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Evaluation of Forage Production Using Maize-Legume Intercropping and Biofertilizer under Low-Input Conditions

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Intercropping as a low-input cropping system has been associated with higher forage yield in comparison with sole crops. This study compared the forage yield of sole maize and intercrops of maize with legumes grown under biofertilizer application, and examined the different competition indices in these intercropping patterns. The field assay was conducted during the 2013 growing season at the University of Maragheh in the East Azerbaijan province of Iran. The study was carried out in randomized complete block design (RCBD) with 14 treatments and 3 replications. Experimental treatments included intercropping of maize (inoculation with nitroxin as biological fertilizer) with hairy vetch (*Vicia villosa* Roth.), maize (no inoculation)-grass pea (*Lathyrus sativus* L.), maize (no inoculation)-sainfoin (*Onobrychis vicifolia* Scop.), maize (inoculated)-berseem clover (*Trifolium alexandrinum* L.), maize (no inoculation)-vetch, maize (inoculated)-vetch, maize (inoculated)-sainfoin, maize (no inoculation) + berseem clover, and monoculture of maize (no inoculation), maize (inoculation), clover, vetch, grass pea, and sainfoin. Results showed that the maize (inoculation)-vetch intercropping pattern had the highest forage production and the lowest yield production was in sainfoin and grass pea sole crops. Intercropping inoculated maize with vetch also had the highest amounts of land equivalent ratio (LER) and monetary advantage index (MAI). The higher relative crowding coefficient (RCC) of maize (K = 1.08) compared with those of legumes (k = 0.93) indicated that maize was more competitive than legumes as intercrops. However, among all intercrops, maize (inoculation)-vetch was found to be most profitable. The results obtained from competition and economic indices indicated superior advantage of this intercrop in terms of more efficient land use and more economic benefits than those of other evaluated intercrops.

Key Words: biofertilizer, forage yield, hairy vetch, monetary advantage, nitroxin

Abbreviations: DM – dry matter, LER – land equivalent ratio, MAI – monetary advantage index, PGPR – plant-growth-promoting rhizobacteria, RCC – relative crowding coefficient, A – aggressivity

INTRODUCTION

Forage supplies are becoming increasingly limited for livestock production in the arid and semi-arid regions where supplies are currently one-third of the demand as a result of water scarcity and low soil fertility (Ibrahim et al. 2014; Sadeghpour et al. 2013). Cereals such as maize (*Zea mays* L.) are widely used as forage and extensively grown as a valuable source of carbohydrates for livestock in Iran (Mohammadi et al. 2012). Although yields of legumes are generally lower than those of cereals (Lauriault and Kirksey 2004), legumes are also important because they help in the fixation of atmospheric nitrogen in symbiosis with Rhizobia bacteria to improve soil fertility (Contreras-Govea et al. 2011; Esmaeili et al. 2011). Therefore, forage yield and the quality of legumes and non-legumes in intercrops are of great importance (Ayub et al. 2008; Ibrahim et al. 2012; Esmaeili et al. 2011).

Intercropping of cereals and legumes is important for the development of sustainable production systems, particularly in cropping systems with limited external inputs (Lameie-Harvani 2013; Strydhorst et al. 2008). Previous studies have shown potential benefits of intercropping such as high productivity and profitability (Lithourgidis et al. 2011), improvement of soil fertility through the addition of nitrogen by fixation and excretion from the legume (Ghosh 2004), efficient use of resources (Knudsen et al. 2004), reduction in the damages caused by pests (Navasero and Calumpang 2013) and weeds (Mohammadi et al. 2012), control of legume root parasite infections (Chen et al. 2004), better lodging resistance (Agegnehu et al. 2006), yield stability (Tuna and Orak 2007; Zhang et al. 2011), and improvement of forage quality through the complementary effects of two or more crops grown simultaneously on the same area of land (Dabbagh Mohammadi Nasab et al. 2011; Sadeghpour et al. 2013).

Biofertilizers are substances containing living microorganisms that can colonize in the rhizosphere or the inner part of the plant and, when applied to the seed, plant surface or soil, can promote plant growth by increasing the availability and supply of primary nutrients (Vessey 2003). Biofertilizers may also decrease soil pH, and thus increase availability of trace elements which enhance plant growth (Mahfouz and Sharaf-Eldin 2007). A group of biofertilizers contain beneficial rhizobacteria, many of which have been called plant growth-promoting rhizobacteria (PGPR) that actively colonize in the rhizosphere and can improve plant growth and crop yield (Wu et al. 2005). Among many of them, strains from *Azotobacter*, *Azospirillium*, *Bacillus*, *Rhizobium*, and *Pseudomonas* genera could be named. According to Simanungkalit (2001), *Azospirillum* sp. and *Azotobacter* sp. are aerobic, free-living soil microbes that can fix nitrogen from the atmospheric source. *Pseudomonas* sp. and *Bacillus* sp. can also increase the availability of N, P and K in the soil and enhance their uptake by plant roots (Han and Lee 2005).

A number of indices, such as land equivalent ratio (LER), relative crowding coefficient (RCC), competitive ratio, and intercropping advantage, have been proposed to describe competition within plant communities and economic advantages of intercropping systems (Dhima et al. 2007). Zhang et al. (2011) found that alfalfa had higher relative crowding coefficients (RCC or K value) and aggressivity (A value) than those of corn. Esmaeili et al. (2011) indicated that yield advantage of intercropping of medic and barley over their monoculture was also confirmed by RCC and monetary advantage index (MAI). Indices can express various attributes of competition in plant communities, including competition intensity, competitive effects, and the outcome of competition. However, such indices have not been used for intercropping maize and legumes grown with biofertilizers in order to evaluate the competition among species as well as the economic advantages of each intercropping system in Iran.

In view of the above considerations, the objectives of this study were (i) to compare the forage yield of sole maize and intercrops of maize with legumes grown under biofertilizer application, and (ii) to examine different competition indices in these intercropping patterns.

MATERIALS AND METHODS

The field assay was conducted in the 2013 growing season at the University of Maragheh (37° 30′ N; 46° 12' E; elev. 1477 m above sea level) located in the East Azerbaijan province of Iran. This region is characterized by a semi-arid cool climate, with an annual mean temperature of 13.2 °C and mean precipitation of 309 mm for the past 30 yr. Mean monthly temperature and rainfall data during the growing season are given in Table 1. The experiment was carried out in randomized complete block design (RCBD) with 14 treatments and three replications. Composite soil samples from a depth of 0–30 cm were taken from each block before planting. The samples were analyzed for their pH, organic matter (O.M), available P and N, and texture (clay, silt and sand). Results of the physicochemical analysis of the soil samples are presented in Table 2.

The seedbed was well prepared through two perpendicular plowings and removing the residual of the previous crop and weeds. Prior to planting, seeds were treated with benomyl at 0.2% to protect them from soil-borne pathogens. The treatments were as follows: (1) intercropping of maize (inoculation with nitroxin)-hairy vetch (*Vicia villosa* Roth.), (2) maize (no-inoculation)-grass pea (*Lathyrus sativus* L.), (3) maize (no-inoculation)-sainfoin (*Onobrychis vicifolia* Scop.), (4) maize (inoculated)-berseem clover (*Trifolium alexandrinum* L.), (5) maize (no-inoculation)-vetch, (6) maize (inoculated)-vetch, (7) maize (inoculated)-sainfoin, (8) maize (no-inoculation)-berseem clover and (9)

Table 1. Monthly mean air temperature, relative humidity and total monthly rainfall during growing seasons at the experiment site.

Weather Parameters	Month					
	April	May	June	July	August	September
Total monthly rainfall (mm)	24.4	25.1	7	3.7	0.3	0
Average monthly temperature (°C)	11.2	12.1	22.4	27.9	28.4	26
Minimum temperature (°C)	5.3	18.6	15.3	20.9	21.4	19.2
Maximum temperature (°C)	17.2	0	29.6	34.8	35.4	32.8
Minimum humidity (%)	28	25	18	18	16	15
Maximum humidity (%)	71	64	52	48	39	41

Table 2. Some physical and chemical properties of the soil.

Clay (%)	Silt (%)	Sand (%)	Total Nitrogen (%)	Zn (av.) ($mg.kg^{-1}$)	Mn (av.) ($mg.kg^{-1}$)	Fe (av.) ($mg.kg^{-1}$)	K (av.) ($mg.kg^{-1}$)	P (av.) ($mg.kg^{-1}$)	Organic Matter (%)	pH	Electrical Conductivity (dS/m)
43	43	14	0.05	0.68	8.52	7.13	321	8.47	0.87	7.96	0.89

monoculture of maize (no-inoculation), (10) monoculture maize (inoculation), (11) monoculture clover, (12) monoculture vetch, (13) monoculture grass pea, and (14) monoculture sainfoin.

There were 42 experimental plots. The plot size of intercropped and monoculture maize was 12 m^2 and the plot size for the other treatments was 4.8 m^2. The optimum density for maize, grass pea, berseem clover, sainfoin and vetch were chosen to be 15, 250, 990, 250 and 250 plants m^{-2}, respectively. Before planting, 2 L per ha of nitroxin biofertilizer was used to inoculate seeds of maize. The method of intercropping was additive so that, on one side of each row, maize and on the other side, the legume was planted. Maize and legumes were sown on 17 June 2013. In each of the intercropped and monoculture plots of maize, there were 4 rows of plants, with each row 5 m long and a row space of 60 cm.

The first irrigation was done immediately after planting and the succeeding irrigations were done weekly as furrow irrigation. After about 15 d, the first weeding was done. In harvesting the intercropped treatments and monoculture maize, lateral and border rows were omitted and only 2 middle rows (4.8 m^2) were harvested. Then the forage fresh wet weight was immediately recorded. The samples were brought to the laboratory, oven-dried at 75 °C, and ground. In the monoculture legumes, an area of 1.8 m^2 was harvested and then the fresh weight was measured. Later samples were oven-dried and chopped.

The advantage of intercropping and the effect of competition between two species cultivated together were calculated using different competition indices, as follows: the land equivalent ratio (LER) was used as the criterion for the mixed stand advantage considering that both barley and legume were the desired species in the combination (Willey and Rao 1980). In particular, LER indicates the efficiency of intercropping in the use of environmental resources compared with mono-cropping. The value of unity is considered to be the critical value for this index. When LER is greater than 1, the intercropping favors the growth and yield of the intercropped species, whereas when LER is lower than 1, the intercropping negatively affects the growth and yield of the species. The LER was calculated on the basis of the formula:

$$LER = (LER_b + LER_L) = \left(\frac{Y_{bL}}{Y_{bb}}\right) + \left(\frac{Y_{Lb}}{Y_{LL}}\right) \quad \text{[Eq. 1]}$$

where Y_{bb} and Y_{LL} are the yields of barley and legumes as sole crop, respectively, and Y_{bL} and Y_{Lb} are yields of barley and legumes in the intercropping, respectively.

Another coefficient used was the relative crowding coefficient (RCC or K), which is a measure of the relative dominance of one species over the other in an intercropping. RCC was calculated using the formula:

$$= K_{bL} \times K_{Lb} = \left[\frac{(Y_{bL} \times Z_{Lb})}{\{(Y_{bb} - Y_{bL}) \times Z_{bL}\}}\right] \times \left[\frac{(Y_{Lb} \times Z_{bL})}{\{(Y_{LL} - Y_{Lb}) \times Z_{Lb}\}}\right] \quad \text{[Eq. 2]}$$

where K_{bL} and K_{Lb} are relative crowding coefficients for barley and legume intercrop, respectively.

Aggressivity is another index, which is often used to indicate how much the relative yield increase in 'a' crop is greater than that of 'b' crop in an intercropping system (Sadeghpour et al. 2013). The aggressivity is derived from the equation:

$$A_{barley} = \left(\frac{Y_{bL}}{Y_{bb} \times b_{bL}}\right) - \left(\frac{Y_{Lb}}{Y_{LL} \times Z_{Lb}}\right) \quad \text{[Eq. 3]}$$

If A_{barley} is equal to 0, both crops are equally competitive; if A_{barley} is positive, then the barley is the dominated species; if A_{barley} is negative, then the cereal species is weak. Accordingly, aggressivity for legumes (vetch and grass pea) can be derived from the equation:

$$A_{legume} = \left(\frac{Y_{Lb}}{Y_{LL} \times L_{Lb}}\right) - \left(\frac{Y_{bL}}{Y_{bb} \times Z_{bL}}\right) \qquad \text{[Eq.4]}$$

where Y_{bL} represents the yield of intercrop barley in combination with legume, Y_{Lb} is the yield of intercrop legume in combination with barley, Z_{bl} represents the sown proportion of intercrop barley in combination with legume, and Z_{lb} shows the sown proportion of intercrop legume in combination with barley. Moreover, none of the above competition indices provide any information on the economic advantages of the intercropping system. For this reason, monetary advantage index (MAI) was calculated, thus:

$$\text{MAI} = \left[\frac{(\text{value of combined intercrops}) \times (\text{LER} - 1)}{\text{LER}}\right] \qquad \text{[Eq.5]}$$

Value of combined intercrops was calculated as:

$$Y_{bl}P_{barley} + Y_{bl}P_{legume}$$

where P_{barley} is the commercial value of barley silage (the current price is 31 Euro per mg), and P_{legume} is the commercial value of legume silage (the current price is 42 Euro per mg). The higher the MAI value, the more profitable is the cropping system. Data were initially subjected to analysis of variance (ANOVA) using the SAS computer software program, assuming that the measured variables are normally distributed (SAS Institute 2003). Mean comparison using LSD in 5% probability level was also done.

RESULTS AND DISCUSSION

Maize Dry Matter (DM) Yield

Analysis of variance showed that there was a significant difference in dry matter yield of forage among various treatments ($p \leq 0.01$) (data not shown). As expected, the inoculated maize sole crop produced the highest dry matter yield (Table 3), although it was not significantly different from that of the inoculated maize-vetch intercrop. The maize (without inoculation) + berseem clover combination had the lowest dry matter yield. Dry matter yield of inoculated maize was higher than that of each of the other non-inoculated treatments. More dry matter production in mono-cultivation of inoculated maize could be related to more leaves, green cover and the light they receive in sole cropping.

On the other hand, use of biofertilizer could decrease the soil pH, and thus increase availability of trace elements which enhance plant growth (Mahfouz and Sharaf-Eldin 2007). Vessey (2003), in a related study on the use of biofertilizer, found that application of *Pseudomonas* sp. increased maize dry matter up to 22.5%.

It is possible that when legumes were added to maize monoculture, the maize forage yield was reduced due to the increase in inter-species competition when compared with its sole cropping. Among legumes, vetch had a low effect on maize forage yield reduction, which could be due to less competition by vetch with maize or due to synergistic effects on maize production (Lauriault and Kirksey 2004). Different responses of various legume species might be due to distinct growth habits (Esmaeili et al. 2011). Based on comparisons of mono-cultivation with intercropping, maize yield reduction in some of the legume intercropping systems was related to competition of legumes for nutrients or the lack of nitrogen transport (Strydhorst et al. 2008). In a related study, Ibrahim et al. (2012) found that reductions in maize yield ranged from 5.8% in intercrops with scarlet runner bean to 11.5% in velvet bean intercrops.

Plant Height

Analysis of variance for maize height indicated that there were significant differences among intercrops ($p \leq 0.01$) (data not shown). The tallest plants were observed in inoculated maize-vetch intercropping (Table 3) while the shortest maize plants (130.9 cm) were observed in the treatment without nitroxin. Studies have shown that biofertilizer application increases nitrogen concentration in plants, thus enhancing more cell division and plant cell elongation (Simanungkalit 2001). This result might be due to low or no crop-weed competition. Enhancement in most of the crop growth parameters under favorable environmental situations can result in better plant growth. Growth enhancement by bacteria may relate to their ability to produce extensive root length (Sheng et al. 2002) and can also improve root development and increase the rate of water and mineral uptake (Vessey 2003). Also, biofertilizers can enhance

Table 3. Dry matter yield, plant height, leaf number, and leaf dry weight of maize under different intercropping patterns.

Intercropping Pattern	Dry Matter Yield ($t\ ha^{-1}$)	Plant Height (cm)	Leaf No.	Leaf Dry Weight ($g\ m^{-2}$)
Maize (inoculation) + vetch	11.93 a	198.5 a	13.93 a	186.7 a
Maize (non-inoculation) + grass pea	8.507 d	150.6 cd	9.733 e	128.9 de
Maize (non-inoculation) + sainfoin	8.817 d	157.1 bcd	10 de	117.8 ef
Maize (inoculation) + berseem clover	9.940 bc	168.4 b	11.93 b	142.3 cd
Maize (no inoculation) + vetch	8.633 d	161.5 bcd	10 de	113.2 ef
Maize (inoculation) + grass pea	10.35 b	169 b	10.40 cde	130.7 cde
Maize (inoculation) + sainfoin	10.46 b	170 b	11.20 bc	164.7 b
Maize (no inoculation) + berseem clover	7.283 e	147.8 d	9.867 de	112.6 ef
Sole maize (no inoculation)	9.217 cd	130.9 e	7.267 f	109.1 f
Sole maize (inoculation)	12.21 a	163.3 bc	10.87 bcd	148.8 bc
$LSD_{0.05}$	1.108	15	1.110	18.28

Different letters in the same column indicate significant difference ($P < 0.05$).

production of plant hormones and can increase internode length and plant height (Tisdale et al. 1985; Vessey 2003). Biofertilizer application with *Azotobacter* and *Pseudomonas* also significantly increased the height of sorghum plant, indicating the positive effects of biofertilizer application (Amal et al. 2010). Zafar et al. (2012) observed that application of PGPR significantly ($p \leq 0.05$) increased lentil growth compared with the control. The relative increase by biofertilizers ranged from 38% to 65% in shoot length, 3% to 43% in shoot fresh weight, and 11% to 63% in shoot dry weight over the uninoculated control.

Tuna and Orak (2007) reported that in vetch and oat intercropping, an increase or decrease in plant height strongly relates to intense competition between plants. Differences between the tallest and the shortest plants in intercropping arise from inter-species competition. In higher densities of additive intercropping systems with intense competition for light, plant height has been found to increase. On the other hand, lack of food and water in higher densities and limitations in photosynthetic substances resulted in reduction of plant height to the lowest level (Ibrahim et al. 2014). Agegnehu et al. (2006) reported slight reduction in plant height of barley when intercropped with faba bean compared with barley sole cropping. Reduction of non-legume plant height in intercropping with legumes might be due to competition for nitrogen adsorption by non-legumes (Ibrahim et al. 2014). Differences in plant height in mono and intercropping cultivation systems might be due to inter-species competition for water, light and nutrients.

Number of Leaves and Leaf Dry Weight

Treatments had significant effects on the number of leaves ($p \leq 0.01$) (data not shown). The highest and the lowest number of leaves belonged to inoculated maize intercropped with vetch and mono maize cultivation (without inoculation), respectively (Table 3). In conformity with a correlation between maize plant height and leaf number, nitroxin application increased internode length and consequently, plant height and number of leaves. As shown in Table 3, there was a significant difference in leaf dry matter among various treatments. The highest amount of leaf dry matter was observed in the vetch-inoculated maize treatment and the lowest leaf dry weight, in maize (non-inoculation) sole crop. This result might be due to the beneficial effect of intercropping vetch with maize. Additional supply of nitrogen by nitrogen-fixing bacteria appeared to have increased the number of leaves and thereby, provided a greater supply of food materials through increased photosynthesis, rapid cell division and cell elongation in the meristematic region, which ultimately gave a significant increase in leaf area index (LAI) (Bali Reddy et al. 2009). Also, increase in number of leaves and leaf dry weight of maize under intercropping conditions might be due to favorable microclimate and biological nitrogen fixation processes in legumes (Lameie-Harvani 2013).

Total Dry Forage Yield

Total dry forage yield was also significantly influenced by cropping systems (data not shown). The greatest forage production was obtained from vetch-inoculated maize probably due to the lower interspecific competition between two crops and also probably to PGPR positive effects. Moreover, the lowest forage yield was observed in sainfoin and grass pea pure stands (Table 4). Forage dry matter yield reduction of legumes had been reported in some studies as due to higher exploitation of the resources by cereals (Strydhorst et al. 2008; Javanmard et al. 2009). In other studies, the enhancement in various agronomic yields by PGPR was attributed to the production of growth-promoting phytohormones, phosphate mobilization, production of siderophore and antibiotics, inhibition of plant ethylene synthesis, and induction of plant systemic resistances to pathogens (Wu et al. 2005; Moradi et al. 2011).

Agegnehu et al. (2006) reported higher yields in barley and bean intercropping than in mono-cultivation, which is due to more water and nutrient adsorption and less input requirements in intercropping cultivation systems. Because of physiological and morphological differences among legumes and forage in the application of environmental resources, they have a supplementary and positive effect on each other (Knudsen et al. 2004). Ansar et al. (2010) found that cereal intercropping increased forage production with better quality in comparison with cereal mono-cultivation. In the present study, leaf number, leaf weight and plant height in intercropping were more than those in mono-cultivation. The increased amounts of the above-mentioned parameters have resulted in more forage yield in intercropping system.

Javanmard et al. (2009) reported that in the intercropping of maize and some legumes (berseem clover, vetch, bean, and bitter vetch), the highest yield was observed in maize-vetch intercropping. This result might be due to the fast growth, early maturity and earlier harvest of vetch even before it was completely covered by maize canopy. Increase in dry matter also resulted in an increase in the total treatment yield. The increased forage yield of maize and vetch intercropping shows that they are the most compatible species in intercropping. The lowest amount of dry matter production in some intercropping treatments is due to greater competitive ability of one of the species (Strydhorst et al. 2008). Several studies have recorded forage yield increase in legume-cereal intercropping (Agegnehu et al. 2006; Contreras-Govea et al. 2011; Sadeghpour et al. 2013). Similar finds were reported by Lithourgidis et al. (2011). Moreover, they explained that production efficiency in cereal and legume intercropping systems is due to minimum inter-species competition among plants for limiting factors. Successful intercrops occur when each species occupies and accesses resources from different ecological niches while minimizing competitive interactions. In general, when two plants grow near one another, basic physiological principles suggest that they will compete for environmental resources regardless of facilitation. If competition and facilitation are both operative, the net effect could switch from positive to negative as a function of density (Vandermeer 1990).

Table 4. Dry matter yield (t ha^{-1}) of different intercropping patterns.

Intercropping Pattern	Total Dry Yield
Maize (inoculation) + vetch	18.13 a
Maize (non-inoculation) + grass pea	10.64 de
Maize (non-inoculation) + sainfoin	9.620 e
Maize (inoculation) + berseem clover	12.8 bc
Maize (non-inoculation) + vetch	13.71 b
Maize (inoculation) + grass pea	12.53 bc
Maize (inoculation) + sainfoin	11.47 cd
Maize (non-inoculation) + berseem clover	9.953 de
Sole maize (non-inoculation)	9.217 e
Sole maize (inoculation)	12.21 bc
Sole berseem clover	3.557 g
Sole vetch	6.697 f
Sole grass pea	2.210 gh
Sole sainfoin	1.237 h
$LSD_{0.05}$	1.556

Means with the same letters are not significantly different at $P< 0.05$.

Land Equivalent Ratio (LER)

The total LER exceeded unity in the intercrops, indicating that there was a yield advantage of mixed cropping systems over monocultures in terms of more efficient use of the environmental resources for plant growth (Table 5). Studies have revealed that partial LER of maize and legumes were higher than unity, which indicated that there was a disadvantage for maize and legumes (Chen et al. 2004). The LER values of these mixtures were between 1.54 and 1.99, which means that 54–99% more land area would be required by a monocropping system to equal the yield of an intercropping system, indicating greater land use efficiency of intercrops than monocrops (Dabbagh et al. 2011). The greatest LER was observed in the inoculated maize + vetch intercrop. Morphological differences in legume and grass growth stages, complementary use of available resources, and better use of light and different soil horizons are the main reasons for LER to be greater than 1 in a cultivation system. LER > 1 in intercropping cultivation systems is due to nitrogen adsorption. Ecological niche separations in resource adsorption and competition-decreasing mechanisms can be a practical explanation of legume/maize intercropping usefulness (Banik et al. 2006).

Table 5. Relative yield total (RYT) and land equivalent ratio (LER) values of different intercropping patterns.

Intercropping Pattern	Relative Yield of Maize (RY_m)	Relative Yield of Legume (RY_l)	RYT	LER
Maize (inoculation) + vetch	0.977	0.926	1.99	1.99
Maize (non-inoculation) + grass pea	0.922	0.936	1.88	1.88
Maize (non-inoculation) + sainfoin	0.956	0.650	1.60	1.60
Maize (inoculation) + berseem clover	0.814	0.819	1.63	1.63
Maize (non-inoculation) + vetch	0.937	0.759	1.69	1.69
Maize (inoculation) + grass pea	0.847	0.981	1.82	1.82
Maize (inoculation) + sainfoin	0.855	0.821	1.67	1.67
Maize (non-inoculation) + berseem clover	0.790	0.752	1.54	1.54

LER – land equivalent ratio, RYT – relative yield total

Relative Crowding Coefficient (RCC)

The partial K values of maize were higher than the partial K of legumes in most of the intercrops (Table 5). This finding indicates that maize is more competitive than vetch, sainfoin and berseem clover crops. However, legume K value was higher than the maize K value in the case of maize (inoculation)-berseem clover, maize (inoculation)-grass pea and maize (without inoculation)-grass pea intercrops. Overall, on the average, the intercropped maize had higher relative crowding coefficient (K= 1.08) values compared with the intercropping legumes (K= 0.93), indicating that maize was more competitive than legumes in mixtures. In addition, K values for grass pea were higher compared with those of vetch and sainfoin, showing that grass pea was more competitive than vetch and sainfoin in the case of legume-maize mixtures. The total K value was equal to one in all of the treatment combinations, which means there is no yield advantage due to intercropping (Dabbagh Mohammadi Nasab et al. 2011).

Aggressivity

The results of aggressivity conformed to those of LER and RCC. In particular, legumes were the dominant species (A_{legume} positive) in the maize (inoculation)-berseem clover, maize (inoculation)-grass pea and maize (without inoculation)-grass pea intercrops (Table 6). Moreover, the A value for grass pea was greater than the A value for legumes in maize (inoculation)-grass pea and maize (without inoculation)-grass pea intercrops. This result indicates that grass pea was more competitive than other legumes. In most mixtures, maize was the dominant species as measured by the positive value of aggressivity. Thus, maize was able to acquire more resources than legumes, and its yield influenced the total biomass of the intercropping system. Cereals (maize, sorghum and pearl millet) were also the dominant species in the groundnut-cereal intercropping system (Ghosh 2004). By contrast, for alfalfa-corn intercropping, aggressivity was higher for alfalfa in most mixtures than for corn (Zhang et al. 2011).

Monetary Advantage Index (MAI)

The MAI values were positive in all of the treatments, showing a definite yield advantage related to intercropping (Lithourgidis et al. 2011). The highest MAI values were for the maize (inoculation)-vetch, followed by the maize (non-inoculation)-vetch intercrops. The high monetary index for maize-vetch intercrops relative to the other intercrops can be attributed to the higher forage dry matter yield of vetch and maize. The lowest MAI value belonged to maize (non-inoculation) + berseem clover intercrops (Table 7). These findings are also parallel to those of LER and competitive indices. Ghosh (2004) and Dhima et al. (2007) reported that if LER was higher, there was also an economic benefit expressed with the MAI values. Banik et al. (2006) reported intercropping advantage due to positive MAI values. The advantage of the intercropping systems found in this study could be attributed to better utilization of growth resources. Economic advantage from the intercrops could be further increased if the value of improved yield stability, enhanced nutrient use, and improved weed, insect, or disease control associated with intercropping, were factored into the analysis (Strydhorst et al. 2008).

CONCLUSION

Higher dry matter yield of maize in vetch-inoculated maize mixture compared with those in maize-grass pea, maize-sainfoin and maize-berseem clover intercrops indicated greater compatibility of vetch in intercropping. Maize DM yields in maize-grass pea, maize-sainfoin and maize-berseem clover intercrops were lower than those of inoculated maize monoculture and therefore not only reduced benefits for the farmers, but also resulted in

Table 6. Relative crowding coefficient and aggressivity of maize and legumes for different intercropping patterns.

Intercropping Pattern	RCC_{zl}	RCC_{lz}	RCC_t	A_z	A_l
Maize (inoculation) + vetch	1.05	0.94	1	0.05	-0.05
Maize (non-inoculation) + grass pea	0.95	1.04	1	-0.04	0.04
Maize (non-inoculation) + sainfoin	1.47	0.67	1	0.30	-0.30
Maize (inoculation) + berseem clover	0.99	1	1	-0.005	0.005
Maize (non-inoculation) + vetch	1.23	0.81	1	0.17	-0.17
Maize (inoculation) + grass pea	0.86	1.15	1	-0.13	0.13
Maize (inoculation) + sainfoin	1.04	0.95	1	0.03	-0.03
Maize (no inoculation) + berseem clover	1.05	0.95	1	0.03	-0.03

RCC_{zl} – Relative crowding coefficient of maize relative to legumes, RCC_{lz} – Relative crowding coefficient of legumes relative to maize, A_z – Aggressivity of maize relative to legumes, A_l – Aggressivity of legumes relative to maize

Table 7. Amount of monetary advantage index (MAI) in maize-legume intercropping.

Intercropping Pattern	MAI
Maize (inoculation) + vetch	2159816
Maize (non-inoculation) + grass pea	1326753
Maize (non-inoculation) + sainfoin	1232843
Maize (inoculation) + berseem clover	1543441
Maize (non-inoculation) + vetch	2133359
Maize (inoculation) + grass pea	1570045
Maize (inoculation) + sainfoin	1471881
Maize (non-inoculation) + berseem clover	1152142

economic disadvantages. Maize had higher relative crowding coefficient values (K = 1.08) than those of legumes (K = 0.93), indicating that maize was more competitive than legumes as intercrops. However, among all of the intercrops, the inoculated maize-vetch and maize (non-inoculation)-vetch intercrops were found to be the most profitable. Thus, vetch was found to be the best-suited for intercropping with maize as crop yields were comparable to that of the sole maize, LER was improved, and the economic advantages were recorded as the highest. The poor performance of sainfoin-maize intercrop was attributed to the relatively poor competitive ability of sainfoin. In general, results obtained from the competition and economic indices indicated the superior advantages of these intercrops because of more efficient land use and greater economic benefits realized than those of other intercrops evaluated in this study.

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