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Effect of maize/legume intercropping on crop productiviy and soil compaction

İlkay Yavaş Üstündağ[a*], Aydın Ünay[b]

[a]*Department of Crops and Animal Production, Koçarlı Vocational High School, University of Adnan Menderes, Aydın*
[b]*Department of Field Crops, Faculty of Agriculture, University of Adnan Menderes, Aydın*
[*]Corresponding author's email: iyavas@adu.edu.tr

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ABSTRACT
This research was conducted in western of Turkey to determine the effects of maize/legume intercropping on productivity and soil compaction. The experiment comprised 7 treatments: sole planting of maize (*Zea mays* L.), cowpea (*Vigna sinensis* L.) and soybean (*Glycine max* L.), and 2 different planting patterns (1- and 2-row proportion) with 4 maize-legumes intercropping series. Intercropping significantly affected plant height, 1000 grain weight, the height of first ear and grain yield of maize. The results revealed that sole maize and maize+soybean double row strips gave maize grain yield as 11680.2 kg ha^{-1} and 8990.5 kg ha^{-1}, respectively. Land equivalent ratio (LER) was greater than 1, indicating that this cropping system was profitable in terms of land utilization. Maximum LER (1.743) was recorded in maize+soybean double row strips. Intercropped legumes were significantly increased soil compaction because of the machine traffic in alternate rows. Based on better interception of sunlight energy, crop growth and grain yield collected during the two growing seasons, 1M:2S (1.74) and 1M:2C (1.69) intercropping systems should be suggested.

Keywords:
Intercropping
Land equivalent ratio
Legume
Maize
Soil compaction
Yield

Mısır/baklagil birlikte ekiminin verimlilik ve toprak sıkışıklığı üzerine etkisi

ÖZET
Bu araştırma Türkiye'nin batısında mısır/baklagil birlikte ekiminin ürün verimliliği ve toprak sıkışıklığı üzerine etkisini belirlemek amacıyla yürütülmüştür. Deneme 7 uygulamadan oluşmuştur: saf mısır (*Zea mays* L.), börülce (*Vigna sinensis* L.) ve soya (*Glycine max* L.) ekimi, ve 2 farklı ekim düzeni (1 ve 2 sıralı) ve 4 mısır-baklagil birlikte ekim serisi. Birlikte ekim mısırda bitki boyu, 1000 tane ağırlığı, ilk koçan yüksekliği ve tane verimini önemli bir şekilde etkilemiştir. Sonuçlar saf mısır ve mısır+soya çift sıra ekim sisteminin sırasıyla 11680.2 kg ha^{-1} ve 8990.5 kg ha^{-1} tane verimi verdiğini ortaya koymuştur. Alan eşdeğer oranının 1'den büyük olması, bu üretim sisteminin alan kullanımı açısından karlı olduğunu göstermiştir. En yüksek alan eşdeğer oranı (1.743), çift sıralı mısır ve soya birlikte ekiminden elde edilmiştir. Baklagiller ile birlikte ekim ardışık sıralara ekimde makine yoğunluğundan dolayı toprak sıkışıklığını önemli bir şekilde artırmıştır. İki yıllık veriler birlikte ekim sisteminde daha iyi alan eşdeğer oranı, güneş enerjisinden daha iyi yararlanma, bitki gelişimi ve verimi açısından 1M:2C (1.69) ve 1M:2S (1.74) ekim sisteminin önerilebileceğini göstermiştir.

Anahtar Sözcükler:
Birlikte ekim
Alan eşdeğer oranı
Baklagil
Mısır
Toprak sıkışıklığı
Verim

1. Introduction

Intercropping can be defined as the agricultural practice of cultivating two or more crops in the same space at the same time, is an old and commonly used cropping practice which aims to match efficiently crop demands to the available growth resources and labor. To overcome the loss of a full growing season, intercropping with legumes is a good alternative. The purpose of intercropping is to generate beneficial biological interactions between the crops. It developes soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation through greater ground cover than sole cropping (Lithourgidis et al., 2011).

Intercropping is used in many parts of the world. Especially cereal-legume intercrops are frequently used. Intercropping systems provides yield stability over mono cropping and supply greater resource use efficiency. Cereal-legume intercropping is a more productive and profitable cropping system in comparison with solitary cropping (Tosti and Guiducci, 2010). Grain legumes such as field pea, soybean, faba bean and narrow-leafed lupin benefit the cropping system, contributing with atmospheric N inputs through biological N_2-fixation and recycling of N-rich residues a fundamental process for maintaining soil fertility in, for example, organic farming systems (Hauggaard Nielsen et al., 2007). The cereal is usually taller and has faster growing or more extensive root system and competitive for soil nitrogen than legumes. Therefore shading may influence the quality of legumes (Wekesa et al., 2015).

Intercropping treatments and spatial arrangement of soybean or cowpea grown in asssociation with maize in Turkey has not been extensively studied and not well documented. Pekşen et al. (1999) revealed that the share of cereals was higher in cereal-legume intercropping systems. In other studies, it was found that sole maize yield was higher than intercrop maize yield (Ertürk, 2011; Sabancı, 2015).

Actually, there is also great interest in the detection of innovative ways in intercropping systems. This practice is not only helping farmer’s double yields but also protecting the crops against diseases and extreme weather conditions. Therefore the objective of this study was to determine the effective spatial arrangement for maize and legumes (soybean and cowpea) in terms of productivity and soil efficiency using competition indices.

2. Material and Methods

The effects of intercropping on productivity and soil compaction were evaluated at the experimental field of Agricultural Faculty the University of Adnan Menderes in the growing season of 2011/2012 and 2012/2013. During the field experiments from May to September the average air temperatures, precipitation and relative humidity and long term (1954-2013) values were given at Table 1.

Table 1. Monthly average temperatures, precipitations and relative humidity

Month	Temperature (°C)			Precipitation (mm)			Relative humidity (%)		
	2011/12	2012/13	1954 /13	2011/12	2012/13	1954/13	2011/12	2012/13	1954/13
May	19.2	20.1	20.9	49	43.6	34.3	72	73	56.4
June	24.7	27.0	25.9	50	2.4	12.6	57	55	48.8
July	27.5	29.6	28.4	0.4	3.2	4.0	55	51	49.5
August	26.9	27.9	27.5	0.0	0.0	1.8	53	45	54.3
September	23.5	22.7	23.4	38.4	0.0	12.9	59	63	56.6

The soil was characterized as sandy loam. The topsoil was alkaline (pH of 7.6), 0.10 mg kg^{-1} N; 2.1 mg kg^{-1} P; 124.0 mg kg^{-1} K, and was poor in organic matter (1.2 %). N-P-K fertilizer was applied at the 30 kg ha^{-1} in the form of 15-15-15. All P, K and with half of N were applied during the time of land preparation. The other half of N was applied at the 12 kg ha^{-1} six weeks after sowing as urea. The site was divided into 30 plots that were the experimental units to which the following treatments were randomly assigned in a completely randomized design and three replications as follows:

(i) (1M:1S): There were four rows of maize sown at spacing of 70×20 cm and between every two rows; a row of soybean was placed at 35 cm from maize rows.

(ii) (1M:1C): There were four rows of maize sown at spacing of 70×20 cm and between every two rows; a row of cowpea was placed at 35 cm from maize rows.

(iii) Sole maize: There were four rows of maize sown at spacing of 70×20 cm.

(iv) Sole legumes: There were four rows of legumes sown at spacing 35×5 cm.

One soybean cultivar (Umut, 2002), one cowpea cultivar (Karagöz-86) were simultaneously seeded as monocrop or intercropped with maize (PR31G98) in alternate or double rows. The crops were sown in 18/05/2011 and 03/05/2012. Irrigation of crops was simultaneously during the third week of June. The subsequent irrigations were applied as per 10 days during the period of the trial.Each plot was 5 m long which sown by planter in four rows. None of the legume seeds were inoculated with *Rhizobium*.

2.1. Examined properties

-Maize grain yield (kg.ha^{-1}): Ear was harvested at complete maturity. The grain moisture content was measured by using a moisture meter and grain yield was adjusted to 15% moisture content using the following formula:

Adjusted Yield=Measured yield x [(100-moisture %)/85]

Legume grain yield (kg.ha^{-1}): The legumes were harvested when both the pods and stems were dry. Grain yield was adjusted to 13% moisture content using the same formula as used for maize.

-The number of pods/ plant: The no. of pods from 10 randomly selected plants was counted and their average was calculated (Raza et al., 2012).

-1000-grain weight (g): The sample of a hundred grains (legume) was taken from seed lot of each plot and expressed in grams (Raza et al., 2012).

-Plant height (cm): At maturity, ten plants were selected randomly from each plot. The maize height was measured from the soil surface to the tip of panicle/flag leaf. Legume height was measured from the soil surface to the growing point. Average plant heights were calculated (Lemlem, 2013).

-Maize first ear height (cm): At maturity, ten maize plants were selected randomly from each plot. Their first ear height was measured from the soil surface to first ear node with the help of a meter rod and average height was calculated.

-Land equivalent ratio (LER): Efficiency of intercropping over sole cropping has been evaluated by various indices. Afe and Atanda (2015) utilize the the concept of land equivalent ratio (LER) described as the total land area required under sole cropping to give the yield acquired in the intercrop system. The LER values were calculated as: LER= (LERM + LERL), where LERM= YIM/YM and LERL= YIL/YL, where YM and YL are the yields of maize and legume as sole while YIM and YIL are the yields of maize and legume as intercrops, respectively.

-Soil compaction (MPa): Soil compaction was evaluated indirectly by measuring soil penetration resistance with Dickey-John soil penetometer. Within each plot, 3 randomly measurements were made. Measurements were taken at the depth of 40 cm and 75 cm at the end of the dent (R5) stage of maize and averaged.

2.2. Statistical analysis

All data were statistically analyzed with the SPSS Statistical Analysis System. Probabilities equal to or less than 0.05 were considered significant. Differences between treatment was performed with LSD test to separate them (SPSS, 1999).

3. Results and Discussion

Table 2 showed that intercropping treatments had significant effect on first ear height, 1000-grain weight, grain yield and soil compaction except plant height. Besides, year x treatment interaction were significant for plant height, first ear height, 1000-grain weight.

Table 3 gave the mean values of agronomic, yield and yield components of maize, soil compaction and land equivalent ratio.

Table 2. Combined analysis of variance for observed characters in maize

Source of variation	PH (cm)	FEH (cm)	1000-GW (g)	GY (kg ha^{-1})	SC (MPa)
Replication	ns	ns	ns	ns	ns
Year	**	**	**	ns	ns
Treatment	ns	**	**	**	**
Year x Treatment	*	**	**	ns	ns

** significant at the 0.01 level, * significant at the 0.05 level, ns; non-significant. PH: Plant height, FEH: First ear height, 1000-GW: 1000- grain weight, GY: Grain yield, LER: Land equivalent ratio, SC: Soil compaction

Table 3. Mean values of observed characters in maize

	PH (cm)		FEH (cm)		1000-GW (g)		GY (kg.ha^{-1})	LER	SC (MPa)
Treatments	1	2	1	2	1	2	1-2	1-2	1-2
1M:1C	214.7b	252.7	55.3d	84.0 ab	312.3bc	349.7c	8800.5c	1.485	2.3a
1M:2C	196.0c	259.8	58.0c	89.8a	291.0d	402.3e	8800.2c	1.692	2.1b
1M:1S	222.0a	252.2	60.7b	77.5b	300.7ab	391.0 b	8860.0bc	1.662	2.1b
1M:2S	195.0c	257.0	55.7d	94.0a	307.7c	418.3d	8990.5b	1.743	2.1b
M	224.3a	263.2	66.0a	88.2a	318.0a	438.7a	11680.2a	1.000	1.0c
LSD Int. $_{0.05}$	5.1		1.9		8.5				
LSD Tre.$_{0.05}$							160.7		0.06

1: 2011-2012 year, 2: 2012-2013 year, 1-2: Combined years; LSD Int. for significant interactions of year x treatment; LSD Tre.; for only significant treatment. PH: Plant height, FEH: First ear height, 1000-GW: 1000- grain weight, GY: Grain yield, LER: Land equivalent ratio, SC: Soil compaction

Plant height was significantly different among the treatments. Maximum plant height was obtained from sole maize with 224.3 cm in 2011/2012 and 263.2 cm in 2012/2013. Minimum plant height values were recorded from 1M:2S and 1M:2C treatments, respectively in 2011/12. Second year the lowest values were observed from 1M:1S and 1M:1C. Similarly, intercropping maize with soybean reduced maize plant height (Undie et al., 2012). But some research results showed that plant height of maize increased with intercropping (Geren et al., 2008). This observation is similar to the findings of Erdoğdu (2004) who evaluated the effect of different seeding rates of intecropped corn and soybean on some plant characteristics and forage yield. In a study results conducted at the Nigeria, showed that the height of corn at R3 was significantly higher under 1:1 intercropping than in sole cropping, while the 1:2 intercropping treatment values of corn height were intermediate (Ariel et al., 2013). The intercropping systems had significant effects on yield and other traits in two growing seasons, except plant height in the first season (Abdel Aziz et al., 2012). Values of first ear height for maize indicated that there was a significant difference in first ear height for all treatments in both growing seasons. In 2011, the highest first ear height for maize was recorded from sole cropping, while the highest height was recorded in the 1M:2C treatments in 2012. Our results was in agreement with Tiryaki et al. (2004) who reported that maize first ear height was significantly higher when it was sown alone as compared to intercropped. Sole cropping system was given the highest 1000-grain weight. Generally higher values of maize may be a sign for legumes improve soil fertility as reported by Birteeb et al. (2011). The lowest values were probably due to availability of less photosynthates for grain development and enhanced shading as reported by Abuzar et al. (2011).

The weight of thousand grain was significantly affected by intercropping treatments. The mean data regarding 1000-grain weight were presented in Table 3. The highest values of one thousand grain weight were obtained from sole maize. The maize 1000- grain weight was calculated with 318.0 g in 2011 and 438.7 g in 2012. The yield obtained from monocropped maize was greater than that produced from intercropped maize (Table 3). This could be due to the greater number of ear and ear weight. In both years, sole maize had significantly higher grain yield. The highest yield were 1168.2 kg.ha^{-1}, 899.5 kg.ha^{-1} and 886.0 kg.ha^{-1} with monocropped maize, 1M:2S and 1M:1S respectively. Higher yield in sole cropping over intercropping had also been stated by Ijoyah et al. (2013). Similar results were found by Dariush et al. (2006). Some researchers found that intercropping maize and cowpea in within-row led to maize yield loss of only 6 %, whereas distinct-row intercropping reduced maize yield by 25% (Rusinamhodzi et al., 2012). Researchers evaluated the growth, yield and water use efficiency of maize-sorgum intercrop. Similar results have been reported by Shahbazi and Sarajuoghi (2012). They found that sole maize had significantly higher grain yield than 2:1 and 3:1 alternate row arrangements. In sorghum-cowpea intercroping arrangements, it was observed that yields of component crops varied with the row arrangements of the crops (Addo Quaye et al., 2011). They also showed that maize planted in alternate rows with soybean gave significantly higher grain yield than those planted in double rows of soybean. On the other hand, sole maize recorded higher grain yield than intercropped arrangements. This finding is in agreement with those of researchers who observed the highest maize grain yield from sole maize in maize-legume intercrooping systems (Geren et al., 2007).

The trend of grain yield and yield advantage in terms of land equivalent ratio, LER, is shown in Table 3. The LER values were higher than one in all intercropping treatments compared to sole crops. LER values showed higher than one. This indicated intercropping an optimum exploitation of the environmental resources. Some researches showed that the land equivalent ratios were higher than one in all intercropping plots and soybean planted simultaneously with maize gave the highest LER (Addo Quaye et al., 2011; Takım, 2012). Besides soybean planted in double rows with maize recorded higher LER than maize alternating with single rows of soybean. Researchers Prasad and Brook (2005) showed that the agronomic advantage measured in terms of LER for both biomass and grain yield of all intercropping treatments was greater than unity, indicating higher land use efficiency of intercrops compared to sole crops. Our findings are strongly supported by Erdoğdu (2004); Geren et al. (2007).

The physical forces applied to the soil leads to soil compaction which destroy soil structure, limit air and water infiltration, reduces soil porosity and crop yield. Data regarding soil compaction showed that intercropping maize with soybean and cowpea increased the soil compaction because of the intensive soil tillage. Soil compaction hinders water movement and distribution in the soil, decrease the availability of water and nutrients to crops (Zegada-Lizarazu et al., 2006). Besides soil compaction from machine traffic could reduce soil respiration by reducing pore space and limiting O_2 diffusion. Reduced soil respiration may show less microbial activity and anaerobic conditions. As a result, this conditions could negatively affect crop yield (Tracy and Zhang, 2008). Researchers stated that they ignores possible yield increasing from decreased compaction resulting from the smaller equipment used in strip intercropping (Ward et al., 2013). It has been reported by Leggett (2013) that soil compaction was higher when intercropping applied with switchgrass and pine as compared to the pine. Finally, it should be recommended that long term tillage experiment (especially least 4 seasons) would be required to detect changes in soil physical properties as a result of the intercropping systems.

Table 4 showed that intercropping treatments had significant effect on all of cowpea and soybean agronomic, yield and yield components.

Table 5 and Table 6 gave the mean values of agronomic, yield and yield components value of cowpea and soybean. The plant height of cowpea was significantly affected from intercropping arrangements. The highest plant height value of cowpea was obtained from 1M:1C treatments with 161.8 cm. Different intercropping treatments caused significant variation in pods plant^{-1} of cowpea. Similar results have been reported by Geren et al. (2007). The number of pods showed that the highest values were observed in monocropping treatments than intercropping.

The pods plant^{-1} were higher in case of cowpea monocropping with 16.9 and 21.0 respectively in 2011 and 2012 as compared to intercropping with maize. The lowest pods plant^{-1} were recorded at 1M:1C systems with 9.8 and 9.3 respectively in years 2011 and 2012. It can be originated from higher pods plant^{-1} in sole cowpea plots might be attributed to no interspecific competition and better utilization of nitrogen being applied as a starter dose. Therefore values directly influences grain yield of cowpea. Number vof pods plant^{-1} of cowpea were higher in monoculture as compared to

Table 4. Combined analysis of variance for observed characters in cowpea and soybean

Source of variation	Cowpea				Soybean		
	PH (cm)	PN	1000-GW (g)	GY (kg ha^{-1})	PH (cm)	PN	GY (kg ha^{-1})
Replication	ns	ns	ns	ns	ns	ns	ns
Year	ns	*	ns	ns	ns	ns	*
Treatment	**	**	**	**	ns	**	**
Year x Treatment	ns	**	ns	**	ns	ns	*

** significant at the 0.01 level, * significant at the 0.05 level, ns; non-significant. PH: Plant height, PN: Pod number per plant, 1000-GW: 1000-grain weight, GY: Grain yield

Table 5. Mean values of observed characters in cowpea

	PH (cm)	PN		1000-GW (g)	GY (kg ha^{-1})	
Treatments	1-2	1	2	1-2	1	2
1M:1C	161.8 a	9.8 c	9.3 c	216.7 b	1061.0b	1052.0b
1M:2C	127.3 b	12.0 b	14.0 b	213.0 c	1372.0a	1401.0a
C	89.5 c	16.9 a	21.0 a	221.9 a	1457.0a	1446.0a
LSD Int. $_{0.05}$		1.6			315.6	
LSD Tre.$_{0.05}$	6.5			2.7		

1: 2011-2012 year, 2: 2012-2013 year, 1-2: Combined years; LSD Int. for significant interactions of year x treatment; LSD Tre.; for only significant treatment. PH: Plant height, PN: Pod number per plant, 1000-GW: 1000-grain weight, GY: Grain yield

Table 6. Mean values of observed characters in soybean

Treatments	PH (cm)	PN	GY (kg ha^{-1})	
	1-2	1-2	1	2
1M:1S	144.0	14.2 b	1957.0 b	1975.0 b
1M:2S	143.3	17.9 b	2115.0 a	2180.0 a
S	142.8	41.2 a	2155.0 a	2203.0 a
LSD Int. $_{0.05}$			178.5	
LSD Tre.$_{0.05}$		4.3		

1: 2011-2012 year, 2: 2012-2013 year, 1-2: Combined years; LSD Int. for significant interactions of year x treatment; LSD Tre.; for only significant treatment.PH: Plant height, PN: Pod number per plant, GY: Grain yield

their corresponding intercropped (Alhaji, 2008). This results are also parallel to the findings of Geren et al. (2007).

The highest 1000-grain weight values obtained from sole cowpea (221.9 g), 1M:1C (216.7 g) and 1M:2C (213.0 g) respectively. Heavier grains were obtained in plots where cowpea was sown as sole while grain weight was lower in plots where cowpea was planted with maize. Data regarding grain yield of cowpea in 2011 and 2012 cropping seasons are given in Table 6. Cowpea grain yield varied significantly in different intercropping systems. Higher grain yield values were obtained with 1457.0 kg.ha^{-1} in 2011 and 1446.0 kg.ha^{-1} in 2012 where cowpea was monocropped. Similarly, Geren et al. (2007) found that sole cowpea yield was between 1410 kg.ha^{-1} and 1740 kg.ha^{-1} in their intercropping studies. Intercropping (1M:1C) significantly reduced grain yield at compared to cowpea planted as a sole crop (Table 6). But 1M:2C intercropping system showed similar results to sole cropping. Because this intercropping system has large row spacing than 1M:1C. If cowpea intercropped with maize, resources such as nutrient, water uptake, sunlight were shared by maize crop which is strong competitior as compared with cowpea. Intercropping treatments with large row spacing have benefitted more from sunlight, soil moisture, nutrient and space. Shading by taller maize plants could have contributed in the reduction of cowpea yield. Similar results are emphasized by the research results of Sikirou and Wydra (2008) who observed that the reduction of cowpea yield when cowpea was intercropped maize. The plant height of soybean was not significantly affected from intercropping arrangements. The plant height values were observed 144.0 cm, 143.3 cm and 142.8 cm for 1M:1S, 1M:2S and sole soybean respectively (Table 6). Due to the direction of sunlight into the plots, the competition for light of plants in intercropping was increased. It has been reported by researchers that the average plant height of the soybean plants was slightly increased as time of introduction of soybean was delayed (Addo Quaye et al., 2011).

Intercropping treatments significantly reduced the number of pods per plot. Monocropping treatments were the highest value (41.2) (Table 6). The greater number of pods produced from monocropped soybean could have been influenced by its greater number of branches and leaves. Similarly it was found that maize/soybean intercropping with nitrogen application increased number of pods per plant (Undie et al., 2013). Some researchers observed that cropping system 2 maize: 4 soybean had significant increases in each no.of pods/plant (Abdel Aziz et al., 2012).

Yield of soybean as sole and intercrop with maize in 2011 and 2012 cropping seasons was given in Table 6. Intercropping (1M:1S) significantly reduced grain yield at compared with soybean planted as a sole crop (Table 6). The lowest soybean yields were 1957.0 kg ha^{-1} and 1975.0 kg ha^{-1} respectively, with 1M:1S treatments in years 2011 and 2012 while 1M:2S intercropping system showed similar results to sole crop. Shading by taller maize plants and narrow spacing could have contributed in the reduction of soybean yield. Researchers stated that the reduction in yield by intercropping could be due to interspecific competition and depressive effect of maize who evaluated the effect of maize planting density on the performance of maize/soybean intercropping system (Muoneke et al., 2007). Similar results have been reported by Addo Quaye et al. (2011).

In this research four maize/soybean-cowpea intercropping treatments were tested for its productivity. The results showed that intercropping of maize with soybean and cowpea in different sowing treatments might influence grain yield, competition between maize and legumes as compared to sole cropping of the maize and legumes. Comparing the productivity of intercrops with the productivity of monocrops of maize, soybean and cowpea by means of LER index, we obtained that intercropping treatments with maize consistently recorded LER values one or greater than one, suggesting that soybean and cowpea simultaneously seeded may be the best treatments. Intercropping treatments increased compaction of the soil because of the intensive soil tillage. In spite of these results, long-term studies needed to comment changes in soil compaction as a result of the intercropping systems.

Results showed that intercropping at 1M:2S and 1M:2C treatments were the most productive treatments after sole cropping pattern, compared with the other treatments.

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