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Identification of Advantages of Maize-Legume Intercropping over Solitary Cropping through Competition Indices in the East Mediterranean Region

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Abstract: Alternate planting combinations of maize (*Zea mays* L.) with common bean (*Phaseolus vulgaris* L.) or cowpea (*Vigna sinensis* L.) were compared with the solitary planting of each crop during 2003 and 2004 under the East Mediterranean conditions in Turkey. The experiment comprised 15 treatments; sole planting of maize (71,500 plant ha^{-1}), sole planting of common bean (285,750 plant ha^{-1}) and cowpea (285,750 plant ha^{-1}), and 2 different planting patterns (1- and 2-row plantings) with 6 maize-legumes intercropping series, 50:50, 67:50, and 100:50, respectively, using randomized complete block design with 3 replications. Evaluation of the planting patterns was performed on basis of several intercropping indices such as land equivalent ratio (LER), relative crowding coefficient (K), aggressivity (A), aggressivity ratio (CR), actual yield loss (AYL), monetary advantage index (MAI), and intercropping index (IA). Competition indices revealed that, compared to solitary planting, the maize-cowpea and maize-common bean intercropping, regardless of planting patterns, at the mix proportions of 67:50 plant density had advantages due to its better yield, land use efficiency, and economics. Methods used in this study should be easily implemented especially by small scale farms in the East Mediterranean region.

Key Words: Maize, common bean, cowpea and intercropping

Doğu Akdeniz Bölgesinde Mısır-Baklagil Karışımlarının Yalın Ekimlere Üstünlüğünün Rekabet İndeksleri Yoluyla Belirlenmesi

Özet: Mısır ile fasulye veya börülcenin farklı ekim sistemleri, aynı bitkilerin saf ekimleri ile karşılaştırmalı olarak 2003 ve 2004 yetiştirme dönemlerinde doğu Akdeniz şartlarında incelenmiştir. Araştırma tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak yürütülmüş olup, denemede 15 uygulama kullanılmıştır. Uygulamalar; saf mısır (71.500 bitki ha), saf fasülye (285.750 bitki ha) ve saf börülce (285.750 bitki ha) ekimi, iki farklı ekim deseni (tek ve çift sıra ekim) ile beraber altı adet mısır:baklagil karışık ekim sistemi (50:50, 67:50 ve 100:50, mısır:baklagil ekim oranı) şeklinde olmuştur. Ekim desenlerinin sonuçlarının yorumlanması, alan eşdeğerlik oranı (AEO), göreceli sıklık katsayısı (GSK), rekabetçilik (R), rekabet oranı (RO), gerçek verim kaybı (GVK), maddi yarar indeksi (MYI) ve karışık ekim indeksi (KEI) gibi bazı rekabet indeksleri yardımıyla yapılmıştır. Eşdeğer alan kullanım indeksi değerleri 67:50, mısır: fasulye ya da mısır: börülce karışım oranlarında ekim desenine bağlı olmaksızın daha yüksek bulunmuştur. Rekabet indeks değerleri göstermiştir ki, yalın ekimler yerine, 67:50 oranındaki mısır-börülce ve mısır-fasulye karışımlarının (ekim deseni dikkate alınmaksızın) verim, alan kullanım etkinliği ve ekonomik yönden önemli avantajlar sağlamaktadır. Kullanılan metotların özellikle doğu Akdeniz bölgesindeki küçük ölçekli tarım işletmelerince uygulamaya aktarılması mümkündür.

Anahtar Sözcükler: Mısır, fasulye, börülce ve karışık ekim

Introduction

Producers and researchers carry out different cropping systems to increase productivity and sustainability by practicing crop rotations, relay cropping, and intercropping of annual cereals with legumes. Intercropping of cereals with legumes has been popular in tropics (Hauggaard-Nielsen et al., 2001; Tsubo et al., 2005) and rain-fed areas of the world (Banik et al., 2000; Ghosh, 2004; Agegnehu et al., 2006; Dhima et al., 2007) due to its advantages for soil conservation (Anil et al., 1998), weed control (Poggio, 2005; Banik et al., 2006), lodging resistance (Anil et al., 1998), yield increment (Anil et al., 1998; Chen et al., 2004), hay curing, forage preservation over pure legumes, high crude protein percentage and protein yield (Qamar et al., 1999; Karadag and Buyukburc, 2004), and legume root

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parasite infections control (Fenandez-Aparicio et al., 2007).

Different seeding ratios or planting patterns for cereal-legume intercropping have been practiced by many researchers (Tsubo et al., 2001; Karadag and Buyukburc, 2004; Banik et al., 2006; Dhima et al., 2007). Competition among mixtures is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Species or cultivar selections, seeding ratios, and competition capability within mixtures may affect the growth of the species used in intercropping systems in rain-fed areas (Santalla et al., 2001; Karadag and Buyukburc, 2004; Carr et al., 2004; Agegnehu et al., 2006; Banik et al., 2006; Dhima et al., 2007). In Turkey, legumes, such as common vetch, common bean and cowpea are extensively used in intercropping with cereals (Kızılsimsek and Saglamtimur, 1996; Akman and Sencar, 1999).

A number of indices such as land equivalent ratio, relative crowding coefficient, competitive ratio, actual yield loss, monetary advantage, and intercropping advantage have been proposed to describe competition within and economic advantages of intercropping systems (Banik et al., 2000; Ghosh, 2004; Agegnehu et al., 2006; Banik et al., 2006; Dhima et al., 2007). However, such indices have not been used for maize and common bean or cowpea intercropping to evaluate the competition among species and also economic advantages of each intercropping system in the East Mediterranean region.

The objectives of the present study were (i) to estimate the effect of competition within cereal-legume intercropping systems, e.g., maize-common bean and maize-cowpea intercropping; (ii) to examine different competition indices in these intercropping systems and, therefore (iii) to evaluate the systems for better management of resources to obtain less competition among plants, higher productivity, sustainability, and economic value.

Materials and Methods

Crop management and experimental design

The experiment was conducted during 2003-2004 growing periods (2 years) on a private farm in Elbistan, Kahramanmaraş province of Turkey (38°21'N, 37°21'E, and 1140 m above sea level). The experimental area had dark brown soil with pH of 7.51, 55 kg ha^{-1} potassium, 48 kg ha^{-1} phosphorus, and 1.61% organic matter at the depth of 0-30 cm. Seed bed preparation included ploughing, disk harrowing, and cultivation. Sowing was performed manually by planting twice more seeds than the expected plant densities and then, rows were thinned to the required experimental density. The experiment was randomized complete blocks design with 3 replications. Fifteen experimental treatments were applied for 2 successive years (2003-2004). The treatments included sole maize (cv. P- 2332) planted at the rate of 71,500 plants ha^{-1}, sole common bean (landrace "Horoz") and a landrace cowpea planted at the rate of 285,750 plant ha^{-1} each, and the 4 intercropping treatment mixtures of maize with common bean and cowpea were i) 1M:1B, 1M:1B, 1M:1B, ii) 2M:2B, 2M:2B, 2M:2B, iii)1M:1C, 1M:1C, 1M:1C, and iv) 2M:2C, 2M:2C, 2M:2C (numbers represent row numbers, and M, B and C represent maize, common bean, and cowpea, respectively). As fixing the plant density of legumes, we modified the proportion of maize in the mixtures of each of 3 planting types in the proportions of 50:50, 67:50, and 100:50 maize-legume, respectively, where 50%, 67%, and 100% of sole maize plus 50% sole legumes were grown for each intercropping treatment. Row spacing of legumes were 70 × 10 cm while alternate row spacings for 50%, 67%, and 100% maize were 70 × 20 cm, 70 × 15 cm, and 70 × 10 cm, respectively. Common bean and cowpea were simultaneously planted with maize. Planting of the seed was done during the first week of May in each growing season. For solitary and intercropped maize treatments, nitrogen and phosphorous were added using urea and DAP fertilizers at the rate of 100 kg ha^{-1} of N and 50 kg ha^{-1} P_2O_5 at the time of sowing. All DAP and 50% of urea were applied during sowing. The other 50% of urea was side banded when the plants (maize) were about 40-50 cm in height. The sole common bean and cowpea treatments received 20 kg ha^{-1} of P_2O_5 during planting. Soil moisture was kept at an adequate level to prevent water deficiency stress during growing. Irrigation was performed on plots equally as needed. Weed control was performed manually. The experimental plots were 6m × 5.6 m = 33 m^2 involving 8 rows. Seed yield was determined by harvesting each crop separately from the mixtures in the middle 4 rows, i.e. the net plot size of 5 × 2.8 = 14 m^2. Maize was harvested at complete maturity and legumes were harvested when the first pod of the plants fully matured and dried. Seeds were weighed and adjusted to constant moisture levels of 14% and 12% maize and legumes, respectively. Weather data (rainfall and average temperature) during the experiment period were recorded daily from the experimental site and are reported as mean monthly data for both years (Figure).

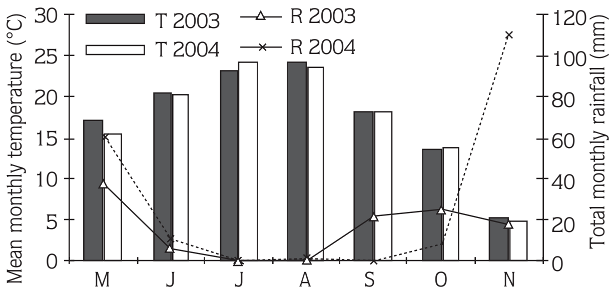

Figure. Monthly rainfall and mean air temperature during the study.

Competitions indices and monetary advantages

The benefit of planting patterns and the effect of competition between the 3 species used in this experiment were calculated using different competition indices. The land equivalent ratio (LER) was used as the first criterion for mixed stand advantage for both legumes (common bean and cowpea) and cereal (maize) (Willey, 1979).

In particular, LER verifies the effectiveness of intercropping for using the resources of the environment compared to sole cropping (Mead and Willey, 1980; Dhima et al., 2007). When LER is greater than 1, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than 1, the intercropping negatively affects the growth and yield of plants grown in mixtures (Ofori and Stern, 1987; Caballero et al., 1995; Dhima et al., 2007). The LER values were calculated as: $LER = (LER_{maize} + LER_{legume})$, where $LER_{maize} = (Yml / Ym)$, and $LER_{legume} = Ylm / Yl$, where Ym and Yl are the yields of maize and legumes as sole crops, respectively, and Yml and Ylm are the yields of maize and legumes as intercrops, respectively.

The second coefficient was the relative crowding coefficient (K) which is a measure of the relative dominance of one species over the other in a mixture (Banik et al., 2006). The K was calculated as:

$K = (K_{maize} \times K_{legume})$, where

$K_{maize} = Yml \times Zlm / ((Ym - Yml) \times Zml)$, and

$K_{legume} = Ylm \times Zml / ((Yl - Ylm) \times Zlm)$ where Zml and Zlm were the proportions of maize and legume in the mixture, respectively. When the value of K is greater than 1, there is a yield advantage; when K is equal to 1, there is no yield advantage; and, when it is less than 1.00, there is a disadvantage (Dhima et al., 2007).

The third index was aggressivity (A) which is often used to determine the competitive relationship between 2 crops used in the mixed cropping (Willey, 1979). The aggressivity was formulated as fallows:

$A_{legume} = (Ylm / Yl \times Zlm) - (Yml / Ym \times Zml)$, and

$A_{cereal} = (Yml / Ym \times Zml) - (Ylm / Yl \times Zlm)$ (Dhima et al., 2007).

For cereal example; if $A_{cereal} = 0$, both crops are equally competitive, if A_{cereal} is positive, then the cereal species is dominant, if A_{cereal} is negative, then the cereal is weak. Also, competitive ratio (CR) is another way to assess competition between different species.

The CR gives more desirable competitive ability for the crops and is also advantageous as an index over K and AYL (Dhima et al., 2007). The CR represents simply the ratio of individual LERs of the 2 component crops and takes into account the proportion of the crops in which they are initially sown. Then, the CR index was calculated using the following formula:

$CR_{maize} = (LER_{maize} / LER_{legume})(Zlm / Zml)$, and

$CR_{legume} = (LER_{legume} / LER_{maize})(Zml / Zlm)$

The next index that was used was the actual yield loss (AYL) index, which gave more acurate information about the competition than the other indices between and within the component crops and the behaviour of each species in the intercropping system, as it is based on yield per plant (Banik et al., 2000). The AYL is the proportionate yield loss or gain of intercrops in comparison to the respective sole crop, i.e. it takes into account the actual sown proportion of the component crops with its sole stand. In addition, partial $AYL_{legumes}$ or AYL_{cereal} represent the proportionate yield loss or gain of each species when grown as intercrops, relative to their yield in sole planting (Dhima et al., 2007). The AYL (Banik, 1996) was calculated as:

$AYL = AYL_{maize} + AYL_{legume}$, where

$AYL_{maize} = ((Yml / Xml) / (Ym / Xm)) - 1$, and

$AYL_{legume} = ((Ylm / Xlm)/ (Yl / Xl)) - 1$ where Xml and Xlm represent the sown proportion of intercrop maize with legume, and legume with maize, respectively.

The AYL can have positive or negative values indicating an advantage or disadvantage remained in intercrops when the main aim is to compare yield on a per plant basis.

Finally, the monetary advantage index (MAI) was calculated since none of the above competition indices provides any information on the economic advantage of the intercropping system. The calculation of MAI was as follows:

MAI = (value of combined intercrops)(LER-1) / LER;

the higher the MAI value, the more profitable the cropping system is (Ghosh, 2004). Additionally, intercropping advantage (IA) was calculated using the following formula (Banik et al., 2000):

$IA_{legume} = AYL_{legume} P_{legume}$, and $IA_{mazie} = AYL_{mazie} P_{maize}$ where P_{legume} and P_{maize} are the commercial value of legumes (the current price of common bean is 891.1 Euro and cowpea is 912 Euro per Mg, respectively), and maize (the current price is 190 Euro per Mg), respectively.

Data were analyzed using the SAS computer software program (SAS, 1998). A combined analysis of variance over 2 years was performed for the seed yield, partial LER, and total LER, as well as for all other indices using Bartlett's test to check for homogeneity of variances of each parameter among years.

Results

The highest maize seed yield was obtained from 1-row 67 maize:50 cowpea mixture while the lowest one was from 2-row 100 maize:50 cowpea mixture. The highest legume seed yield was from sole planting and the lowest one was from 2-row 100 maize:50 cowpea mixture (Table 1). Intercropping of maize with common bean and cowpea at a mix-proportion of 50:50 or 67:50 under 2 planting patterns gave higher seed yield

Table 1. Seed yield, land equivalent ratio (LER) and relative crowding coefficient (K) for sole stands and mixture of maize with common bean and cowpea in 6 planting patterns (maize–legumes, common bean, and cowpea).

		Seed yield (Mg ha^{-1})			LER values			K		
Planting patterns*	Mix-proportions (%)	Maize	Legume (B/C)	Total	Maize	Legume	Total	K_{maize}	K_{legume}	K_{total}
Maize (M) (Sole)	100	11.02	-	11.02				1.00		1.000
Bean (B) (Sole)	100	-	2.01	2.01				-	1.00	-
1 M:1 B	50:50	12.20	0.99	13.19	1.11	0.49	1.60	-10.34	0.97	-10.04
1 M:1 B	67:50	13.17	0.83	14.00	1.20	0.41	1.61	-4.60	0.93	-4.27
1 M:1 B	100:50	11.00	0.73	11.73	1.00	0.36	1.36	275.0	1.13	311.7
2 M:2 B	50:50	11.97	0.79	12.76	1.09	0.39	1.48	-12.6	0.65	-8.19
2 M:2 B	67:50	13.30	0.64	13.94	1.21	0.32	1.53	-4.38	0.63	-2.74
2 M:2 B	100:50	10.45	0.59	11.04	0.95	0.29	1.24	9.17	0.83	7.56
Cowpea (C) (Sole)	100	-	1.18	1.180				-	1.00	-
1 M:1 C	50: 50	12.15	0.68	12.83	1.10	0.58	1.68	-10.75	1.37	-14.78
1 M:1 C	67: 50	13.40	0.60	14.00	1.22	0.51	1.72	-4.23	1.37	-5.79
1 M:1 C	100: 50	10.68	0.54	11.22	0.97	0.46	1.43	15.71	1.71	26.78
2 M:2 C	50: 50	12.20	0.57	12.77	1.11	0.48	1.59	-10.34	0.94	-9.73
2 M:2 C	67: 50	12.98	0.51	13.49	1.18	0.43	1.61	-4.97	0,99	-4.96
2 M:2 C	100: 50	9.86	0.490	10.35	0.89	0.42	1.31	4.25	1.42	6.04
Mean		11.95	0.664	12.61	1.09	0.43	1.51	20.16	1.08	24.30
LSD (0.05)		0.43	0.05	0.52	0,56	0,12	0,15	3.56	0,01	7,07

*1M:1B, 2M:2B, represents planting pattern of maize-common bean, numbers represent number of rows. 1M:1C, 2M:2C, represents planting pattern of maize-cowpea, numbers represent number of rows.

compared to sole planting. Such results may be misleading when one disregards the other external inputs as to be explained under several competition indices below.

Land equivalent ratio and relative crowding coefficient

In general, partial LER_{legume} was lower in maize:common bean mixture compared to cowpea:maize (Table 1). As expected, partial LER of common bean and cowpea decreased as the proportion of maize increased in mix-proportions (Table 1). The partial $LER_{legumes}$ values were higher than 0.50 in the 1- or 2-row maize:cowpea mixtures in proportions of 50M:50C and 67M:50C; however, the partial LER_{maize} was higher than 0.50 in all cases while it decreased when the maize was more than 67% (Table 1).

The intercropped common bean and cowpea had higher K_{legume} values than the intercropped maize in the cereal-legume mixtures of 50:50 and 67:50 (Table 1). When the maize was higher than 67%, the K_{maize} had larger values (Table 1). The total K was much higher than one in the case of 100M:50B and 100M:50C. On the other hand, in the maize-common bean and maize-cowpea mixtures (mix proportions of 50:50 and 67:50), the total K values was close to one (Table 1).

Aggressivity, competitive ratio, and actual yield loss

In all planting patterns, positive A_{maize} values showed that maize was the dominant species (Table 2). Intercropped maize had higher competitive ratios (CRs) in both mixtures and in all planting patterns; however, cowpea had higher CR values than those of common bean (Table 2). In particular, AYL_{maize} had positive values in maize:common bean and maize:cowpea intercroppings when the maize proportion was less than 100% in all planting pattern and the highest AYL_{maize} value was obtained from 1- and 2-row 50 maize:50 common bean or 50 cowpea mixtures while the lowest was from 1-row 100 maize:50 cowpea (Table 2). The highest AYL_{legume} value belonged to 1-row 50 maize:50 cowpea mixture while the lowest value was to 2-row 100 maize:50 common bean (Table 2). Comparing 2 legumes, cowpea had the higher AYL_{legume} values than those of common bean (Table 2).

Intercropping advantages and monetary advantage index

The IA, which is an indicator of the economic feasibility of intercropping systems, affirmed that the most advantageous mixture was the maize-cowpea mixture at the mix-proportion of single-row 50M:50B

Table 2. Aggressivity (A), competitive ratio (CR), and actual yield loss (AYL) for mixtures of maize and legumes in 6 planting patterns (maize legumes; common bean, and cowpea).

		A		CR		AYL		
Planting patterns*	Mix-Proportion (%)	A_{maize}	A_{legume}	CR_{maize}	CR_{legume}	AYL_{maize}	AYL_{legume}	AYL_{total}
1M:1B	50:50	1.23	-1.23	2.25	0.45	1.21	-0.02	1.20
1M:1B	67:50	0.97	-0.97	2.19	0.46	0.79	-0.18	0.62
1M:1B	100:50	0.28	-0.28	1.38	0.73	-0.002	-0.28	-0.28
2M:2B	50:50	1.38	-1.38	2.76	0.36	1.17	-0.21	0.96
2M:2B	67:50	1.17	-1.17	2.84	0.35	0.81	-0.36	0.45
2M:2B	100:50	0.36	-0.36	1.62	0.62	-0.05	-0.42	-0.47
1M:1C	50:50	1.05	-1.05	1.91	0.53	1.21	0.16	1.36
1M:1C	67:50	0.81	-0.81	1.80	0.56	0.83	0.01	0.84
1M:1C	100:50	0.05	-0.05	1.05	0.95	-0.03	-0.08	-0.11
2M:2C	50:50	1.25	-1.25	2.28	0.44	1.21	-0.03	1.18
2M:2C	67:50	0.91	-0.91	2.07	0.48	0.77	-0.14	0.62
2M:2C	100:50	0.06	-0.06	1.08	0.93	-0.11	-0.17	-0.28
Mean		0.79	-0.79	1.94	0.57	0.65	-0.14	0.51
LSD (0.05)		0.12	0.12	0.14	0.05	0.03	0.04	0.03

*1M:1B, 2M:2B, represents planting pattern of maize-common bean, numbers represent number of rows. 1M:1C, 2M:2C, represents planting pattern of maize-cowpea, numbers represent number of rows.

plant density (mix proportion) with IA value of +372.75 (Table 3). The lowest IA value of -382.53 showed that 2-row 100M:50B lead to highest loss and there were fewer negative values for cowpea than for common bean (Table 3).

The values of MAI was higher in maize-cowpea intercropping than the maize-common bean intercropping and the highest MAI was observed for 1M:1C (mix-proportion of 67M:50C) intercropping (Table 3). The lowest MAI value belonged to 2-row 100 M:50 B (Table 3). Compared to common bean, 1-row yielded better MAI values than did 2-row and cowpea had higher MAI values (Table 3).

Discussion

The results showed that the sole cropping of legumes yielded higher than did all the maize-legume combinations although such mixture indeed increased the seed yield of maize especially in mix-proportions of 67M:50B (13.3 Mg ha^{-1}) in 2-row planting and 67M:50C (13.4 Mg ha^{-1}) in single-row planting (Table 1). The reason for increased seed yield in maize may be attributed to nitrogen fixing ability of legumes and extensive root system of cereals (Chen et al., 2004). Increasing maize proportion from 50 to 67 increased maize seed yield around 10%. Total grain yield was higher in the proportion of 67:50 maize-common bean or maize-cowpea mixtures (both 14.0 Mg ha^{-1}) compared to the total of solitary grown crops (13.03 Mg ha^{-1}) (Table 1).

By combining several other external indices, optimum yield advantages may also be provided. The land equivalent ratio indices were the greatest in maize-cowpea (1.72) and maize-common bean (1.61) in the 1-row and 67:50 mix-proportion, indicating that for the same amount of grain yield, 72%-61% more area would be required for solitary cropping system compared to intercropping. Total LER values were higher than one showing the advantage of intercropping over sole stands in regard to the use of environmental sources for plant growth (Mead and Willey, 1980). Similar results were reported for mix-proportions of pea-barley (Chen et al., 2004), bean-wheat (Hauggaard-Nielsen et al., 2001), and maize-faba bean (Li et al., 1999). On the other hand, Banik et al. (2000) reported intercropping reduced the yield of mustard-pea, mustard-lentil, and mustard-gram mixtures over sole cropping. Partial LER values also showed that, compared to common bean, cowpea appears to have more beneficial land use efficiency in all mixtures.

Table 3. Intercropping advantage (IA) and monetary advantage index (MAI) for mixtures of maize and legumes in 6 planting patterns (maize-legumes; common bean, and cowpea).

Planting patterns*	Mix-proportion (%)	IA			MAI
		IA_{maize}	IA_{legume}	IA_{total}	
1 M:1 B	50:50	230.69	-13.37	217.32	1201.2
1 M:1 B	67:50	150.94	-160.50	-9.55	1222.4
1 M:1 B	100:50	-0.34	-247.88	-248.22	725.4
2 M:2 B	50:50	222.76	-189.92	32.84	967.9
2 M:2 B	67:50	154.31	-323.67	-169.36	1069.5
2 M:2 B	100:50	-9.83	-372.71	-382.53	486.5
1 M:1 C	50:50	228.97	143.79	372.75	1187.8
1 M:1 C	67:50	156.90	12.37	169.27	1296.7
1 M:1 C	100:50	-5.86	-72.67	-78.53	758.1
2 M:2 C	50:50	230.69	-27.83	202.86	1055.6
2 M:2 C	67:50	146.03	-131.42	14.61	1104.0
2 M:2 C	100:50	-20.00	-154.61	-174.61	549.0
Mean		123.77	-128.20	-4.43	968.7
LSD (0.05)		8.01	5.49	9.57	43.7

*1M:1B, 2M:2B, represents planting pattern of maize:common bean, numbers represent number of rows. 1M:1C, 2M:2C, represents planting pattern of maize:cowpea, numbers represent number of rows.

The crowding coefficient (*K*) values for maize was much higher than 1, indicating an absolute yield advantage of maize over the other legumes in the intercropping systems of 1 maize-1 legume planting pattern and 100:50 mix-proportion. Such a result was expected since cereals are more competitive than legumes. In addition, increased seed amount per unit area cereals especially with large canopy could drastically overcrowd legumes. Similar results reported by Banik et al. (2000) in chickpea-wheat intercropping and Dhima et al. (2007) in cereal-vetch intercropping. Partial *K* values of legumes were higher than partial *K* values of maize in the 50:50 or 67:50 mix-proportion of 1- or 2-row planting pattern. In addition, *K* values for cowpea were higher compared to common bean, indicating that cowpea was more competitive than common bean in cereal-legume mixtures. In a groundnut-cereal mixtures, cereals overcrowded groundnut (K_{cereal} values > 1; Ghosh, 2004). In the present study, we also found that variation in *K* values may change when the density and types of plants were modified. When maize-legume intercropping was considered in close rates such as 50:50 or 67:50 ratios, competition among the plants seemed to be against maize while it was in favor of cowpea (Table 1).

Considering all mix-proportions and planting patterns, A_{maize} values were always positive and A_{legume} values were all negative, showing that maize was the dominant species as reported by previous cereal-legume mixture studies (Ghosh, 2004; Dhima et al., 2007). The results of competitive ratio (CR) index were also in corroboration with those of the aggressivity index. The values of A and CR for cowpea were greater than those of common bean in all planting patterns. This indicated that cowpea was more competitive than common bean in maize mixtures. Although increasing the cereal rate in mixtures elevated the crowding efficiency over legumes, doubling the rate per se may commence competition among maize plants, which probably resulted in weaker growth, thereby, lower CR and A_{maize} values. This was also confirmed with the negative AYL_{maize} values that were negative only when the maize ratio was the highest. This was probably due to the fact that nitrogen fixing ability of the legumes did not compensate vigorous growth of cereals over a certain proportion. According to Banik et al. (2000), AYL index gave more accurate information than the other indices on inter- and intraspecific competitions in intercropping systems. Thus, there was a 16% (AYL_{cowpea} = + 0.16) and 1% (AYL_{cowpea} = +0.01) increase in yield of cowpea in the maize-cowpea intercropping (50M:50C and 67M:50C mix-proportions in 1-row planting, respectively), when compared to their sole crop yields. However, in all other planting patterns and mix-proportions, the AYL_{legume} ranged from -0.42 to -0.02 indicating a yield loss of 42%-2%, compared to sole crop yield. The magnitude of AYL_{cowpea} that is greater than $AYL_{common\ bean}$ indicated that cowpea was more resistant to yield loss than common bean in maize-legume intercropping. The AYL_{maize} had positive values in maize-cowpea intercropping when the maize proportion was either 50% or 67% regardless of planting patterns, respectively (Table 2), indicating an advantage of intercropping over sole stands.

The intercropping advantage (IA) affirmed that the most advantageous mixtures were observed in single rows of maize-cowpea and maize-common bean in 50:50 mix-proportions with the highest IA values of +372.75 and +217.32, respectively (Table 3). The Monetary Advantage Index (MAI) values were positive in all planting patterns and mix-proportions, which shows definite yield and economic advantages compared to the sole cropping systems tested in our study. In particular, MAI was higher in maize-cowpea intercropping than in maize-common bean intercropping. The highest MAI (1296.7) was observed with maize-cowpea intercropping at the mix-proportions of 67:50, which implies the most advantageous economic mixture. These findings are also parallel to those of LER and competitive indices. Ghosh (2004) and Dhima et al. (2007) reported that if LER and K values were higher, there was also economic benefit expressed with MAI values. More net income was obtained compared to sole cropping when bush beans intercropped with sweet maize (Santalla et al., 2001). Higher seed yield and net income under planting pattern with changing mix-proportions may be explained in higher total productivity under intercropping with relatively less input investment (Banik et al., 2006).

Conclusions

The present study concludes that intercropping of maize with common bean and cowpea in different planting patterns and mix-proportions may affect seed yield, competition between the 2 species (maize and legumes), and economics of the planting patterns as compared to solitary cropping of the same species. Regardless of planting patterns, maize-cowpea or maize-common bean intercropping both at the 67:50 mix-proportions had the yield advantages of intercropping and optimum exploitation of the environmental resources as opposed to other intercropping systems. Additionally, these 2 intercropping systems (mix-proportions of 67:50 for maize-cowpea or maize-common bean) were observed to be the most profitable. Furthermore, cowpea intercropped with maize was more competitive than common bean. Generally, maize was the dominant species in all mixtures and planting patterns. Although legumes had lower yield in mixture but are more expensive in markets, solitary planting of them would not reach the profitable level gained with maize or other cereals cited in literature. In addition, the ratio of proportion also seemed to significantly affect the efficiency of intercropping. For example, the mix-proportion of 67:50 plant density in all mixtures resulted in significant advantages of intercropping as confirmed by the economic and land use efficiency values. The monetary profit may increase as much as 65% for 67M:50C and 34% for 67M:50B in 1-row planting per unit area compared to sole legume or sole maize planting. Such a system can be easily practiced especially by small farmers in the East Mediterranean region of Turkey as well as in other countries which have similar climate. Therefore, along with profitability for farmers, sustainability of agriculture, and soil conservation may be improved in such environments.

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