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EVALUATION OF HIGH DENSITIES OF SOME CORN VERITIES ON SOYBEAN PRODUCTIVITY

A.A. Metwally*[1], S.A. Safina[1], M.N. Sherief[2] and Dina R.E. Abo-Hegazy[2]

[1]Agronomy Department, Faculty of agriculture, Cairo University, Giza, Egypt.
[2]Crop Intensification Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt.

Abstract

The present study was carried out to evaluate the effects of high plant densities of three corn varieties on soybean productivity and land equivalent ratio (LER) under two intercropping systems. Three corn varieties S.C. 128, S.C. 130 and Syn. Cairo 1 with soybean variety Giza 111 were tested under intercropping and solid plantings. Intercropping systems adopted were alternating 2:2 ridge (70 cm/ridge) and mixed one (140cm/bed). Soybean plants were grown in two rows per ridge and beds and thinned to two plants at 15 and 20 cm between hills under intercropping and solid plantings, respectively. Corn plants were thinned to two plants per hill distanced at 20, 25 and 30 cm between hills under intercropping and solid plantings. A split plot distribution in randomized complete block design with three replications was used. Corn varieties were randomly assigned to main plots, whereas, cropping systems were distributed in the sub-plots and corn plant densities were assigned to sub sub-plot. Results showed that soybean with corn variety S.C. 130 gave the highest seed yield. Alternating ridges 2:2 system produced higher yield than mixed one. Increasing distance between corn hills from 20 to 30 cm increased yield of intercrops. Alternating ridges 2:2 gave higher productivity and land usage by intercropping soybean with corn varieties of Syn. Cairo 1 and S.C. 130, distanced 30 cm between hills in case of increasing number of corn plants per unit area from 50 to 100% of recommended solid culture.

Key words: Corn varieties, Soybean, Intercropping systems, Corn plant density, LER

Introduction

In Egypt, it is not feasible to expand the area of soybean (*Glycine max* L. Merr.) Crop because of high competition from the other summer crops like corn (*Zea mays* L.) that is the world's most widely grown cereal and it is ranked third among major cereal crops. There is a decline in soybean area in the Nile Valley and Delta, where it reached about 7, 812 ha in 2016, while, under corn was about 4, 877, 829 ha in 2016. Consequently, intercropping system is the proper management to keep the area of soybeans without significant change in crop structure. However, it was realized that the efficiency of intercropping can be enhanced by the proper choice of corn variety (Metwally *et al*., 2003 and Abdel-Galil *et al*., 2014).

To obtain maximum yield, an optimum plant population and planting arrangement are necessary. (Bavec and Bavec 2002) showed that high plant density can result in an increased number of cobs per unit area, with an eventual increase in grain yield. In another study, (Metwally *et al*., 2009a) found that increasing plant density per unit area from 47600 to 95200 per ha decreased grain yield per plant, alternating ridges 2:2 gave the highest net return, meanwhile the highest LER was recorded by mixed system. (Abdel-Wahab and Abd El-Rahman, 2016).

Therefore, the objective was to evaluate effects of high plant densities of three corn varieties on soybean productivity and LER under two intercropping systems.

Materials and methods

A two-year study was carried out at the experimental and research station, Faculty of Agriculture, Cairo

***Author for correspondence :** E-mail : mhassanein11@hotmail.com

University, Giza, Egypt, during 2013 and 2014 summer seasons to evaluate effects of high plant densities of three corn varieties on soybean productivity and LER under two intercropping systems. Three corn varieties: two Single Crosses 'S.C.' 128 and 130 were procured from Field Crops Research Institute, (ARC), Egypt and Synthetic variety 'Syn.' Cairo 1 which was developed from Agronomy Department, Faculty of Agriculture, Cairo University, Egypt (Sayed Galal, 1984), Also, soybean variety Giza 111 was obtained from ARC.

The experiment included:

- Alternating ridges 2:2 by growing two corn ridges alternating with two of soybean. Corn was grown in one side of ridges 70 cm width and thinned to two plants per hill at 20, 25 and 30 cm between hills, meanwhile soybean seeds were drilled in both sides of ridges 70 cm width separately and thinned to two plants at 15 cm between hills.
- Mixed intercropping system by growing corn in middle of beds 140 cm width and thinned to two plants per hill at 20, 25 and 30 cm between hills, meanwhile soybean seeds were drilled in both sides of the corn beds and thinned to two plants at 15 cm between hills.
- Solid I planting was conducted by growing one plant of corn per hill at 20, 25 and 30 cm between hills in one side of ridges 70 cm width.
- Solid II planting was conducted by growing two plants of corn per hill at 20, 25 and 30 cm between hills in one side of ridges 70 cm width.
- Solid planting of soybean was conducted by growing two rows of soybean in ridges 70 cm width. Soybean was thinned to two plants at 15 cm between hills.

Growing two corn plants per hill distanced at 20, 25 and 30 cm between hills formed 71400, 57120 and 47600 plants per ha, respectively under all intercropping and solid I plantings. Meanwhile, growing two corn plants per hill distanced at 20, 25 and 30 cm between hills formed 142800, 114240 and 95200 plants per ha, respectively, under solid II planting. To estimate LER, pure stand of corn was used as recommended by growing one corn plant per hill distanced at 30 cm in ridges 70 cm width.

The soil texture was clay loam and the preceding winter crop was Egyptian clover in both seasons. Corn was sown on May 15th and 28th in 2013 and 2014 seasons, respectively, while, soybean was sown one week later. The field experiment was laid out in split plot distribution in randomized complete block design with three replications. Corn varieties were randomly assigned to main plots, whereas, cropping systems were distributed in the sub-plots and corn plant densities were assigned to sub sub-plot. Sub sub-plots area was 25.2 m^2. With regard to 2:2 intercropping system and solid plantings of corn and soybean, each plot contained six ridges, each ridge was 6.0 m in length and 0.7 m in width. Each plot of mixed system contained three beds, each bed was 6.0 m in length and 1.4 m in width.

Data of yield per plot (kg) was weighted and converted to ton per ha, while LER was calculated according to (Mead and Willey 1980), LER = $(Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})$

Where, Y_{aa} = Pure stand yield of crop a (corn); Y_{bb} = Pure stand yield of crop b (soybean); Y_{ab} = Intercrop yield of crop a (corn); Y_{ba} = Intercrop yield of crop b (soybean). The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed 1991). Mean comparisons were done using least significant differences (L.S.D) at 5 percent level of probability to compare differences between the means (Gomez and Gomez 1984).

Results and Discussion

Corn grain yield

The effect of main factors

a. Corn varieties

Grain yield was not affected by the corn varieties in both seasons (Table 1). These data reveal that there was insignificant effect of corn varieties on grain yield.

b. Effect of cropping systems

Grain yield was affected significantly by cropping systems in both seasons (Table 1). Solid I planting had higher grain yield in both seasons. However, solid II planting had lower grain yield than others in both seasons. Doubling number of corn plants per hill from one to two plants under solid II planting had negative effects on yielding ability as a result of high population density compared to others. Alternating ridges 2:2 system produced higher grain yield than mixed one in both seasons. These results may be due to mixed system increased inter-specific competition between corn and soybean plants for available environmental conditions than intercropping system 2:2. Similar results were obtained by (Metwally *et al*., 2009 a, c).

c. Effect of corn plant densities

The effect of corn plant densities per unit area differed significantly for grain yield in both seasons (Table 1). Decreasing distances between hills from 30 to 20 cm decreased significantly grain yield by 15.67 and 7.73%, in the first and second seasons, respectively. It is expected

Table 1: Effect of corn varieties, cropping systems, corn plant densities and their interactions on corn yield in 2013 and 2014 seasons.

Corn varieties	Cropping systems	Grain yield per ha (ton)							
		2013 season Distance between corn hills				2014 season Distance between corn hills			
		30 cm	25 cm	20 cm	Mean	30 cm	25 cm	20 cm	Mean
S.C. 128	Inter 2:2	6.70	5.87	5.17	5.91	7.07	6.75	5.77	6.53
	Mixed	6.30	6.00	5.43	5.91	6.62	6.35	5.83	6.26
	Solid I	8.70	8.00	7.70	8.13	8.60	8.50	8.40	8.50
	Solid II	6.23	5.07	4.10	5.13	4.83	5.77	6.87	5.82
Average of S.C. 128	6.98	6.23	5.60	6.27	6.78	6.84	6.71	6.77	
Syn. Cairo 1	Inter 2:2	6.93	6.07	5.77	6.25	7.13	6.93	6.03	6.69
	Mixed	6.27	5.73	5.63	5.87	6.57	6.54	5.82	6.31
	Solid I	7.40	6.70	6.00	6.70	8.20	7.60	6.90	7.56
	Solid II	5.83	5.57	5.40	5.60	6.43	6.17	6.30	6.30
Average of Syn. Cairo 1	6.60	6.01	5.70	6.10	7.08	6.81	6.26	6.71	
S.C. 130	Inter 2:2	7.30	6.67	6.20	6.72	7.55	7.04	6.58	7.05
	Mixed	6.40	6.00	5.40	5.93	6.51	6.19	5.80	6.16
	Solid I	8.40	8.10	7.50	8.00	8.60	8.40	8.30	8.43
	Solid II	6.27	5.90	5.50	5.89	7.27	6.90	6.20	6.79
Average of S.C. 130	7.09	6.66	6.15	6.63	7.48	7.13	6.72	7.11	
Average of cropping systems	Inter 2:2	6.97	6.20	5.71	6.29	7.25	6.90	6.12	6.75
	Mixed	6.32	5.91	5.48	5.90	6.56	6.36	5.81	6.24
	Mean	6.65	6.05	5.60	6.10	6.90	6.63	5.96	6.49
	Solid I	8.16	7.60	7.06	7.60	8.46	8.16	7.86	8.16
	Solid II	6.11	5.51	5.00	5.54	6.17	6.28	6.45	6.30
Average of corn densities		6.89	6.30	5.81	6.33	7.11	6.92	6.56	6.86
L.S.D. 0.05 corn varieties (V)				N.S.					N.S
L.S.D. 0.05 cropping systems (S)				0.38					0.50
L.S.D. 0.05 corn plant densities (D)				0.46					0.42
L.S.D. 0.05 V x S				1.44					1.24
L.S.D. 0.05 V x D				0.10					0.38
L.S.D. 0.05 S x D				0.58					0.64
L.S.D. 0.05 V x S x D				1.78					1.48

that two corn plants that grow together at distance of 20 cm between hills suffered from higher competition than others.

The effect of interactions

Grain yield was affected significantly by the interaction between corn varieties and cropping systems (Table 1). All corn varieties had higher grain yield under solid I planting followed by all the corn varieties of intercropping system 2:2 than the other treatments in both seasons. Grain yield was affected significantly by interaction between cropping systems and corn plant densities (Table 1). Solid I planting had the highest grain yield compared with others in both seasons. With respect to interaction between corn varieties, cropping systems and corn plant densities, higher grain yield was obtained by growing all tested varieties in solid I planting. Yield ability of corn variety Syn. Cairo 1 in intercropping system 2:2 adapted with increasing plant density from 47600 to 71400 plants per ha compared with others. These data confirmed with (Metwally *et al.,* 2003).

Soybean seed yield

The effect of main factors

a. Effect of corn varieties

Seed yield was not affected by the corn varieties in both seasons (Table 2). These data reveal that there was insignificant effect of corn varieties on seed yield.

b. Effect of cropping systems

Seed yield was affected significantly by cropping systems in both seasons (Table 2). Soybean solid planting had higher values of seed yield than intercropped soybean in both seasons. This may attributed to increments number

Table 2: Effect of corn varieties, cropping systems, corn plant densities and their interactions on soybean yield in 2013 and 2014 seasons.

Corn varieties	Cropping systems	Grain yield per ha (ton)							
		2013 season Distance between corn hills				2014 season Distance between corn hills			
		30 cm	25 cm	20 cm	Mean	30 cm	25 cm	20 cm	Mean
S.C. 128	Inter 2:2	1.39	1.36	1.32	1.35	1.43	1.35	1.28	1.35
	Mixed	1.34	1.30	1.28	1.30	1.38	1.30	1.27	1.31
	Solid		2.97		2.97		3.09		3.09
Average of S.C. 128		1.90	1.87	1.85	1.87	1.96	1.91	1.88	1.91
Syn. Cairo 1	Inter 2:2	1.37	1.34	1.28	1.31	1.38	1.40	1.24	1.34
	Mixed	1.31	1.28	1.24	1.27	1.35	1.28	1.23	1.28
	Solid		2.97		2.97		3.09		3.09
Average of Syn. Cairo 1		1.88	1.86	1.83	1.85	1.94	1.92	1.85	1.90
S.C. 130	Inter 2:2	1.46	1.34	1.30	1.36	1.45	1.36	1.28	1.36
	Mixed	1.44	1.31	1.28	1.34	1.38	1.32	1.28	1.32
	Solid		2.97		2.97		3.09		3.09
Average of S.C. 130		1.95	1.87	1.85	1.89	1.97	1.92	1.88	1.92
Average of cropping systems	Inter 2:2	1.40	1.33	1.29	1.34	1.42	1.37	1.26	1.35
	Mixed	1.36	1.29	1.26	1.30	1.37	1.30	1.26	1.31
	Mean	1.38	1.31	1.27	1.32	1.39	1.33	1.26	1.33
Solid culture of soybean			2.97		2.97		3.09		3.09
Average of corn densities		1.91	1.87	1.84	1.87	1.96	1.92	1.87	1.91
L.S.D. 0.05 corn varieties (V)					N.S.				N.S.
L.S.D. 0.05 cropping systems (S)					0.07				0.20
L.S.D. 0.05 corn plant densities (D)					0.03				0.08
L.S.D. 0.05 V x S					0.20				0.40
L.S.D. 0.05 V x D					.10				0.08
L.S.D. 0.05 S x D					N.S.				N.S.
L.S.D. 0.05 V x S x D					N.S.				N.S.

of soybean plants/unit area, as well as, seed yield/plot (more light intensity). Intercropping system 2:2 had higher seed yield per plant than mixed one. Mixed intercropping soybean with corn was more aggressive than intercropped soybean with corn in alternating ridges 2:2 (El-Shamy *et al.,* 2014).

c. Effect of corn plant densities

Seed yield was affected significantly by corn plant densities in both seasons (Table 2). Decreasing corn plant densities from 71400 to 47600 plants per ha increased seed yield in both seasons. These results probably attributed to increase in distance between corn hills from 20 to 30 cm number furnished suitable above – ground conditions for soybean plant that converted more solar energy to chemical energy and more translocation of photosynthates metabolites to the sink (seed) during soybean growth and development.

Effect of the interactions

Seed yield was affected significantly by the interaction between corn varieties and cropping systems in both seasons (Table 2). Soybean solid planting recorded higher seed yield followed by soybean plants of intercropping system 2:2 that grown with corn variety S.C. 130 than the other treatments in both seasons. With respect to the interaction between corn varieties and corn plant densities, the highest seed yield was achieved by solid planting followed by growing corn variety S.C. 130 at distances of 30 cm between corn hills compared with others in both seasons. Meanwhile, the other interactions did not affect seed yield.

LER

The values of LER were estimated by using data of solid cultures of both crops. Intercropping corn with soybean increased LERs as compared with solid cultures of both crops in 2013 and 2014 seasons (Table 3). With regard to corn varieties, corn variety Syn. Cairo 1 gave the highest LER, followed by corn variety S.C.130. With respect to intercropping systems, intercropping system 2:2 recorded higher LER than mixed one. With respect

Table 3: LER of corn varieties, intercropping systems, corn plant densities and their interactions in 2013 and 2014 seasons.

Corn varieties	interrop-ping systems	LER							
		2013 season Distance between corn hills				2014 season Distance between corn hills			
		30 cm	25 cm	20 cm	Mean	30 cm	25 cm	20 cm	Mean
S.C. 128	Inter 2:2	1.23	1.13	1.03	1.13	1.28	1.22	1.08	1.18
	Mixed	1.17	1.12	1.05	1.11	1.20	1.15	1.08	1.13
Average of S.C. 128		1.20	1.12	1.04	1.12	1.24	1.19	1.08	1.16
Syn. Cairo 1	Inter 2:2	1.39	1.27	1.21	1.28	1.31	1.29	1.13	1.24
	Mixed	1.28	1.20	1.17	1.22	1.23	1.21	1.09	1.17
Average of Syn. Cairo 1		1.34	1.23	1.19	1.25	1.27	1.25	1.11	1.20
S.C. 130	Inter 2:2	1.36	1.24	1.17	1.25	1.33	1.25	1.17	1.24
	Mixed	1.24	1.15	1.07	1.15	1.20	1.14	1.08	1.13
Average of S.C. 130		1.30	1.19	1.12	1.20	1.27	1.20	1.13	1.19
Average of intercropping systems	Inter 2:2	1.32	1.21	1.13	1.22	1.31	1.25	1.12	1.22
	Mixed	1.23	1.15	1.09	1.16	1.21	1.16	1.08	1.15
Average of corn plant density		1.28	1.18	1.11	1.19	1.26	1.21	1.10	1.18
L.S.D. 0.05 corn varieties (V)					0.08				0.04
L.S.D. 0.05 intercropping systems (S)					0.05				0.02
L.S.D. 0.05 corn plant densities (D)					0.03				0.01
L.S.D. 0.05 V x S					0.08				0.07
L.S.D. 0.05 V x D					0.07				0.06
L.S.D. 0.05 S x D					0.05				0.04
L.S.D. 0.05 V x S x D					0.11				0.07
Recommended solid culture		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

to corn plant densities, growing soybean with corn that grown at distance of 30 cm between hills had the highest LER as compared to others. With reared to interactions, growing soybean with corn variety Syn. Cairo 1 under alternating ridges 2:2 recorded the highest LER compared with others. Conversely, growing soybean with corn variety S.C.128 under mixed system recorded the lowest LER.

Growing soybean with corn variety Syn. Cairo 1 that distanced at 30 cm recorded the highest LER compared with others. However, intercropping system 2:2 with distance of 30 cm between corn hills recorded the highest LER compared with others. Conversely, mixed system with distance of 20 cm between corn hills recorded the lowest LER compared with others. Growing soybean with corn variety Syn. Cairo 1 that distanced at 30 cm recorded the highest LER under alternating ridges 2:2 compared with others. Accordingly, the fundamental reason to change the values of LER was due to values of relative yield of corn varieties under interaction between intercropping systems and corn plant density. Two plants of corn variety Syn. Cairo 1 integrated positively with each of the wide distance between corn hills and alternating ridges 2:2 to decrease competitive pressure between the same or the two species for basic growth resources. These results are in accordance with those observed by (Metwally *et al*., 2009a, b; Metwally *et al.,* 2017; Metwally *et al.,* 2018).

Conclusion

Choice of suitable corn variety at proper distance between corn hills have important role for increasing soybean productivity and land usage. Intercropping soybean in alternating ridges with corn varieties of Syn. Cairo 1 and S.C. 130 growing in two plants/hill with population density 47600 plants/ha gave 100% productivity in solid culture, in addition to 40% soybean yield.

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