International Journal of Plant Production 2 (3), July 2008
ISSN: 1735-6814 (Print), 1735-8043 (Online)
This is a refereed journal and all articles are professionally screened and reviewed.

GUASNR
www.ijpp.info

Agronomic performance of two intercropped soybean cultivars

A. Biabani[a,*], M. Hashemi[b], S.J. Herbert[b]

[a]*Gonbad Agricultural Faculty, Gorgan University of Agricultural Sciences and Natural Resources. Gorgan, Iran*
[b]*Department of Plant, Soil, and Insects Sciences, University of Massachusetts, Amherst, MA 01003-9294, U.S.A*
*Corresponding author. Email: abs346@yahoo.com

Received 10 Dec. 2007; Accepted 15 Mar. 2008; Published online 01 June 2008

Abstract

Broader environmental tolerance associated with mixed population of soybean (Glycine max Merr.) cultivars may increase soybean yield potential and play a significant role in yield stability. A field study was carried out to assess whether intercropping of two commonly used cultivars of soybean with different morphological characteristics may increase seed yield in Iran. A split-plot design was used with three replications. The main plots were 3 densities; 23.8, 33.3, and 55.5 plants m^{-2}. Sub-plots consisted of intercropping ratios row by row of 100:0 (pure stand of Harcor), 75:25, 50:50, 25:75, and 0:100 (pure stand of Bonus) of Harcor and Bonus cultivars, respectively. The results indicated that the highest seed yield was obtained from 50:50 ratios of the cultivars which had land equivalent ratio (LER) above 1.11. Calculation of LER revealed that seed yield in treatment HBHB was 11% higher than the pure stand. The superiority of intercropping over pure stands occurred only in the highest plant density. Intercropping ratio showed no significant effect on any of yield components. However, pod number per plant was decreased with increasing plant density.

Keywords: Intercropping; Density; Land Equivalent Ratio

Introduction

Intercropping is defined as the intensification and diversification of cropping in time and space dimensions (Francis, 1986). The suggested advantages of this cropping system include yield stability under adverse environmental conditions, efficient use of limited growth resources, biological diversity, and potential control of pests and diseases. Many studies have shown that intercropping system out yielded monocultures of component crops (Baumann et al., 2001; Lesoing and Francis, 1999; Ghaffarzadeh et al., 1997; Fortin et al., 1994; Mandal et al., 1990). However, some potential disadvantages associated with intercropping often have limited its practicing to low-input and small-scale agricultural systems. The disadvantages are related mainly to use of agricultural machineries especially when the component crops have different requirements for planting pattern, fertilizer, herbicides among other factors.

A yield advantage of mixed cultivars has been observed in various crops including barley (Jokinen, 1991; Valentine, 1982), oat (Qualset and Granger, 1970; Grafius, 1966), flax (Gubbles and Kenachuk, 1987), small grain cereals (Juskiw et al., 2000) and soybean (Schweitzer et al., 1986; Wilcox and Schapaugh, Jr., 1978; Wilcox, 1985). The superiority of mixed cultivars over pure stands has been attributed generally to the significant variations of morphological characteristics including root system, plant height, and leaf orientation which result in efficient exploitation of environmental resources, specifically light interception. Increased lodging resistance (Grafius, 1966), improved disease resistance (Wolfe, 1985), and better weed control (Jokinen, 1991) also have been reported**.** Some investigators have concluded that the advantage of intercropping of cultivar mixtures depends on plant population density (Herbert et al., 1984; Putnam et al., 1985; Putnam et al., 1986).

In some regions, such as Iran, where stressful conditions including drought and high temperature occur frequently, broad environmental tolerance associated with mixed population of soybean cultivars may play a significant role in yield stability. The main objective of this experiment was to evaluate the seed yield of two soybean cultivars differing in maturity as influenced by intercropping at different population ratios and densities.

Materials and methods

Experimental site

This study was conducted in 1998-1999 in the experimental site of Karaj Seed and Plant Improvement Institute (35°, 56' N and 50°, 58' E) Iran. In this location, the average annual temperature is 13.5 °C and average annual rainfall is 243 mm. The soil of the experimental site was a silty clay loam with pH 7.8 the experimental site received 50 kg N ha^{-1} and 45 kg P ha^{-1} as urea and mono ammonium phosphate, broadcasted prior to the planting. Soil test revealed that no potassium was required at the experimental site. Tillage consisted of moldboard plowing to a depth of 20 cm followed by disking. Irrigation was applied during the growing season when required. The total amount of irrigation water per experimental site was equal to 256 mm. Weeds were controlled manually.

Treatments and experimental design

Two cultivars were used in this study. Harcor is an indeterminate cultivar, monobranched, maturity group II (105 - 110 days) with average height of 53 cm. Bonus is also an indeterminate cultivar, multibranched, maturity group III (115-120 days) with average height of 80 cm. The design of the experiment was a split plot with three replications. The main plots were 3 densities; 23.8 (low), 33.3 (medium), and 55.5 (high) plants m^{-2}. Six-row sub-plots were used with rows 10-m long and 0.6-m apart. The final harvest area for measurement of seed at maturity was 6 m^2 taken from the 4 central rows. Subplots were consisted of intercropping ratios of 100:0 (pure stand Harcor), 75:25, 50:50, 25:75, and 0:100 (pure stand Bonus) of Harcor and Bonus cultivars. All plots were overseeded and handthinned at 23 days after planting (DAP) to obtain the desired densities.

Measurements and analyses

Grain harvesting was completed at 127 DAP for Harcor and 140 DAP for Bonus. At harvest time, 5 plants of each cultivar were harvested randomly and used for determination of yield components including number of pods per plant, number of seed per pod, and seed weight, and some selected morphological characteristics. These characteristics included plant height, height of the first pod from the ground surface, number of branches, number of pods per plant, number of seeds per pod, and seed size. Seed oil and protein analyses were performed using the procedures of Nelson et al. (1988). Land equivalent ratio (LER) was calculated (Mead and Willey, 1980) and used to evaluate the advantages in yields from intercropping of the two cultivars:

$$LER = Y_{1.2}/Y_{1.1} + Y_{2.1}/Y_{2.2}$$

Where $Y_{1.1}$ and $Y_{2.2}$ are the crop yield for cultivar 1 and cultivar 2 grown in monoculture, and $Y_{1.2}$ and $Y_{2.1}$ are yield of cultivars in the mixture.

Data were analyzed using ANOVA and GLM procedures of SAS (SAS Institute, 1990). Effects were considered significant for *P*-values ≤0.05 from the F-test. Least significant differences (LSD) analysis and Duncan multiple range test were conducted for mean comparison.

Results

The summary of statistical analysis of data for seed yield, yield components and some morphological characteristics is shown in Table 1.

Plant height and branching

Plant density had no significant effect on plant height (Table 1). However, the height of the first pod from the ground surface increased and number of branches per plant reduced significantly ($P \leq 0.05$) as plant density increased (Table 2). Averaged across plant density, Bonus produced 64% more branches than Harcor. Also, the height of the first pod from ground surface was 22% higher in Bonus than Harcor (Table 4).

Seed yield

Density showed a significant ($P \leq 0.05$) effect on seed yield. Averaged over intercropping ratios, seed yields were increased about 18% as density increased from 23.8 plants m^{-2} to 55.5 plants m^{-2} (Table 2). Expected and actual seed yields for Bonus and Harcor at different planting density are shown in Table 3. In high density, actual seed yield for Harcor was lower than predicted yield for all intercropping ratios. This difference can be attributed to the shading effect of Bonus, which was taller and had greater branching ability than Harcor. This effect also explains higher actual yield of Bonus compared with the predicted yield for this cultivar (Table 3). The results suggest clearly that Bonus was the dominant cultivar compared with Harcor in a mixed planting system where Bonus could have utilized environmental resources available to both cultivars more efficiently. Therefore, in a condition like this, higher yield would be obtained from intercropping of the two cultivars compared with the yield from their monoculture.

Table 1. Analyses of variance for selected morphological characteristics, seed yield and yield components.

Treatment	Plant height (cm)	1st pod height (cm)	Branch plant^{-1}	Seed yield (kg ha^{-1})	Pod plant^{-1}	Seed pod^{-1}	Seed weight (cm)	Seed oil (%)	Seed protein (%)
Density (D)	NS	*	*	*	**	NS	NS	NS	NS
Ratio (R)	**	*	*	*	NS	NS	NS	*	*
D×R	NS	*	NS	*	NS	NS	NS	NS	NS

*, ** significant at the 0.05 and 0.01 probability levels, respectively; NS = not significant ($P≤0.05$)

Table 2. Density effect on selected morphological characteristics, seed yield and yield components of mixed soybean cultivars. Means are averaged over intercropping ratios.

Plant Density	Morphological characteristics			Yield and yield components					
	Plant height (cm)	1st pod height (cm)	Branch plant^{-1}	Seed yield (kg ha^{-1})	Pod plant^{-1}	Seed pod^{-1}	Seed weight (cm)	Seed oil (%)	Seed protein (%)
Low	98 a†	9.5a	1.7a	3889b	38.7a	2.22a	227ab	22.5a	38.4a
Medium	94a	13.3b	1.1b	4135ab	30.7b	2.28a	221b	22.0a	37.8a
High	95a	14.3b	0.8c	4600a	21.8c	2.29a	236a	21.8a	37.9a

† Values within the same column followed by the same letters are not significantly different according to Duncan's multiple range test ($P≤0.05$).

Significant ($P≤0.05$) yield differences occurred between intercropping ratios (Table 1). Averaged over planting density, the seed yields obtained from pure stands of the two cultivars were 4542 kg ha^{-1} and 3926 kg ha^{-1} for Bonus and Harcor, respectively. Replacing one row of Bonus with one row of Harcor resulted in about 7% increase in seed yield compared with Bonus monoculture, although the difference was not statistically significant. The results indicated that yield of the dominant cultivar could be enhanced by some degree of intergenotypic competition. A significant ($P≤0.05$) intercropping ratio × density interaction occurred (Table 1). Our results indicated that superiority of intercropping over monoculture was obtained only at the highest density. The LER characterizes the performance of an intercrop by giving the relative land area under sole crops, required to produce the yields achieved in intercropping (Mead and Willey, 1980). A value of greater than one for LER indicates the advantage of intercropping over monoculture cropping system. In our experiment LER values were lower than 1 for almost all intercropping ratios in low and medium densities. Advantage in total intercrop yield observed only with highest seeding rates where maximum LER value (1.114) obtained from 50:50 intercropping ratio (HBHB) of the two cultivars (Table 5). The results indicated an 11.4% yield increase compared with the sole crop of the two cultivars.

Components of seed yield and seed composition

Among the components of seed yield, only pod number per plant had a significant response to density (Table 1). Pod numbers per plant decreased linearly as plant density increased. Plants in high density produced 44% fewer pods per plant than low density plants (Table 2).

Table 3. Expected and actual yield (kg ha^{-1}) of Bonus and Harcor cultivars for different densities in various intercropping ratios.

Density/Intercropping	HHBH†	HBHB	BBHB
	----------------------Kg h ha^{-1}----------------------		
Low density			
Bonus expected yield	941	1882	2823
Bonus harvested yield	1027	2393	3265
Difference	86	511	442
Harcor expected yield	2519	1680	840
Harcor harvested yield	2985	1665	987
Difference	466	-15	147
Medium density			
Bonus expected yield	1126	2251	3377
Bonus harvested yield	1254	2172	3688
Difference	128	-79	311
Harcor expected yield	2918	1946	973
Harcor harvested yield	2594	1695	888
Difference	-324	-251	-85
High density			
Bonus expected yield	1101	2201	3302
Bonus harvested yield	1278	2940	3838
Difference	177	739	536
Harcor expected yield	3290	2194	1097
Harcor harvested yield	3182	2014	959
Difference	-108	-180	-138

† B and H = Bonus and Harcor cultivars, respectively. HHBH=75%H and 25%B.

Table 4. Mean comparisons of selected morphological characteristics, seed yield and yield components at different intercropping ratios. Means are averaged over Plant densities.

Intercrop. Ratio	-Morphological characteristics---			-------------yield and yield components -------------					
	Plant height (cm)	1st pod height (cm)	Branch plant^{-1}	Seed yield (kg ha^{-1})	Pod plant^{-1}	Seed pod^{-1}	Seed weight (cm)	Seed oil (%)	Seed protein (%)
HHHH†	84.3 b‡	10.2 b	1.0 b	3926 b	33.2 a	2.23 a	221 a	22.8 a	36.4 b
HHBH	93.7 b	15.6 a	1.2 b	4107 b	29.7 a	2.36 a	229 a	22.4ab	36.6 b
HBHB	93.2 b	12.4 ab	1.1 b	4293 ab	29.1 a	2.33 a	232 a	23.2 a	37.7 b
BBHB	95.2 b	12.0 b	0.8 b	4542 a	28.7 a	2.29 a	234 a	21.3ab	39.2 a
BBBB	111.2 a	12.5 ab	1.7 a	4254ab	26.5 a	2.28 a	224 a	20.7 b	40.2 a

† B and H = Bonus and Harcor cultivars, respectively. HHBH=75%H and 25%B.
‡Values within the same column followed by the same letter are not significantly different according to the Duncan's multiple range test (P≤0.05).

However, the relationship between pod number and plant density translated into an increased number of pods per unit of ground area as plant density was increased. Herbert and Litchfield (1984) and Gon et al. (2002) reported that pod number per plant was the most responsive component of soybean seed yield to changes in plant density. Other yield components including seed number per pod and seed weight were not affected significantly by plant density (Table 1). The percentages of protein and oil of the seeds also did not change in response to density changes. Seed composition is mainly determined by genotypic rather than environmental factors or cultural practices. Our results indicated that plant density would not be an effective mean of altering protein and oil content of soybean seeds. The oil and protein percentages averaged over plant density for Harcor were 22.8 and 36.4 and for Bonus were 20.7 and 40.2, respectively (Table 4). As a result, intercropping ratio showed a significant ($P\leq0.05$) effect on seed composition (Table 1). In general, the more presence of Harcor in the cultivar mixtures resulted in lower oil but higher protein percentages.

Table 5. Land Equivalent Ratio (LER) for grain yield production at different plant densities and intercropping ratios for two soybean cultivars.

Density		--------------Intercropping ratio--------------		
		HHBH†	HBHB	BBHB
Low	Lb‡	0.229	0.533	0.727
	Lh	0.766	0.380	0.225
	LER	0.995	0.913	0.952
Medium	Lb	0.279	0.484	0.821
	Lh	0.591	0.386	0.202
	LER	0.870	0.870	1.023
High	Lb	0.285	0.655	0.855
	Lh	0.725	0.459	0.219
	LER	1.01	1.114	1.074
$LSD_{0.0.5}$ = 0.112				

† B and H = Bonus and Harcor cultivars, respectively. HHBH=75%H and 25%B.

‡ Lb and Lh are Land Equivalent Ratio for Bonus and Harcor cultivars, respectively.

Discussion

Creation of a broader environmental tolerance and canopy architecture associated with intercropping of soybean cultivars may enhance soybean seed yield. In the present study, intercropping of the two soybean cultivars created a wavy type canopy consisted of alternate rows of shorter and taller plants. In contrast to the monoculture of either cultivar, this canopy architecture had a greater potential for intercepting radiation and thus dry matter production (authors observation). Both cultivars showed a higher vegetative growth, evident by plant height and branch number per plant, compared to the agronomic characteristics originally reported for the two genotypes (data not shown). The increased vegetative growth of Bonus apparently was not at the expense of Harcor. If it had been, vegetative growth of Harcor should have been lower when bordered by Bonus (HBHB) than when self-bordered (HHHH). Earlier studies have demonstrated an enhancement effect of intergenotypic competition on seed yield of soybean cultivars grown in mixed planting systems (Wilcox and Schapaugh, 1978; Schweitzer et al., 1986). The results obtained in the present study are consistent with these reports. The yield advantage of the intercropping system reflected in LER value indicated an 11.4% increase compared with the sole crop of the two cultivars. Schweitzer et al. (1986) also have shown increased seed yield by 12% by intercropping of determinate and indeterminate cultivars of soybean. However, the pattern of intergenotypic competition was not similar for all three plant densities used in the present study. In our study the advantage of intercropping of the two genotypes was obtained only from the highest plant density where Harcor and Bonus planted in alternate rows (HBHB).

In summary, the results obtained in this study confirmed that planting of a mixture of two soybean hybrids that are different in morphological characteristics may improve the final seed yield. Yield increase could be due to the results of boosting the competitive ability of one or both hybrids and/or improving canopy architecture of the crop mixture.

References

Baumann, D.T., Bastiaans, L., Kropff, M.J., 2001. Competition and crop performance in a leek-celery intercropping system. Crop Sci. 41, 764-774.

Fortin, M.C., Culley, J., Edwards, M., 1994. Soil water, plant growth, and yield of strip-intercropped corn. J. Prod. Agric. 7, 63-69.

Francis, C.A., 1986. Multiple cropping systems. Vol. 1. Macmillan Publishing Co., New York.

Ghaffarzadeh, M., Garcia Prechac, F., Cruse, R.M., 1997. Tillage effect on soil water content and corn yield in a strip intercropping system. Agron. J. 89, 893-899.

Gon, Y., Stulen, I., Van Keulen, H., Kuiper, P.J.C, 2002. Physiological response of soybean genotypes to plant density. Field Crop Res. 74, 231-241.

Grafius, J.E., 1966. Rate of change of lodging resistance, yield and test weight in varietal mixtures of oats, *Avena sativa* L. Crop Sci. 6, 369-370.

Gubbles, G.H., Kenachuk, E.D., 1987. Performance of pure and mixed stands of flax cultivars. Can. J. Plant Sci. 67, 267-302.

Herbert, S.J., Litchfield, G.V., 1982. Partitioning soybean seed yield components. Crop Sci. 22, 1074-1079.

Herbert, S.J., Putnam, D.H., Poos-Floyd, M.I., Vargas A., Creighton J.F., 1984. Forage yield of intercropped corn and soybean in various planting patterns. Agron. J. 76, 507-510.

Jokinen, K., 1991. Yield and competition in barley variety mixtures. J. Agric. Sci. Finland. 63, 287-305.

Juskiw, P.E., Helm, J.H., Salmon, D.F, 2000. Forage yield and quality for monocrops and mixtures of small grain cereals. Crop Sci. 40, 138-147.

Lesoing, G.W., Francis, C.A., 1999. Strip intercropping effects on yield and yield components of corn, grain sorghum, and soybean. Agron. J. 91, 807-813.

Mandal, B.K., Dhara, M.C., Mandal, B.B., Das, S.K., Nandy R., 1990. Rice, mungbean, soybean, peanut, ricebean, and blackgram yields under different intercropping systems. Agron. J. 82, 1063-1066.

Mead, R., Willey, W.R., 1980. The concept of Land Equivalent Ratio and advantages in yields from intercropping. Exp. Agric. 16, 217-228.

Nelson, R.L., Andaor, P.J., Orf, J.H., Cavins, J.F., 1988. Evaluation of the USDA soybean germplasm collection. Maturity groups 000 to IV (PI 427.136 to PI 445.845). p. 188. In USDA Tech. Bull. No. 1726. U.S. Gov. Print. Office, Washington, DC.

Putnam, D.H., Herbert, S.J., Vargas, A., 1985. Intercropped corn-soybean density studies. I. yield omplementarily. Expl. Agric. 21, 41-51.

Putnam, D.H., Herbert, S.J., Vargas, A., 1986. Intercropped corn-soybean density studies. II. yield composition and protein. Expl. Agric. 22, 373-381.

Qualset, C.O., Granger, R.M., 1970. Frequency dependent stability of performance in oats. Crop Sci. 10, 386-389.

SAS Institute, 1990. SAS users guide. Statistics. 6^{th} ed. SAS Inst., Cary, NC.

Schweitzer, L.E., Nyquist, W.E., Santini, J.B., Kimes, T.M., 1986. Soybean cultivar mixtures in a narrow-row, noncultivatable production system. Crop Sci. 26, 1043-1046.

Valentine, J., 1982. Variation in monoculture and in mixture for grain yield and other characters in spring barley. Ann. Appl. Biol. 101, 127-141.

Wilcox, J.R., 1985. Dry matter partitioning as influenced by competition between soybean isolines. Agron. J. 77, 738-742.

Wilcox, J.R., Schapaugh, W.T., 1978. Competition between two soybean isolines in hill plots. Crop Sci. 18, 346-348.

Wolfe, M.S., 1985. The current status and prospects of multiline cultivars and variety mixtures for disease resistance. Ann. Rev. Phytopath. 23, 251-255.