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Productivity, relative yield and plant growth of forage corn intercropped with soybean under different crop combination ratio

Ali Baghdadi[1], Ridzwan A. Halim[1]*, Radziah Othman[2], Martini Mohammad Yusof[1] and Ali Reza Mahdavi Atashgahi[3]

Department of Crop Science, Faculty of Agriculture,
Universiti Putra Malaysia, 43400 Serdang, Malaysia.
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ABSTRACT

An experiment was carried out to evaluate influence of different crop combination ratios of corn and soybean in terms of forage yield in corn-soybean intercropping. The experiment compared both corn and soybean as monocultures and in different intercropping ratios from 25:75, 50:50 and 75:25 of corn to soybean. The crop combination ratio had significant effects on physiological traits and dry matter yield of forage. The ratio of 75:25 and 50:50 recorded DM yields similar to those of monocropped corn (14.77 t/ha). Relative yield total (RYT) values of intercropping were higher than that of monocrop corn and soybean. Mixtures with 50:50 combination ratio had higher mean total relative yield values (1.15) in comparison with the other ratios. Land equivalent ratio (LER) increased with corn-soybean intercropping and the highest total LER value was recorded with 50:50 ratio (1.13). The crop ratio of 50:50 gave the best combination based on DM yield, relative yield, LER of the combined forage.

Key words: Corn-legume forage, Forage yield, Intercropping, LER, Relative yield.

INTRODUCTION

With the rapid population increase, the demand for food has been increasing while land availability has been declining. Thus, the only way to increase agricultural production is to increase yield per unit area (Hirpa, 2014).

In tropical regions, corn has been considered as the best component in most of intercropping system (Ijoyah, 2012). Intercropping is an effectual and the economical production system not only increases the production per unit area and time, but also increases the resource use efficiency and economic stock of the growers (Bhatti *et al.*, 2013). Presently, intercropping is gaining acceptance among small holder farmers as it provides a yield advantage compared to sole cropping through yield stability and achieving diversified domestic needs (Nazir *et al.*, 2002; Bhatti *et al.*, 2006; Bhatti *et al.*, 2013).

Intercropping practices have some benefits such as improving yield (Esmaeili *et al.*, 2011; Sadeghpour and Jahanzad, 2012) and increasing biological activities in the soil, and decreasing pests (Smith and McSorley, 2000). A number of indices such as LER, crop combination ratio, real yield loss, financial advantage, and intercropping benefits have been proposed to describe competition within and economic advantages of intercropping systems (Carr *et al.*, 2004; Banik *et al.*, 2006; Agegnehu *et al.*, 2006; Dhima *et al.*, 2007). Forage corn responds differently to crop combination ratio under different environmental and cultural factors, which influence corn forage yield and quality.

Different crop combination ratio for intercropping of legumes and cereals have conflicting experimental results on the potential productivity advantage of mixed cropping over monoculture including cereal and legume mixtures. Similarly, the yield advantage of intercropping has not been so marked in several situations possibly due to the use of supra-optimal plant population proportions and, in some cases, to the use of sub-optimal population proportions for component crops (Refay *et al.*, 2013).

The effect of management, such as crop combination of the intercrops used in the system has an effect on yield and yield components, under various densities in the intercropping system. Waktola (2014) reported that LER was superior in all intercrops implying that the productivity of corn-soybean intercropping has a higher RY advantage over sole cropping under the additive intercropping system. The RYT may be lower than one if one species or both are more affected than might be expected when there is crowding for the same space. RYT value of less than one is thus a reflection of intense competition. Nassab *et al.* (2011) reported an RYT value of less than one in corn/soybean intercrops and attributed it to more competition between the intercrop components. Productivity and long-term maintenance of corn-soybean mixtures depend on the crop

*Corresponding author's e-mail: ridzwan@upm.edu.my.
[1] Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia.
[2] Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia.
[3] Department of Animal Science, Faculty of Agriculture, Islamic Azad University of Rasht-Iran.

combination of intercropping systems. For this reason, determining the ideal crop combination is a very important research topic. The objective of the experiment therefore, is to evaluate the effect of different crop combination ratio of corn and soybean on yield of mix forage.

MATERIALS AND METHODS

An experiment was conducted at research field, Universiti Putra Malaysia (UPM) (latitude 3: 02' N longitude of 101: 42' E and altitude 31m above sea level). Total annual rainfall in the year 2013 was approximately 1623.5 mm. Mean monthly minimum and maximum temperatures ranged from 24.1°C to 26.1 °C and 31.7 °C to 34.6 °C respectively (Figure 1), while the mean relative humidity was 78.9%.

A composite soil sample was collected at random in the entire plot before the experiment to determine the physical and chemical characteristics. Soil texture was a sandy loam type. Textural analysis showed that the soil contains 18.77% clay, 18.41% silt and 62.61% sand with an organic carbon 1.55%, sand pH of 6.18 at 0-30 cm depth. Details of soil physical and chemical properties of the experimental site are given in Table 1.

Table 1: Soil physical and chemical properties of the experimental site (0-30 cm depth)

Soil characteristics	Values
Organic carbon (%)	1.55
Clay (%)	18.77
Silt (%)	18.41
Sand (%)	62.61
Texture	Sandy loam
pH	6.18
EC (ds/m)	3.16
K (ppm)	19.7
N (%)	0.11
P (ppm)	18.7

The experiment was established in a RCBD with four replications. Corn (variety 926) was intercropped with soybean (*Glycine max*). The treatments consisted of five-crop combination ratio of corn and soybean (100:0, 75:25, 50:50, 25:75, and 0:100). The size of each plot was 10.0 m long and 5.0 m wide. A buffer zone of 2.0 m spacing was provided between plots. The intercrop composition was based on replacement design. Each experimental unit was composed of eight crop rows, each 10 m long. Within rows, spacing of corn was 20 cm while for legumes it was 10 cm with inter row spacing of 60 cm. One plot comprised of corn monocrop and one plot comprised of soybean monocrop.

The previous crop on this field was corn. The land was ploughed once with mould board plough, harrowed and rotovated twice to bring the soil to fine tilth. The seed moisture and germination percentage were 15 and 95%, respectively. Corn and soybean intercrops were planted at the same time. The sowing date of the field experiment was on 25 November 2013. Two seeds were hand planted per point and plants were thinned to the target population just prior to the six-leaf stage.

Based on soil analysis, the required levels of N, P and K to support the yield goals were 130 kg ha^{-1} N, 130 kg ha^{-1} P and 80 kg ha^{-1} K in the form of urea, triple super phosphate (TSP) and Muriate of potash (MOP). The whole of phosphorus and potassium and one-third of N fertilizer were applied at the sowing time. The rest of N fertilizer was applied at 8-leaf stage of corn. Each plot was covered with plastic sheet mulch in order to control the growth of weeds within the plots. Irrigation water was adequately applied using a sprinkler system. All agronomic practices except those under study were kept uniform for all treatments.

Corn and soybean intercrops were harvested at the same time. Corn was harvested when the kernel milk-line

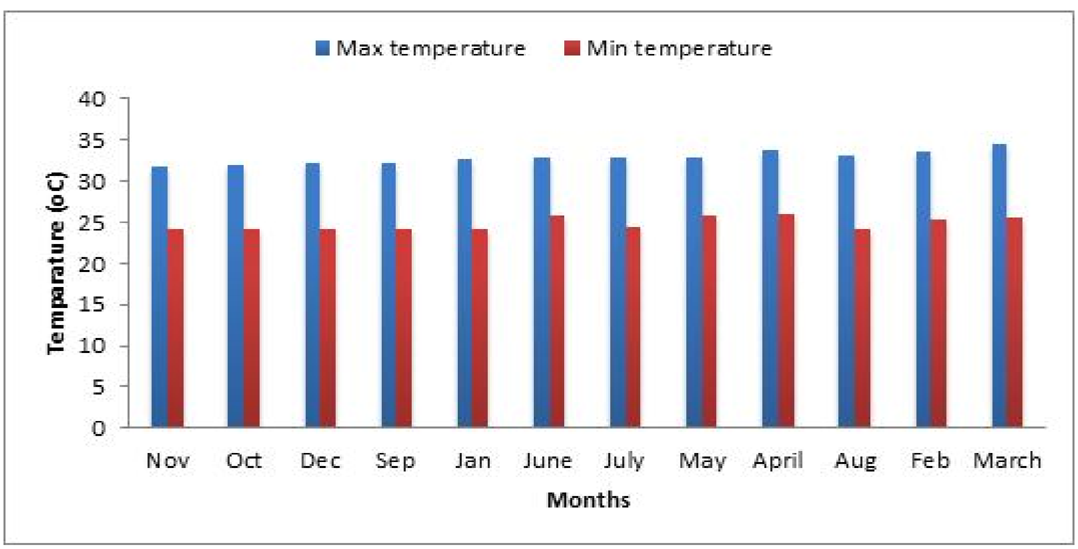

Fig 1: Mean Monthly Minimum and Maximum Temperature for Year 2013

was between 50 and 75%. The soybean harvest time was at seed fill stage. They were weighed fresh to determine fresh forage yield. The sampled area was 5 m^2 for the monoculture and intercropping treatments at the center of each plot and fresh biomass weight was determined as g DM m^{-2} and above plant parts were harvested by hand cutting the plant 2 cm above the soil surface. Samples were oven-dried at 70°C for at least 72 hours. In addition, whole plant weight was measured fresh and after oven drying. Forage DM yield was calculated from the fresh and dry weights of respective components listed above.

Plant heights of 10 plants from each treatment were measured in each crop and mean values were calculated. A carpenter's tape was used for measuring the height from the ground level to the top-most leaf. Prior to harvest, measurements of parameters such as leaf area index (LAI) and crop growth rate (CGR) were taken.

The LICOR LAI-2000 Plant Canopy Analyzer for measurement of leaf area index consisted of a probe connected to a meter. At the commencement of measurement, the meter was put on with the probe held horizontally above the plant. Thereafter the probe was placed in a parallel manner around the plant to be measured in four locations, readings were then taken.

Crop growth rate (CGR) was determined using equation 1 (Valadabadi and Farahani, 2010).

CGR = $[(W_2 - W_1) / (T_2 - T_1)] \times 1/ GA \times 100$ (Equation 1)

Where:
W_1 = Total dry matter of plant at time t_1
W_2 = Total dry matter of plant at time t_2
T_1 = Time of first observation
T_2 = Time of second observation
GA = Ground area

Land Equivalent Ratio (LER): The ratio of area needed under sole cropping to that of intercropping at the same management level to produce an equivalent yield, according to Mead and Willey (1980). It was calculated as follows:

LER = (Yab/Yaa) + (Yba/Ybb)

Where, Yaa and Ybb are the sole crop yields of crops a and b, respectively, Yab is the intercrop yield of crop a, and Yba is the intercrop yield of crop b.

Relative yield (RY) and relative yield total (RYT) were calculated according to the following equations:

RY= RYab =DMYab/DMYaa,
RYba = DMYba/DMYbb
RYT = DMYab/DMYaa + DMYba/DMYbb (Ghosh *et al*., 2006)

In the above equations, the following definitions apply, ab refers to performance of corn (a) mixed with soybean (b), ba is the performance of soybean (b) mixed with corn (a), aa is the performance of corn in monoculture and bb is the performance of soybean as a monoculture.

All data were analyzed with the analysis of variance (ANOVA). The Least Significant Difference (LSD) was used to compare treatment means at the 0.01 and 0.05% probability levels. The Mixed Linear Model in SAS Statistical Software Package (Version 9.1) was used to perform an analysis of variance appropriate for a RCBD.

RESULTS AND DISCUSSION

Results showed crop combination ratio significantly affected the total DM yield and RY of corn-soybean forage (Table 2). Among the corn and soybean monocrop and corn-soybean intercropping, the total DM yield of corn monocrop (14.77 t ha^{-1}), 75:25 (14.68 t ha^{-1}) and 50:50 (14.59 t ha^{-1}) corn-soybean combination ratio were not significantly different, but they were significantly greater than total DM yield of 25:75 (12.38 t ha^{-1}) ratio and soybean sole crop (10.44 t ha^{-1}) (Table 3).

Mixtures with 50:50 corn-soybean combination ratio had a higher relative yield total (1.15) compared to 75:25 and 25:75 corn-soybean ratios (1.08 and 1.07, respectively). There was no significant difference between 75:25 and 25:75 corn-soybean ratios.

Graphs of the mean RY of corn and soybean against their crop combination are shown in Figure 2. The figure shows that corn and soybean had higher relative yield when grown in intercrop than when grown as a sole crop and the best relative yield total was at the 50:50 ratio of corn and soybean.

Combination ratio had a significant effect on plant height of corn and soybean (Table 4). Corn plant height was

Table 2: Mean Squares from analysis of variance dry matter (DM) yield and relative yield (RY) of corn, soybean and total under different crop combination ratios in corn-soybean intercrops

S.O.V	df	Corn Dry Matter Yield (t ha^{-1})	Soybean Dry Matter Yield (t ha^{-1})	Total Dry Matter Yield (t ha^{-1})	Relative Yield (corn)	Relative Yield (soybean)	Relative yield total
Block	3	0.02	2.68	0.02	0.0001	0.0001	0.0001
Crop combination ratio	4	87.06**	28.78**	15.28**	0.32**	0.23**	0.0008**
Error	12	0.01	2.74	0.02	0.0001	0.0001	0.0001
cv		1.10	29.67	1.06	0.39	1.01	0.46

*, ** significant at P<0.05, 0.01, respectively

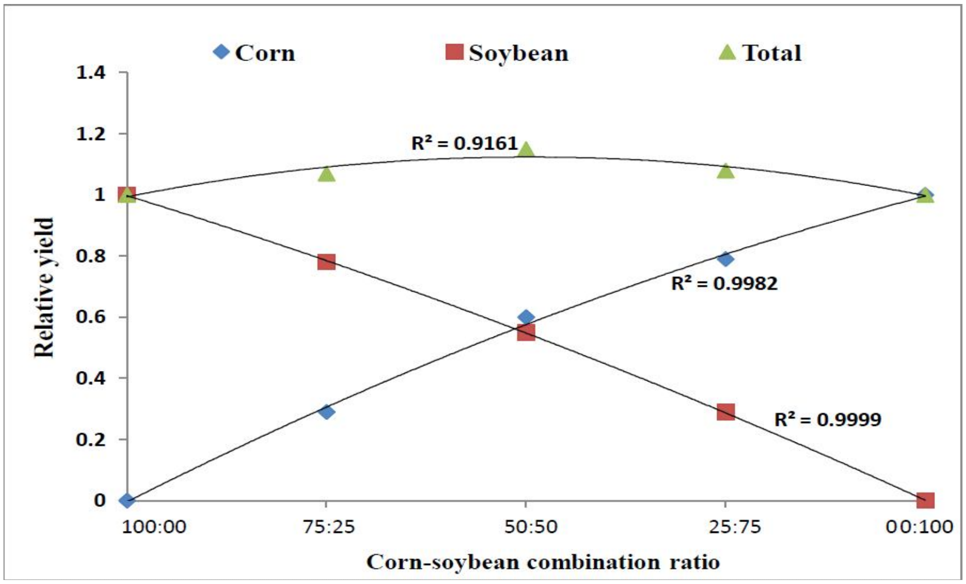

Fig 2: Graph of relative yield of corn-soybean combination ratio

Table 3: Dry matter yield and relative yield (RY) of sole and intercropped corn and soybean as influenced by crop combination ratio

Treatment	Corn Dry Matter Yield (t ha^{-1})	Soybean Matter Yield (t ha^{-1})	DryTotal Dry Matter Yield(t ha^{-1})	Relative Yield (corn)	Relative Yield (soybean)	Relative yield total
100 : 0	14.77a	-	14.77a	-	-	-
75 : 25	11.68b	3.00d	14.68a	0.79a	0.29c	1.08b
50 : 50	8.83c	5.76c	14.59a	0.60b	0.55b	1.15a
25 : 75	4.24d	8.14ab	12.38b	0.29c	0.78a	1.07b
0 : 100	-	10.44a	10.44c	-	-	-
LSD(0.05)	0.15	2.59	0.22	0.004	0.01	0.01
P value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Mean values followed by the same letter in the same column are not significantly different at P<0.05, based on least significant difference test (LSD).

Table 4: Mean Squares from analysis of variance growth parameters and land equivalent ratio (LER) of corn and soybean under different crop combination ratios in corn-soybean intercrops

S.O.V	df	Corn			Soybean			LER corn	LER Soybean	LER total
		Plant Height (cm)	Leaf Area Index	Crop growth rate (g m^{-2} day^{-1})	Plant Height (cm)	Leaf Area Index	Crop growth			
rate(g m^{-2} day^{-1})										
Block	3	3.27	0.004	0.46	3.40**	0.01**	0.14**	0.0001	0.0001	0.0001
Crop Combination ratio	4	17.30**	0.001	0.11	59.33**	0.01**	0.15**	0.27**	0.25**	0.0004**
Error	12	2.60	0.004	0.53	0.53	0.001	0.1	0.0001	0.0001	0.0001
cv		0.82	2.53	2.34	0.64	0.75	1.26	0.43	1.04	0.41

*, ** significant at P<0.05, 0.01, respectively

similar for sole crop corn (200 cm) up to 50:50 corn-soybean combinations. Soybean plant height was similar for sole soybean (118.50 cm) up to 25:75 corn-soybean combination but at higher ratios of corn, soybean height was significantly lower (Table 5).

Different corn-soybean combination ratios did not significantly affect corn LAI, which ranged from 2.61 to 2.65 and corn CGR, which ranged from 30.92 to 31.27 g m^{-2} day^{-1}.

In contrast, significant differences were observed in LAI and CGR of soybean plants among crop combination ratios. Soybean LAI was similar for sole soybean (3.27) up to 25:75 corn-soybean combination ratio but further increase in the ratio of corn reduced the LAI significantly. Similarly, CGR of soybean sole crop (9.28 g m^{-2} day^{-1}) and 25:75 ratio (9.23 g m^{-2} day^{-1}) were significantly higher than those with higher ratios of corn.

Results indicated that LER was higher than one in all of the mixtures indicating a yield advantage over sole crops. Among intercropping treatments, significantly higher total LER value was recorded with 50:50 corn-soybean ratio (1.13) followed by 1.07 and 1.04 for 75:25 and 25:75 corn-soybean combination ratio, respectively (Table 5).

The mixed corn-soybean gave similar DM yield as monocrop corn but increasing soybean more than 50% resulted in lower dry matter yield. This implies that to get good quality silage without a reduction in yield the soybean component should not exceed 50% of the combination. These results were in an agreement with Hulet *et al*. (1986) who recommended that farmer could increase the ratio of the legume in the mixture to 50% without decreasing millet yields. In addition, Dhima *et al*. (2014) reported that oat-fababean intercrops provided lower than or similar to total DM yields of oat as a sole crop up to 25:75 ratio.

Relative yield total above one suggests partial or no competition among species in the mixtures, probably made possible by the contribution of the legume to the environment of the corn via nitrogen fixation (Tessema and Baar, 2006). Relative yield total of less than one connotes a situation where one species is or both are more affected than might be expected when there is crowding for the same space. Mean relative yield total values of all mixture treatments were greater than one, which indicates the advantages of mixtures. The results were in agreement with observations made by Tessema and Baar (2006) who reported that relative yield total of mixtures were greater than one in grass-legume intercropping. Additionally, Arlauskienë *et al*. (2011) indicated that the relative yield total (RYT) was > 1.0 with a relative proportion of grain legume and spring cereal seeds (50:50).

The LER values were greater than one in all intercropping with different crop combination ratio, which indicated a yield advantage of intercropping over monocropping of corn. The highest LER index was observed with a 50:50 combination ratio, indicating strong evidence that corn and bean crops can provide much higher income when intercropped together rather than when planted as sole crop (Çiftçi *et al*., 2006). These results were in an agreement with (Bildirici *et al*., 2009) who reported that LER index increased as the percentage of soybean increased in the mixture up to a 50:50 corn-soybean seeding ratio. Similarly higher LER than one was recorded in 50:50 combination ratio in corn-bean (Koocheki *et al*., 2010) and corn-cowpea (Takim, 2012) intercropping. Higher LER in intercropping than monocropping has been reported in corn-legume intercropping by Dhima *et al*. (2006), Yilmaz *et al*. (2007), corn-soybean intercropping (Raji, 2007; Ullah *et al*., 2007; Addo-Quaye *et al*., 2011; Kebebew, 2014), corn-mungbean and cowpea (Eskandari, 2012), corn-bean (Mutungamiri *et al*., 2001; Tsubo *et al*., 2003) and sweet corn-mungbean (Sarlak *et al*., 2008).

CONCLUSION

Total forage dry matter yield from intercrop treatments from 100% corn, 75:25 corn-soybean and 50:50 corn-soybean were not significantly different but further increase in soybean components progressively reduced total forage yield. Corn-soybean intercrops provided LER's greater than one, leading to the conclusion that these intercrops were productive systems than corn monocrop. Intercropping systems enhanced land use efficiency and cropping intensity over sole cropping systems. Among all the combination ratios, the 50:50 corn-soybean ratio was the optimum combination giving highest forage yield.

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Table 5: Growth parameters and land equivalent ratio (LER) of sole and intercropped corn and soybean as influenced by crop combination ratio

Treatment	Corn			Soybean			LER	LER	LER
	Plant Height (cm)	Leaf Area Index	Crop Growth rate (g m^{-2} day^{-1})	Plant Height (cm)	Leaf Area Index	Crop growth rate (g m^{-2} day^{-1})	corn	Soybean	total
100 : 0	200.00a	2.65	31.09	-	-	-	-	-	-
75 : 25	199.00a	2.64	31.27	110.50c	3.17b	8.87b	0.79a	0.28c	1.07b
50 : 50	198.50a	2.61	30.92	113.25b	3.18b	9.03b	0.56b	0.57b	1.13a
25 : 75	195.5b	2.63	30.93	117.75a	3.25a	9.23a	0.26c	0.78a	1.04c
0 : 100	-	-	-	118.50a	3.27a	9.28a	-	-	-
LSD(0.05)	2.48	ns	ns	1.12	0.04	0.18	0.003	0.01	0.01
P value	0.0046	0.8999	0.9442	<.0001	<.0001	0.0005	<.0001	<.0001	<.0001

Mean values followed by the same letter in the same column are not significantly different at P<0.05, based on least significant difference test (LSD).

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