J. Basic. Appl. Sci. Res., 2(1)355-360, 2012
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Intercropping of Maize (*Zea mays*) with Cowpea (*Vigna Sinensis*) and Mungbean (*Vigna radiata*): Effect of Complementarity of Intercrop Components on Resource Consumption, Dry matter Production and Legumes Forage Quality

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ABSTRACT

maize and two legumes (cowpea and mungbean) sole crops and their mixture in (M_1: within row intercrop of maize and cowpea in replacement design; M_2: within row intercrop of maize and mungbean in replacement design; M_3: row intercrop of maize and cowpea in additive design; M_4: row intercrop of maize and mungbean in additive design) were used to investigate the amount of resource consumption (in terms of PAR interception, water and nutrient uptake) and legumes forage quality. The experiment was carried out as randomized complete block design with four replications. The results showed that intercropping systems had a significant effect on environmental resources consumption, where intercropping systems had more light interception and water and nutrient uptake and compared to sole crops, suggesting the complimentarily effect of intercropping components in resources consumption. Total dry matter production was improved by intercropping systems resulted from more environmental resource consumption. Forage quality of cow pea and mungbean in terms of crude protein was decreased in intercropping compared to their sole crops. It was related to reduction of biological nitrogen fixation induced by low PAR and phosphorus availability for legumes in intercropping.

KEY WORDS: crude protein, forage, intercropping, photosynthetically active radiation (PAR).

INTRODUCTION

It is generally understood that the combinations of a legume and cereal are most common among farmers in the semi-arid tropics and would benefit them in resource limiting condition, compared with corresponding sole crops. Yield advantages have been recorded in many legume-cereal intercropping systems, including soybean-sorghum [11], cowpea-maize [8], fababean-wheat [10]. The reason of yield advantage of intercropping are mainly that environmental resources such as water, light and nutrients can be utilized more efficiently in intercropping than in the respective sole cropping systems [17]. The underlying principle of better environmental resource use in intercropping is that if crops differ in the way they utilize resources when grown together, they can complement each other and make better combined use of resources than they grown separately [19]. In the other word, 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 [10]

Growth and yield of component crops in intercropping are depended on environmental resources availability. When other resources (e.g. water and nutrients) are not severely limiting crop growth, solar radiation is a major resource determining productivity of intercropping systems. According to [19] concluded that spatial complementarity of resources use in intercropping occurs because of architectural differences in canopy. It was stated that [18] (1993) in maize-cowpea intercrops an increase of radiation interception by the intercrops caused an increase in dry weight. There is an increasing requirement that environmental resource consumption by crop plants should be as efficient as possible. Additionally, studies have shown greater uptake where intercropping has produced a yield advantage [5, 8].

High quality of forage has been notified 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 [9]. Cow pea (*Vigna sinensis*) and mungbean (*Vigna radiata*) which are also used for farm animal nutrition, can improved the forage quality in intercropping with maize (*Zea mays*), because of low protein content of maize (less than 100 $g.kg^{-1}$ dry matter) [2]. Since the quality of forage produced in intercropping is mostly depended on legumes quality, this research was

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aimed to evaluate the effect of intercropping on resource consumption by intercrop components and its relation with dry matter production and, also, forage quality of cowpea and mungbean.

MATERIALS AND METHODS

The field experiment was conducted at a Research farm in Ramhormoz, Iran (46º 36´ N, 31º 16´ E, altitude 150 m a.s.l) in 2009-2010 growing seasons. Soil texture was silt loam with pH 7.42 and 0.66% organic matter as showed in Table 1.

Table 1: Physical and chemical characteristics of the soil of experimental field.

Depth (cm)	pH	N ($mg.kg^{-1}$)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	Ca ($mg.kg^{-1}$)	Mg ($mg.kg^{-1}$)	Texture	Organic matter (%)
0-60	8.0	2.06	40.16	175.16	3153.15	61.4	Silt loam	0.66

Seven treatments (maize, cowpea and mungbean monoculture and four mixtures of maize with cowpea and mungbean) were included in the experiment as showed in Tab. 1. The experimental design was a randomized complete block (RCB) with three replications.

Table 2: The description of experimental treatments.

Treatment	Description
C	Sole maize
C_p	Sole cowpea
M_b	Sole mungbean
M_1	Within-row intercrop of maize and cowpea (replacement design)
M_2	Within-row intercrop of maize and mungbean (replacement design)
M_3	Within-row intercrop of maize and cowpea (additive design)
M_4	Within-row intercrop of maize and mungbean (additive design)

The seed-bed of experimental site was well prepared through two perpendicular plowing and removing residual of the previous crop (wheat) and weeds. Prior to planting, seeds were treated with mancozeb at 0.2% (wt/wt) in order to protect them from soil-borne pathogens. The additive and replacement method was used for intercropping systems. In replacement design one maize was replaced by three cowpea and three mungbean plants. Total population of intercrop components in replacement designs were half of their sole crops. The plots size was 15m^2 consist of six rows of 5m long. The rows located 50 cm apart. Treatments were separated by a 2m buffer zone. 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. Maize, cow pea and mungbean seeds were simultaneously sown in July 28, 2010. The seeds were sown at high density to ensure adequate emergence. After seedling establishment, the plots were thinned to 6.7, 20 and 25 plants/m^2, respectively.

Photosynthetically active radiation (PAR) was measured 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 plant canopy as follows:

$$\% \, PAR_i = [1- (PAR_b / PAR_a)] \times 100$$

Where the subscript i designates intercepted PAR, and subscripts a and b designate Par above and below the plant canopy, respectively.

The soil water balance was expected to be influenced by different cropping systems. Soil water content at 0–0.25 m depth was determined during the growing season. Soil samples were taken from three locations within each plot and a well mixed sample was used to determine soil moisture content by gravimetric measurement. Soil temperature was also recorded at a depth of 0–10 cm below the surface using a soil thermometer.

Maize and legumes were harvested at the milk and flowering stages, respectively. At the stages of harvest an area of 3.0 m^2 for the monoculture maize and intercropping treatments were harvested from the center of each plot and weighed fresh biomass was determined as g of DM per m^2. Thereafter, forage dry matter was measured after drying at 105°C for 24 h. The dried forage samples of both experiments were ground in a cyclone mill to pass a 1 mm screen for chemical analysis.

The samples were analyzed for DM and crude protein (CP). The N concentration was measured using the Kjeldahl method and the CP was achieved by N multiplied to 6.25. Ca, Mg and K were measured using Atomic absorption and phosphorus was measured by spectrophotometrically means.

Data were subjected to analysis of variance (ANOVA), using MSTATC software. The differences among means were tested using the least significant difference (LSD) method at 0.05 % probability level.

RESULTS AND DISCUSSIONS

The percentage of PAR interception was significantly (P<0.05) affected by cropping system. The men of PAR interception averaged over sampling dates by intercrop treatments and were significantly (P<0.05) higher than that for sole crop systems. The mean percentage of PAR interception for intercrop treatments with additive design was also higher than that for intercropping with replacement design and sole maize (Table 3). The mean PAR interception averaged over cropping system increased up to 85 DAS (Table 3) and, then, declined.

Table 3: Effect of different cropping system on percentage of PAR interception by crop canopies.

Cropping system	55 DAS	65 DAS	75 DAS	85 DAS	95 DAS	105DAS
C	70.79 c	80.23 c	89.2 c	89.20 c	83.02 c	78.21 c
C_p	71.22 c	80.23 c	89.5 c	89.54 c	86.45 c	77.77 c
M_b	71.55 c	81.71 c	88.0 c	89.21 c	85.03 c	77.78 c
M_1	75.08 b	84.75 b	94.75 b	93.56 b	91.04 b	81.21 b
M_2	74.21 b	86.02 b	93.71 b	93.78 b	91.52 b	80.06 b
M_3	79.06 a	88.72 a	98.75 a	98.52 a	96.09 a	87.21 a
M_4	79.11 a	89.62 a	98.61 a	99.21 a	97.21 a	88.76 a

Different letters in each column indicates significant at 0.05 % probability level. C: sole maize; C_p: sole cowpea; M_p: sole mungbean; M_1: within row intercrop of maize and cowpea (replacement design); M_2: within row intercrop of maize and mungbean (replacement design); M_3: row intercrop of maize and cowpea (additive design); M_4: row intercrop of maize and mungbean (additive design)

Soil temperature was significantly (P<0.05) affected by cropping systems. The soil temperature for intercrops treatments at all three sampling dates was significantly (P≤0.05) lower than for sole crop systems (Table 4). This could be due to higher light interception by intercrops compared to sole crops resulting in more shading and lower soil temperatures.

Table 4: Effect of different cropping system on soil temperature at 0-10 cm depth (ºC).

Cropping system	C	C_p	M_b	M_1	M_2	M_3	M_4
65 DAS	16.1 c	15.6 c	15.5 c	14.3 b	14.4 b	12.7 a	12.5 a
85DAS	16.6 c	14.1 c	14.9 c	14.8 b	14.0 b	12.2 a	12.1 a
105 DAS	20.7 c	19.6 c	19.1 c	18.6 b	18.7 b	17.0 a	16.6 a

Different letters in each row indicates significant at 0.05 % probability level. C: sole maize; C_p: sole cowpea; M_p: sole mungbean; M_1: within row intercrop of maize and cowpea (replacement design); M_2: within row intercrop of maize and mungbean (replacement design); M_3: row intercrop of maize and cowpea (additive design); M_4: row intercrop of maize and mungbean (additive design)

The moisture content of soil was significantly (P<0.05) influenced by cropping system (Table 5). Moisture content of soil in sole crops at all thee sampling dates was significantly (P<0.05) higher than for intercrop treatments. Intercropping of additive design has lower soil moisture content compared with replacement design of intercropping.

Table 5: Effect of different cropping system on soil moisture content.

Cropping system	C	C_p	M_b	M_1	M_2	M_3	M_4
65 DAS	21.5 c	19.5 c	19.1 c	17.5 b	17.0 b	17.5 a	16.8 a
85DAS	18.7 c	17.4 c	17.7 c	14.2 b	15.5 b	13.7 a	12.4 a
105 DAS	23.0 c	21.5 c	22.0 c	16.5 b	16.7 b	16.2 a	16.1 a

Different letters in each row indicates significant at 0.05 % probability level. C: sole maize; C_p: sole cowpea; M_p: sole mungbean; M_1: within row intercrop of maize and cowpea (replacement design); M_2: within row intercrop of maize and mungbean (replacement design); M_3: row intercrop of maize and cowpea (additive design); M_4: row intercrop of maize and mungbean (additive design)

Total nutrient uptake was significantly (P<0.05) affected by cropping system (Table 6). Nutrient uptake by intercrops was significantly greater than for sole crop systems. There were no significant differences between intercrops for Mg uptake. Total nutrient uptake for legume cropping systems (cowpea and mungbean) was significantly higher than that for sole crop maize.

Table 6: Effect of different cropping system on nutrient uptake (kg ha^{-1}).

Cropping system	Mg	Ca	K	P
C	4.58 c	4.36 b	55.76 c	11.23 c
C_p	12.55 b	37.89 b	192.71 b	27.29 b
M_b	12.51 b	36.18 b	189.14 b	28.14 b
M_1	14.02 a	43.97 a	214.91 a	34.46 a
M_2	14.95 a	43.52 a	202.86 a	32.31 a
M_3	14.19 a	40.37 a	204.64 a	32.10 a
M_4	15.4 a	42.15 a	206.51 a	30.89 a

Different letters in each column indicates significant at 0.05 % probability level. C: sole maize; C_p: sole cowpea; M_p: sole mungbean; M_1: within row intercrop of maize and cowpea (replacement design); M_2: within row intercrop of maize and mungbean (replacement design); M_3: row intercrop of maize and cowpea (additive design); M_4: row intercrop of maize and mungbean (additive design)

Dry weights of all intercrops were significantly ($P<0.05$) greater than those of sole crops (Table 7). There was no significant difference between intercrops grown with different planting patterns. Maize sole crop produced significantly greater dry weight than cowpea and mungbean sole crop systems.

Table7: Effect of different cropping system on crops dry weight ($t.ha^{-1}$).

Cropping system	C	C_p	M_b	M_1	M_2	M_3	M_4
Crop dry weight	**10.38 b**	**6.24 c**	**7.1 c**	**14.94 a**	**14.68 a**	**14.52 a**	**15.2 a**

Different letters indicates significant at 0.05 % probability level. C: sole maize; C_p: sole cowpea; M_p: sole mungbean; M_1: within row intercrop of maize and cowpea (replacement design); M_2: within row intercrop of maize and mungbean (replacement design); M_3: row intercrop of maize and cowpea (additive design); M_4: row intercrop of maize and mungbean (additive design)

The mean level of resource complementarity, as measured by relative yield total (RYT) was significantly greater than 1.0, indicating that the component crops used at least partially different resources (Table 8). RYT across intercrop treatment were similar. The mean RYT averaged over the intercrop treatments for dry weight was 1.36. Therefore intercrop treatments were 36% more advantageous than sole crops, respectively.

Table 8: Relative yield total (RYT) values of different maize-legume intercropping systems.

Intercropping	RYT
M_1	**1.31**
M_2	**1.35**
M_3	**1.41**
M_4	**1.39**

M_1: maize-cowpea intercrop (replacement design); M_2: maize-mungbean intercrop (replacement design); M_3: maize-cowpea intercrop (additive design); M_4: maize-mungbean.

The mean level of resource complementarity in terms of nutrient uptake, as measured by relative yield total (RYT) for Mg, Ca, P and K were significantly ($P<0.05$) greater than 1.0 (Table 9). This means that in terms of nutrient uptake thee was resource complementarity between mazie and legumes in intercropping. The higher mean RYT averaged over intercrops for nutrient uptake was recorded for Ca (1.80), followed by K (1.68), Mg (1.55) and P (1.21). This indicate that for Ca, K, Mg and P use efficiency, intercrops were 80, 68, 55 and 21 percentages more efficient compared to maize, cowpea and mungbean sole crops.

Table 9: Effect of different cropping system on relative yield total for nutrient uptake.

Cropping system	M_1	M_2	M_3	M_4	LSD ($P<0.05$)
RYT for Mg	1.60	1.52	1.57	1.52	**0.176**
RYT for Ca	1.96	1.82	1.73	1.72	**0.204**
RYT for K	1.79	1.62	1.59	1.60	**0.138**
RYT for P	**1.73**	**1.53**	**1.54**	**1.55**	**0.218**

M_1: maize-cowpea intercrop (replacement design); M_2: maize-mungbean intercrop (replacement design); M_3: maize-cowpea intercrop (additive design); M_4: maize-mungbean.

The forage quality of cow pea and mungbean in terms of crude protein content ($g.kg^{-1}$ dry matter) was significantly ($P \leq 0.05$) affected by cropping systems, where sole crops had higher crude protein content than cowpea and mungbean in intercrop systems (Table 10). Thus, the forage quality of legumes was decreased by intercropping. There was no significant difference between intercrops for component legumes crude protein content.

Table 10: Effect of cropping system on cow pea crude protein ($g.kg^{-1}$).

Cropping system	CP
C_p	130.14 a
M_b	112.40 b
M_1	111.53 b
M_2	111.21 b
M_3	113.71 b
M_4	112.43 b

C_p: sole cowpea; M_p: sole mungbean; M_1: within row intercrop of maize and cowpea (replacement design); M_2: within row intercrop of maize and mungbean (replacement design); M_3: row intercrop of maize and cowpea (additive design); M_4: row intercrop of maize and mungbean (additive design)

It is concluded [7], intercropping leads to an increase in the total amount of PAR captured and would PAR seem to play a relatively important role in determining total intercrop productively**.** Keating and Carberry [15] concluded that wheat and bean can differ in PAR interception because of differences in their vertical arrangement of foliage and canopy architecture and can therefore intercept more PAR compared to sole crops.

The soil temperature was changed by the cropping system with agree with the other researchers finding [6] so that soil temperatures under intercrops and bean sole crops were lower than under wheat sole crops. This could be due to higher light interception (table 5), causing a higher shading and lower temperature. Since, the micro climate within the canopy of cropping systems were altered, so that shading reduced canopy temperature [12], it seems that percent of light interception by canopies would be a major factor affecting soil temperature [9].

Root system morphology and fine root distributions are cardinal factors in determining the magnitude of belowground interspecific competition in mixed species systems. To improve the utilization efficiency of soil nutrient resources by intercropping systems, the spatial distribution and activities of roots requires elucidation [13]. Intercropping may be more efficient at exploiting a larger total soil volume if component crops have different rooting habits, especially depth of rooting [1]. Lower soil moisture content in intercrops treatments compared to sole crops could not be due to higher evaporation from the soil surface, because soil temperatures under intercrops were lower than sole crops. One explanation for more water extraction with intercrops and bean sole crops could be as a result of more intensive canopies such that the sole bean and intercrops were able to extract more water from the soil layers, finally resulting in a drier soil profile compared to that for sole wheat.

The nutrient uptake in terms of Mg, Ca, K, P and N in intercropping was higher than the mean for sole crops. Greater nutrient uptake is usually presumed to be possible because of some complementary exploration of the soil profile by the components crops [1] or fuller use of resources over time [19]. Higher total nutrient uptake has been reported by several authors (3, 4, 5]. The greater nutrient uptake has very often claimed to be associated yield advantages [19].

Dry matter for all intercrop treatments was greater than those sole crops. More PAR interception, nutrient uptake and also greater water extract by intercrops could be the major reason for greater dry weight observed for intercropping over sole cropping. Greater resource use by intercrops was considered as the biological basis for obtaining yield advantage [6, 8, 10, 19]. It is reported that the pea-barley intercrop used light, soil water and nutrients more efficiently than sole crops due to differences in the competitive ability for environmental sources for plant growth [13].

Photosynthetically active radiation and phosphorus are essential factors for legumes to fix atmospheric nitrogen [16]. Thus, decreasing availability of these environmental resources results in reduction of biological nitrogen fixation. Cereals are more competitive than legumes for phosphorus [10]. Thus, phosphorus supply for cow pea and mungbean in intercropping was less than their sole crop. Furthermore, in intercropping the taller maize was able to compete with the shorter cow pea and mungbean for light, because cow pea plants were shaded by maize canopy. In the other words, light interception by legumes 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 legumes to cover its nitrogen requirement [14, 15], reducing light and phosphorus supply for cowpea and mungbean in intercropping resulted in decreasing its nitrogen and, therefore, crude protein content. Thus, the forage quality of cow pea and mungbean was decreased in intercropping compared to their sole crop.

CONCLUSION

In general, it was concluded that environmental resource consumption, especially PAR interception and nutrient uptake in intercropping system was better than sole crop, suggesting that intercrop components have "complementarity effect" in environmental resource obtaining which is result of different morphological and physiological characteristics of intercrop components. The results of this experiment could provide some quantitative evidence for the hypothesis that greater environmental resources consumption (such as PAR and soil moisture) by intercrops is a primary cause of yield advantages.

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