Data analyses were conducted using SAS as a factorial experiment 8 × 2 with four replicates.

Mineral nutrient analysis

Nitrogen was determined by Kjeldahl procedure. Potassium was measured by flame photometer (Corning 405). Phosphorus was determined spectrophotometrically (Olsen methods U.V).

Calculation of land equivalent ratios (LER)

The LER was calculated as:

LER = (Yiw/Ysw) + (Yic/Ysc),

Where Yim and Ysm are the yields of intercropped and monocrop maize, and Yic and Ysc are the yield intercropped and monocrop cowpea, respectively. Where LER was more than 1.0, this indicates a positive intercropping advantage which shows that interspecific facilitation is higher than interspecific competition (Vandermeer, 1989).

Table 2a. Effect of harvest time and cropping system on total dry matter yield ($t.ha^{-1}$) during the 2007 growing season.

Harvest time	1 M	2 M	3 M	4 M	5 M	6 M	7 M	8 M	Mean
Milky stage	a89.28	b25.22	d12.15	b92.21	e27.13	c00.20	d56.14	f30.9	b16.18
Doughty stage	a14.32	c54.24	d67.20	b86.31	e15.18	c89.23	f28.16	g62.11	a39.22
Mean	51a.30	c39.23	e89.17	b89.26	f71.15	d94.21	f42.15	g46.10	27.20

1 M:100% maize + 100% cowpea2 ‹M: 100% maize + 50% cowpea3 ‹M: 50% maize + 50% cowpea4 ‹M: 50% maize + 100% cowpea5 ‹ M: 25% maize + 75% cowpea6 ‹:M 75% maize + 25% cowpea7 ‹M: sole maize8 ‹:M sole cowpea.

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

Year	Depth of soil (cm)	PH	Ec (mmohs/cm)	N (%)	P (ppm)	K (ppm)	Sand	Silt	Clay
2007	0 -20	8	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

Table 3. Effect of harvest time and cropping system on total dry matter yield ($t.ha^{-1}$) during the 2008 growing season.

	Cropping system								
Harvest time	1 M	2 M	3 M	4 M	5 M	6 M	7 M	8 M	Mean
Milky stage	a39.21	b36.19	e33.15	c26.17	d43.16	d32.16	e32.15	f22.11	b57.16
Doughty stage	a86.24	a33.24	d40.19	c57.21	e22.18	b71.22	e01.18	f78.13	a36.20
Mean	a12.23	b84.21	d36.17	c41.19	d36.17	c52.19	d66.16	e50.12	46.18

1M:100 % maize + 100 % cowpea2 ‹M: 100 % maize + 50 % cowpea3 ‹M: 50 % maize + 50 % cowpea4 ‹M: 50 % maize + 100 % cowpea5 ‹M: 25% maize + 75 % cowpea6 ‹:M 75 % maize + 25 % cowpea7 ‹M: sole maize8 ‹:M sole cowpea.

RESULTS AND DISCUSSION

Total dry matter yield

Harvest time was highly significant ($P < 0.01$) for total dry matter yield (Tables 2b and 3). The forage yield average over eight cropping systems ranged from 18.16 to 22.39 $t.ha^{-1}$ in 2007 and from 16.57 to 20.36 $t.ha^{-1}$ in 2008. The highest dry matter yield average over cropping system was achieved at the doughty stage, which were 23% greater than milky stage in 2007 and 22% in 2008. Dry matter yield was significantly ($P < 0.01$) affected by cropping system. The highest dry matter yield was obtained with M_1 and the lowest with M_8. Forage yield produced by M_1 was 97 and 191% greater than that for sole maize and sole cowpea in first year and greater than that for sole maize and sole cowpea in second year 38 and 84%.

Data presented in Table 2b and 3 demonstrate a highly significant harvest time × cropping system interaction effect on dry matter yield. The maximum dry matter yield during 2007 (32.14 $t.ha^{-1}$) and during 2008 (23.12 $t.ha^{-1}$) were produced by M_1 at Doughty stage. Therefore it can be concluded that M_1 produced significantly greater forage yields than sole crop treatments at two dates of harvesting.

Land equivalent ratio

The mean LER values were always greater than 1.0 (Tables 4 and 5). So intercropping showed an advantage over sole cropping. LER values significantly increased up to M_1 and therefore showed different between M_1 and other treatment at two years. LER ranging from 2.31 to 1.32 in first year and from 2.57 to 1.07 in second years indicated that there were a 131 to 32% in first year and 157 to 7% at second year greater yield advantage over component sole crops.

Nitrogen, phosphorous and potassium concentration in soil

There was significant ($P < 0.01$) effect of cropping system on nitrogen, potassium and phosphorus content of soil. The nitrogen content of soil increased as the intercrop to high ratio of cowpea. The nitrogen content of soil with an application of M1 (100% maize + 100%) was significantly greater than those other treatments (Table 6). With used of cropping system the nitrogen, phosphorus and potassium content of soil following M_8 was significantly higher than that of other cropping systems (Tables 5a and 6). The lowest of N, P and K was obtained at sole

Table 4. Effect of cropping system on land equivalent ratio of maize, cowpea and total land equivalent ratio during the 2007 growing season.

	1 M	2 M	3 M	4 M	5 M	6 M	Compared to 1.0	S. E
LER (maize)	28.1	26.1	70.0	79.0	38.0	02.1	-	051.0
LER (cowpea)	03.1	41.0	67.0	42.1	94.0	34.0	-	057.0
LER Total	a31.2	c67.1	cd37.1	b21.2	d32.1	d36.1	e1	062.0

1 M:100% maize + 100% cowpea2 ،M: 100% maize + 50% cowpea3 ،M: 50% maize + 50% cowpea4 ،M: 50% maize + 100% cowpea ، 5M: 25% maize + 75% cowpea6 ،:M 75% maize + 25% cowpea،

Table 5a. Effect of cropping system on land equivalent ratio of maize, cowpea and total land equivalent ratio during the 2008 growing season.

	1 M	2 M	3 M	4 M	5 M	6 M	Compared to 1.0	S. E
LER(maize)	90.0	94.0	53.0	57.0	23.0	77.0	-	038.0
LER (cowpea)	67.1	62.0	61.0	46.1	29.1	29.0	-	095.0
LER Total	a57.2	c57.1	d15.1	b04.2	c52.1	de07.1	e1	101.0

1 M:100% maize + 100% cowpea 2 ،M: 100% maize + 50% cowpea3 ، M: 50% maize + 50% cowpea4 ، M: 50% maize + 100% cowpea5 ، M: 25% maize + 75% cowpea6 ، :M 75% maize + 25% cowpea،

Table 5b. Effect of cropping system on nutrient element of soil during the 2007 growing season.

Nutrient element	1 M	2 M	3 M	4 M	5 M	6 M	7 M	8 M	S.E
(%)Nitrogen	b066.0	def052.0	cde055.0	c058.0	cd056.0	ef051.0	g025.0	a072.0	0048.0
(ppm) Phosphorus	b8.9	ef38.5	de46.6	c61.8	d05.7	fg46.4	g98.3	a11.14	177.1
(ppm) Potassium	a96.254	d54.160	d7.176	b49.215	c79.191	e37.137	f05.112	a83.268	35.19

1 M:100% maize + 100% cowpea2 ،M: 100% maize + 50% cowpea3 ، M: 50% maize + 50% cowpea4 ،M: 50% maize + 100% cowpea5 ، M: 25% maize + 75% cowpea6 ، :M 75% maize + 25% cowpea7 ، M: sole maize8 ،:M sole cowpea.

Table 6. Effect of cropping system on nutrient element of soil during the 2008 growing season.

Nutrient element	1 M	2 M	3 M	4 M	5 M	6 M	7 M	8 M	S.E
Nitrogen (%)	ab036.0	c022.0	bc027.0	abc031.0	abc029.0	e010.0	d011.0	a037.0	01.0
Phosphorus (ppm)	b9.42	def6.23	cde7.26	bc8.31	cd1.28	ef1.21	f6.18	a2.67	61.5
Potassium (ppm)	b4.270	e7.177	de7.191	c5.223	d0.203	e2.184	f5.146	a0.292	2.17

1 M:100 % maize + 100% cowpea2 ،M: 100% maize + 50% cowpea3 ،M: 50% maize + 50% cowpea4 ،M: 50% maize + 100% cowpea5 ،M: 25% maize + 75% cowpea6 ،:M 75% maize + 25% cowpea7 ،M: sole maize8 ،:M sole cowpea.

maize. Nitrogen, phosphorus and potassium content following sole maize was significantly less than that following sole cowpea and intercrops. Intercrops treatment have N, P and K content between sole maize and sole cowpea. At the between intercrop treatment, M_1 was significantly higher than that treatments during the 2007 and 2008 growing seasons. High cowpea percentage in intercrop was caused increased N, P and K content in soil. The ability of grain legumes or cereal - legume intercrops compared to cereal to maintain or increase the soil Nitrogen supply for a following cereal crop has been reported by other researchers (Ghanbari and Lee, 2003; Armstrong et al., 1997). Increased growth and increased of LER in intercropping to compare with sole cropping is possible to cause of the competition of maize roots, part of P to be taken up by the intercropped maize. This result also indicated that cowpea could facilitate phosphorus nutrition in associated Maize. However, the mechanism of the facilitation was unknown. In the present study, it is possible that cowpea root was able to secret greater amounts of acid phosphates in soil than maize. Hayes et al. (1999) showed that under conditions of P deficiency, acid phosphates secreted from roots is increased. To increase cowpea ratio in intercropping amount of P was increased.

DISCUSSION

Total dry matter yield was increased by harvest time, with the largest differences recorded between milky stage and doughty stage. A relatively higher forage yield with later compared to earlier harvest time has been reported by several workers who have been working with wheat (Ghanbari and lee, 2003; forozmand et al., 2005). The mean dry matter yield averaged over harvest times by different maize - cowpea intercrops was significantly greater than comparable sole crops. In the present experiment one possible explanation is the ability of the component crop to exploit different soil layer without competing with each other (willey, 1979).

There was probably better use of resource such as (i) light as stated by (Gustavo et al., 2008), (ii) nutrients (willey, 1990) and water (willey, 1990). A similar result from cereal - legume intercrops has been reported by other researchers (Ghanbari and lee, 2003) who reported that intercrop forage yields were greater than either species alone. Land utilization efficiency of intercrops measured by LER values at all intercrops were higher 1.0. Therefore this showed that land utilization efficiency for maize- cowpea intercropping was more advantageous than for sole cropping. A LER greater than 1.0 has been reported with bean maize intercropping (Saban et al., 2007) and wheat - lentil (Carr et al., 1995). Nitrogen, phosphorus and potassium content of soil following intercrops were improved compared to following sole maize. The ability of grain legumes or cereal – legume intercrops compared to cereal to maintain or increase the soil Nitrogen supply for a following cereal crop has been reported by other researchers (Ghanbari and Lee, 2003; Armstrong et al., 1997).

Conclusion

Results from this research with maize and cowpea suggest that the optimum harvest times to achieve maximum forage yield under the conditions of this experiment could be doughty stage. Maize - cowpea intercrops produced greater dry matter yield than either species grown alone. The most productive intercrop concerning yield was for a high density of maize and high density of cowpea (100% maize + 100% cowpea). Intercropping maize with cowpea showed advantages in land use efficiency expressed as LER, when compared with the optimum density of either sole crop. Probably the greater LER of the intercrops was mainly due to a greater resource use and resource complementarily than when the species were grown together. Inclusion of cowpea in sole or intercrop systems might make extra soil N, P and K available to the following cereal crops such as maize because annual legumes contribute N though biological N fixation and was prepared suitable condition of soil for P and K available. Like the soils with low fertility in these ecological conditions, enough forage yields with high soil fertility were obtained from 100% maize + 100% cowpea intercrop and harvested in doughty stage.

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