EFFECT OF DIFFERENT IRRIGATION TREATMENTS ON SOYBEAN AND MAIZE YIELD GROWN UNDER DIFFERENT INTERCROPPING PATTERNS

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ABSTRACT

Two field experiments were conducted at Giza Agricultural Research Station during 2008 and 2009 seasons respectively. Three irrigation regimes i.e irrigation at 1.2, 1.0 and 0.8 evaporation pan coefficient were combined with four intercropping pattern of maize and soybean crop (1:1, 1:2, 2:1, and 2:2) with three replications. The main results obtained were as follows:

- Maize grain yield and its components were significantly affected by different irrigation regimes during the two growing seasons. The maximum values of maize crop were obtained with irrigation at 1.2 evaporation pan coefficient. The same trend was obtained with soybean crop.
- Maize grain yield was significantly affected under the intercropping pattern 1.2 alternated rows of soybean and maize.
- The highest soybean yield obtained under intercropping pattern 2:1 alternated rows of soybean and maize.
- Land equivalent ratio and relative crowdedness coefficient were higher under intercropping pattern 2:2 and 1:2 soybean and maize using 0.8 and 1.2 evaporation pan coefficients, respectively.
- The highest seasonal consumptive use (60.83 and 63.81 cm) and water use efficiency (0.51 and 0.47 cereal unit/cm. during the two growing seasons were obtained under the intercropping pattern 1:2 soybean/maize, respectively.

Key words: Soybean, Maize yield, Irrigation treatments and Intercropping.

INTRODUCTION

Legume/cereal intercropping pattern is generally more productive than reference sole crop **(Tsubo *et al.*, 2005).** The biological basis for intercropping involves complementary uses of resources by the two crops **(Borhom, 2001).** Increasing productivity of intercropped soybean and maize over the sole crop has been attributed to better use of solar radiation **(Keating and Carberry, 1993),** nutrients **(Willey, 1990)** and water **(Morris and Garrity, 1993).** Spatial arrangement of intercrops is an important management practice that can improve radiation interception through more complete ground cover **(Abd El-Gwad *et al.*, 1985).** Thus, intercropping soybean with maize in alternated rows increased yield and yield components of the two crops **(Galal *et al.*, 1984; Sherif, 1984 and Abd El-Gwad *et al.*, 1985).**

In Egypt, irrigation water conservation is a practice should be done to insure the horizontal agricultural expansion prevailing water limitation conditions. Cereal-legume intercropping could be a way increasing water productivity, especially in situations of limited water resources **(Tsubo *et al.*,**

2005). Morris and Garrity (1993) stated that water capture by intercrops is higher by about 7% compared by sole crop. Furthermore, water use efficiency was the highest under soybean/maize intercropping, compared with sole maize and sole soybean **(Borham, 2001). Similarly, Morris and Garrity (1993)** indicated that water utilization efficiency of intercrops was higher by about 18% compared by sole crop.

Water stress during maize growing season resulted in reduction of plant height, leaf area index **(Cassel *et al*., 1985)** and total leaf area reduction **(El-Shenawy, 1990).** In addition, number of ovules that fertilized and developed into grains decreased rapidly when drought occurred during flowering **(Cassel *et al*., 1985).** Moreover, both final maize yield and kernels number were reduced as a result of water stress during grain filling period **(Ritchie *et al.*, 1993).**

The most important times for soybean plants to have adequate water are during pod development and seed fill **(Kranz *et al*., 1998).** These are the stages when water stress can lead to a significant decrease in yield. Stressful conditions, such as moisture deficiency reduces soybean yield. As the soybean plant ages from beginning bloom through seed enlargement, its ability to compensate under stressful conditions decreases and yield losses could increases **(Foroud *et al.*, 1993).**

The objectives of the present research work is to find out the extent to which soybean/maize intercropping patterns affects the unit of both land and consumed water.

MATERIALS AND METHODS

Two field experiments were conducted at Giza Agricultural Research Station, Agricultural Research Center, Egypt during the two successive seasons of 2008 and 2009, respectively. The aim of this experiment was to study the effect of three irrigation treatments and four intercropping soybean/maize patterns on yield, yield components and water relations of the both crops. The experimental treatments were arranged in a split plot design with three replicates. The main plots represented three irrigation regimes, whereas, intercropping patterns were assigned to the sub plots, in addition to the sole planting of each of the two crops. Plot area was 14.0 m^2 for 1:1 and 2:2 of alternated rows of soybean and maize intercropping, whereas it was 10.5 m^2 for 1:2 and 2:1 of alternated rows of soybean and maize intercropping for both growing seasons. Soybean variety Giza 111 and maize hybrid TWC 310 were used in the experiments. 31 kg P_2O_5/fed was added as calcium super phosphate (15.5% P_2O_5) and was incorporated into the soil during land preparation for the two crops soybean and maize. Soybean seeds were inoculated before sowing and planted on May 18th in both growing seasons, 17 kg N/fed. in form of ammonium nitrate (33.5% N) before the second irrigation. Furthermore, 24 kg KO_2/fed. in form of potassium sulfate (48% KO_2) was added before the third irrigation. The second irrigation (after planting irrigation) was applied to soybean on June, 9th in both growing seasons. Maize grains were sown on June 9th in both growing seasons. 120 kg N/fed in form of ammonium nitrate (33.5% N) was added before the 2nd irrigation. 24 kg KO_2/fed in form of Potassium sulfate (48% KO_2) was applied before the second irrigation under Surface irrigation system. The second irrigation (after planting irrigation) was applied on June 26th in both growing seasons. Evaporation data were obtained from a standard Class-A-Pan located near the experimental field and collected on a daily basis. Irrigation treatments were initiated after the second irrigation for maize and the third irrigation for soybean. Irrigation amounts were calculated with the following equation **(Doorenbos and Pruitt, 1992)**:

I= Epan*Kp (1)

Where: I is the applied irrigation water amount (mm), Epan is the cumulative evaporation amount in the period of irrigation interval (mm), Kp is the pan evaporation coefficient. Experimental treatments can be stated as followed:

1. Irrigation treatments: (irrigation according to pan evaporation coefficient records)

1.1. Irrigation at 1.2 evaporation pan coefficient.
1.2. Irrigation at 1.0 evaporation pan coefficient.
1.3. Irrigation at 0.8 evaporation pan coefficient.

2. Soybean/maize intercropping patterns:

2.1. Intercropping at 1:1 of soybean/maize pattern.
2.2. Intercropping at 1:2 of soybean/maize pattern.
2.3. Intercropping at 2:1 of soybean/maize pattern.
2.4. Intercropping at 2:2 of soybean/maize pattern.
2.5. Sole soybean.
2.6. Sole maize.

Harvest took place on October 10^{th} and 17^{th} in the 1^{st} and 2^{nd} growing seasons for both crops maize and soybean, respectively, Yield data were collected from five plants (randomly selected) located at the middle three rows in each plot. These data were taken from all treatments, in addition to sole soybean and sole maize on the following characters:

1. Soybean

1. Number of pods per plant.
2. Number of seeds per plant.
3. Seeds weight per plant (g).
4. 100-seed weight (g).
5. Seed yield (kg/fed.).

2. Maize

1. Ear length (cm).
2. Grains weight per ear (g).
3. Number of grains per row.
4. 100-grain weight (g).
5. Grain yield (kg/fed).

Soil mechanical analysis according to **Piper (1950**) of the experimental field in the depth of 0-60 cm is shown in Table (1).

Table (1): Soil Mechanical analysis at Giza Agricultural Station

Soil fraction	Content (%)
Coarse sand	2.91
Fine sand	13.04
Silt	30.51
Clay	53.18
Texture class	Clay

The soil moisture constants (%per weight) and bulk density (g/cm^3) for the depth of 0-60 cm are shown in Table (2).

Table (2): Soil moisture constants and bulk density of the experimental site at Giza Agricultural Research Station

Depth (cm)	Field capacity (%, w/w)	Wilting point (%,w/w)	Available water		Bulk density g/cm^3
			(%)	(mm)	
0 – 15	41.85	18.61	23.24	40.0	1.15
15 – 30	33.68	17.50	16.18	30.1	1.24
30 – 45	28.36	16.92	11.44	20.6	1.20
45 – 60	28.05	16.54	11.51	22.1	1.28

Some metrological data for Giza Agricultural Research Station are included in Table (3).

Table (3): Meteorological data for Giza region in 2008 and 2009 seasons

Season	2008						
Month	T.max (ºC)	T.min (ºC)	W.S. (m/s)	R.H. (%)	S.S. (h)	S.R. ($cal/cm^2/day$)	E. pan (mm/month)
May	31.6	19.2	3.9	54	11.4	647	4.4
June	33.9	23.1	3.9	49	12.2	679	8.3
July	35.2	25.1	2.8	38	12.1	670	7.1
August	35.0	25.5	3.4	42	11.8	646	6.5
September	34.0	23.2	7.6	47	10.8	572	5.4
October	28.3	18.1	3.7	53	10.1	488	5.2
Season	2009						
Month	T.max (ºC)	T.min (ºC)	W.S. (m/s)	R.H. (%)	S.S. (h)	S.R. ($cal/cm^2/day$)	E. pan (mm/month)
May	32.1	18.9	3.0	47	11.4	647	7.6
June	35.4	23.4	3.8	35	12.2	679	8.0
July	35.6	24.9	2.7	59	12.1	670	7.7
August	36.4	25.8	2.8	61	11.8	646	7.6
September	34.3	23.6	3.3	53	10.8	572	6.7
October	31.8	21.7	3.8	59	10.1	488	5.9

T. max= Maximum temperature; T.Min=Minimum temperature; W.S.=Wind speed; R.H.=Relative humidity; S.S.=Actual sunshine duration; E. pan = Evaporation pan; S.R.= Solar radiation.

3. Crop-water relations measurements:

1- Seasonal actual water consumptive use (evapotranspiration)

Actual evapotranspiration (ETc) was estimated by the soil sampling just before and 48 hrs.after each irrigation, besides at harvest and calculated according to the equation of **Israelsen and Hansen (1962)** as follows:

$$CU = \frac{(\Theta_2 - \Theta_1) \text{ X Bd X 60 X 4200}}{\text{100 X 100}}$$

Where:

CU=water consumptive use in m^3/fed.

Θ_2=soil moisture percentage by weight 48 hrs after irrigation.

Θ_1=soil moisture percentage by weight just before next irrigation.

Bd=bulk density in g/cm^3

2- Water use efficiency (WUE)

Water use efficiency values were calculated as (kg final yield /m^3 water consumed) for the different treatments by the following equation **(Vites, 1965).**

$$WUE = \frac{\text{Final yield (kg/fed.)}}{\text{Consumptive use (m}^3\text{/fed.)}}$$

In order to examine the nature and the degree of competition between soybean and maize plants under intercropping, two parameters were determined i.e. land equivalent ratio (LER, Willey and Osiru, 1972) and relative crowdedness coefficient (RCC, Hall, 1974).

LER = Yab/Yaa +Yba/Ybb

RCC = [(Yab*Zba)/((Yaa-Yab)*Zab)]*[(Yba*Zab)/((Ybb-Yba)*Zba)]

Where:

Yab = the yield of crop (a) intercropped with crop (b).

Yaa = the yield of sole crop (a).

Yba = the yield of crop (b) intercropped with crop (a).

Ybb = the yield of sole crop (b).

Zab = % area of crop (a) intercropped with (b).

Zba = % area of crop (b) intercropped with (a).

The yield of soybean and maize under intercropping was changed to units of cereal **(Brochhaus, 1962).** The reason for that was to simplify the comparison between different intercropping patterns on the basis of yield and water use efficiency. This method stated that each 150 kg of soybean seeds equals to 1 unit of cereal and each 100 kg of maize grains equals to 1 unit of cereal. Thus, the units of soybean and maize were added together for each intercropping pattern and used in the calculation of water use efficiency **(Vites, 1965)** for each intercropping pattern.

Statistical Analysis

Data were statistically analyzed according to **Snedcor and Cochran (1980)** and treatment means were compared by least significant difference test (LSD) at 0.05% level of significance.

RESULTS AND DISCUSSION

1. Effect of irrigation regime

1.1 Maize yield and its components

Regarding to maize grown under different irrigation treatments, results in Table (4) indicated that all the studied characters were significantly affected by irrigation treatments over the two growing seasons. Also, results showed that the highest maize yield and its components were obtained under irrigation using evaporation pan coefficient equal to 1.2 without significantly 1.0 of 1, over all the two growing seasons exceptg yield for 2008 season. This could be attributed to the fact that increasing available soil moisture during vegetative and reproductive growth of maize increased maize yield and its components **(Shalaby and Mekhail, 1979; Ashoub *et al*., 1996; Khedr *et al*., 1996).** Furthermore, maize yield and its components tend to be higher in 2009 growing season, compared with 2008 growing season. This may be attributed to favorable climatic conditions that were prevailing during 2008 growing season.

Table (4): Effect of irrigation treatments on maize yield and its components under intercropping with soybean for 2008 and 2009 growing seasons.

I	Ear length (cm)		Grain weight /ear (g)		No. of grains/row		100-grain weight (g)		Grain yield (kg/fed)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1.2	22.16	25.10	144	208	47.41	55.91	35.77	34.08	2385	2590
1.0	21.56	24.77	141	199	46.27	51.28	35.22	33.21	2098	2385
0.8	18.85	19.8	104	154	24.09	44.39	23.38	29.72	1528	1666
$LSD_{0.05}$	1.52	1.96	9.61	17.24	3.20	2.39	0.7	1.57	169.06	230.68

I = irrigation treatments; 1.2 = irrigation using 1.2 pan evaporation coefficient; 1.0 = irrigation using 1.0 pan evaporation coefficient; 0.8 = irrigation using 0.8 pan evaporation coefficient.

1.2. Soybean yield and its components

Results in Table (5) indicated that only seed yield (kg/fed) was significantly affected by irrigation treatments in 2008 growing season. Whereas, in 2009 growing season, all the studied characters were significantly affected by irrigation treatments, except for number of seeds/plant and 100-seed weight (g). Moreover, Also, results showed that the highest soybean yield and its components were abtained under irrigation using evaporation pan coefficient equal to 1.2, over all the two growing seasons except for seed yield/fed was obtained under irrigation using evaporation pan coefficient equal to 1.0 without singnificant for 1-2. Similar to soybean yield and its components tend to be higher in 2009 growing season, compared with 2008 growing season. This may be due to favorable climatic conditions that were prevailing during 2009 growing season.

Table (5): Effect of irrigation treatments on soybean yield and its components under intercropping with maize for 2008 and 2009 growing seasons.

I	No. of pods/plant		No. of seeds/plant		seeds weight /plant (g)		100-seed weight (g)		seed yield (kg/fed.)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1.2	46.51	58.96	99.54	134.91	15.88	26.43	16.02	19.15	466	679
1.0	43.98	59.66	100.82	128.72	15.10	23.55	15.48	18.49	489	558
0.8	37.44	51.53	87.00	100.55	11.87	17.71	15.35	17.80	302	361
$LSD_{0.05}$	n.s.	3.65	n.s.	n.s.	n.s.	4.26	n.s.	n.s.	27.72	12.10

I = irrigation treatments; 1.2 = irrigation using 1.2 pan evaporation coefficient; 1.0 = irrigation using 1.0 pan evaporation coefficient; 0.8 = irrigation using 0.8 pan evaporation coefficient.

2. Effect of intercropping patterns

2.1. Maize yield and its components

Regarding to 2008 growing season, all the studied characters were found significantly affected by intercropping patterns (Table 6). Moreover, in 2009 growing season, only number of grains per row and grain yield (kg/fed.) were found to be significantly affected by intercropping patterns. Results in table (6) implied that the highest maize yield could be obtained under intercropping pattern 1:2 alternated rows of soybean and maize. This could be attributed to the competitive ability that maize have at higher populations under intercropping **(Willey and Osiru, 1972).**

Table (6): Effect of intercropping patterns on maize yield and its components for 2008 and 2009 growing seasons.

IC	Ear length (cm)		Grain weight /ear (g)		No. of grains/row		100-grain weight (g)		Grain yield (kg/fed.)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1:1	20.58	23.21	133	187	44.71	50.33	33.92	32.28	1733	1982
1:2	21.89	23.31	140	191	46.89	50.73	35.3	32.71	2100	2321
2:1	19.57	23.08	106	180	41.58	47.69	31.94	32.11	1178	1390
2:2	20.81	23.31	134	188	46.84	50.64	34.02	32.3	1783	2050
Maize	21.44	23.21	135	188	46.27	51.56	37.09	32.27	3226	3326
$LSD_{0.05}$	1.54	n.s.	11.17	n.s.	2.33	2.24	2.87	n.s.	155.70	183.76

IC =intercropping patterns; 1:1 = one row of soybean and one row of maize; 1:2 = one row of soybean and two rows of maize; 2:1 = two rows of soybean and one row of maize; 2:2 = two rows of soybean and two rows of maize.

2.2. Soybean yield and its components

With regards to soybean planted in 2008 growing season, three characters were significantly affected by intercropping patterns i.e. seeds weight per plant (g), 100-seed weight (g) and seed yield, kg/fed. (Table 7). Furthermore, in 2009 growing season, only 100-seed weight (g) and seed yield (kg/fed) were significantly affected by intercropping patterns. Results in Table (7) indicated that the highest soybean yield could be obtained under intercropping pattern 2:1 alternated rows of soybean and maize. One benefit attained from intercropping soybean and maize is the shad that maize plants do, which reduced the number of weeds grown between soybean rows **(Gardner *et al.*, 1985).** Thus, this result implied one maize row could lower the number of weeds grown between the two rows of soybean and that consequently could improve final soybean yield.

Table (7): Effect of intercropping patterns on soybean yield and its components in 2008 and 2009 growing seasons.

IC	No. of pods/plant		No. of seeds/plant		seeds weight/plant (g)		100-seed weight (g)		seed yield (kg/fed.)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1:1	42.63	56.46	93.45	116.79	13.01	21.73	14.31	17.69	430	455
1:2	40.26	55.22	89.74	11.73	12.65	21.58	13.63	17.56	264	311
2:1	46.48	58.08	100.15	124.36	16.68	23.04	17.66	19.92	495	590
2:2	43.81	56.84	103.00	119.60	14.78	22.47	15.47	18.70	437	476
Soybean	40.04	56.99	92.59	130.30	14.3	23.99	17.02	18.53	683	851
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.	2.46	n.s.	0.97	1.61	25.22	23.59

IC =intercropping patterns; 1:1 = one row of soybean and one row of maize; 1:2 = one row of soybean and two rows of maize; 2:1 = two rows of soybean and one row of maize; 2:2 = two rows of soybean and two rows of maize.

3. Effect of the interaction between irrigation regimes and intercropping patterns

3.1. Maize yield and its components

Results in Table (8) revealed that all the studied characters were significantly affected by the interaction between irrigation treatments and intercropping patterns, except for 100-grain weight (g) in 2008 growing season. In 2009 growing season, grains weight/ear (g) and grain yield (kg/fed) were significantly affected by the interaction between irrigation treatments and intercropping pattern. The results in that table also indicated that the highest maize yield could be obtained under irrigation using evaporation pan coefficient equal 1.2 and intercropping one row of soybean with two rows of maize in both growing seasons. Furthermore, under the interaction between all irrigation treatments and one row of soybean with two rows of maize, the reduction in maize yield compared with the sole crop was between 23-35% in the first growing season. Whereas, the reduction was 29% in the second growing season. These losses were compensated by the obtained yield of soybean.

Table (8): Effect of the interaction between irrigation regimes and intercropping patterns on maize yield and its components for 2008 and 2009 growing seasons.

I	IC	Ear length (cm)		Grains weight/ear (g)		Number of grain/row		100-grain weight (g)		Grain yield (kg/fed)	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1.2	1:1	23.53	25.03	159	206	50.47	53.00	36.13	33.58	2038	2304
	1:2	23.47	25.30	165	203	48.67	54.60	36.6	34.48	2798	2823
	2:1	18.23	25.23	83	208	37.87	53.87	29.43	33.32	1377	1562
	2:2	22.43	25.00	153	216	50.47	53.80	36.53	34.30	2090	2373
	Maize	23.13	24.93	162	206	49.60	54.27	40.13	34.69	3824	3990
1.0	1:1	20.73	24.67	137	199	45.20	53.07	33.10	32.16	1813	2087
	1:2	22.13	24.53	142	213	47.67	53.00	35.77	33.49	2646	2588
	2:1	21.47	24.67	137	180	44.40	47.87	33.47	33.90	1213	1397
	2:2	21.00	25.03	142	193	47.53	54.00	35.23	32.81	1872	2184
	Maize	22.47	24.97	145	209	46.53	53.47	38.53	33.67	3447	3668
0.8	1:1	17.47	19.93	104	154	38.47	44.93	32.53	31.09	1348	1555
	1:2	20.07	20.10	114	158	44.33	44.60	33.53	30.16	1555	1651
	2:1	19.00	19.33	99	153	42.47	41.33	32.93	29.11	943	1211
	2:2	19.00	9.90	106	156	42.53	44.13	30.30	29.78	1388	1594
	Maize	18.73	19.73	97	149	42.67	46.93	32.60	28.44	2407	2319
$LSD_{0.05}$		2.67	n.s.	19.34	16.74	4.04	n.s.	n.s.	n.s.	269.68	318.28

I = irrigation treatments; 1.2 = irrigation using 1.2 pan evaporation coefficient; 1.0 = irrigation using 1.0 pan evaporation coefficient; 0.8 = irrigation using 0.8 pan evaporation coefficient; IC =intercropping patterns; 1:1 = one row of soybean and one row of maize; 1:2 = one row of soybean and two rows of maize; 2:1 = two rows of soybean and one row of maize; 2:2 = two rows of soybean and two rows of maize.

3.2. Soybean yield and its components

Regarding to the effect of the interaction between irrigation treatments and intercropping patterns, results in table (9) showed that in 2008 growing season, seeds weight/plant (g),100-seed weight (g) and seed yield (kg/fed.) were found to be significantly affected by the interaction between irrigation and intercropping patterns. Furthermore, in 2009 growing season, number of pods/plant and seeds yield (kg/fed.) were found to be significantly affected by the interaction between irrigation and intercropping patterns. Furthermore, under the interaction between all irrigation treatments and one row of soybean with two rows of maize, the reduction in soybean yield compared with the sole crop was between 25-28% in the first growing season. Whereas, the reduction was between 32-51% in the second growing season, when sole soybean was compared with two rows soybean and one row maize intercropping pattern. These losses were compensated by the obtained yield of maize.

Table (9): Effect of the interaction between irrigation and intercropping patterns treatments on soybean yield components in 2008 and 2009 growing seasons.

I	IC	Number of pods/plant		Number of seeds/plant		Seeds weight /plant (g)		100-seed weight (g)		Seeds yield (kg/fed)	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1.2	1:1	47.33	54.47	87.89	143.01	12.87	23.97	15.17	19.16	544	603
	1:2	40.22	58.10	98.56	124.68	12.62	27.97	13.37	17.25	610	395
	2:1	62.67	61.33	93.78	125.38	19.19	25.53	18.37	20.48	374	727
	2:2	43.00	58.47	104.89	128.99	16.86	25.67	14.74	19.96	553	645
	Soybean	39.33	62.43	112.56	152.51	17.87	29.00	18.77	18.92	848	1078
1.0	1:1	39.44	63.33	96.00	103.98	14.14	23.13	14.47	16.71	454	484
	1:2	45.00	56.10	95.89	109.44	11.70	19.03	13.07	18.17	548	334
	2:1	46.00	60.90	96.78	141.67	20.69	22.67	17.60	20.72	220	600
	2:2	41.33	58.43	127.78	133.67	15.49	24.57	16.07	18.32	460	492
	Soybean	48.11	59.53	84.67	154.84	13.48	28.37	16.2	18.52	765	880
0.8	1:1	41.11	51.57	96.45	103.39	12.03	18.10	13.3	17.21	293	278
	1:2	35.55	51.47	74.78	106.02	13.63	17.73	14.47	18.55	327	195
	2:1	30.78	52.20	106.89	113.06	10.16	20.93	17.30	17.27	157	204
	2:2	47.11	53.63	76.33	96.13	11.99	17.17	15.60	17.84	298	292
	Soybean	32.67	49.00	80.56	84.13	11.54	14.60	16.10	18.14	436	596
$LSD_{0.05}$		n.s.	5.15	n.s.	n.s.	4.25	n.s.	1.67	n.s.	43.69	40.86

I = irrigation treatments; 1.2 = irrigation using 1.2 pan evaporation coefficient; 1.0 = irrigation using 1.0 pan evaporation coefficient; 0.8 = irrigation using 0.8 pan evaporation coefficient; IC =intercropping patterns; 1:1 = one row of soybean and one row of maize; 1:2 = one row of soybean and two rows of maize; 2:1 = two rows of soybean and one row of maize; 2:2 = two rows of soybean and two rows of maize.

4. Land equivalent ratio (L.E.R) and relative crowdedness coefficient (R.C.C) under different soybean/maize intercropping patterns

The highest L.E.R were obtained when 2:2 intercropping pattern of soybean and maize was used under the three irrigation treatments in both growing seasons (Table 10). Results also showed that the highest L.E.R was equal to 1.26 obtained under 2:2 soybean and maize using 0.8 pan coefficient in the two growing seasons. Moreover, the highest RCC was obtained using 1:2 soybean and maize under the three irrigation treatments for both growing seasons. The highest RCC was equal to 10.14 obtained under 1:2 soybean and maize using 1.2 pan coefficient in the first growing season.

Table (10): Land equivalent ratio (LER) and relative crowdedness coefficient (RCC) under different soybean/maize intercropping patterns in 2008 and 2009 growing seasons.

Irrigation treatments	Intercropping patterns	2005		2006	
		LER	RCC	LER	RCC
1.2	1:1	1.17	2.04	1.14	1.74
	1:2	1.12	10.14	1.08	5.79
	2:1	1.08	0.35	1.07	0.33
	2:2	1.20	2.26	1.19	2.21
1.0	1:1	1.13	1.36	1.12	1.61
	1:2	1.11	7.05	1.09	2.61
	2:1	1.07	0.34	1.06	0.32
	2:2	1.14	1.81	1.16	1.87
0.8	1:1	1.18	3.18	1.14	1.77
	1:2	1.14	4.23	1.08	5.32
	2:1	1.01	0.47	1.05	0.78
	2:2	1.26	2.92	1.26	2.16

I = irrigation treatments; 1.2 = irrigation using 1.2 pan evaporation coefficient; 1.0 = irrigation using 1.0 pan evaporation coefficient; 0.8 = irrigation using 0.8 pan evaporation coefficient; IC =intercropping patterns; 1:1 = one row of soybean and one row of maize; 1:2 = one row of soybean and two rows of maize; 2:1 = two rows of soybean and one row of maize; 2:2 = two rows of soybean and two rows of maize.

5. Water consumptive use and water use efficiency

5.1. Effect of irrigation treatments

The intercropping patterns were evaluated on the basis of three items: units of cereal, consumptive water use and water use efficiency (Table 11 and 12). Regarding to 2008 growing season, the results in table (11) revealed that the highest unit of cereals for all soybean and maize intercropping patterns and for sole soybean and sole maize was obtained under irrigation with 1.2 pan evaporation coefficient, i.e. 24 units. Furthermore, the highest water use efficiency and the highest water consumptive use were obtained under this treatment also. The average value of water consumptive use was 59.13 cm and average value of water use efficiency was 0.40 cereal unit /cm (Table 11). Units of cereals were 20 and 15 units for irrigation with 1.0 and 0.8 pan evaporation coefficients, respectively. Moreover, water consumptive use values were 54.78 and 51.12 cm for irrigation with 1.0 and 0.8 pan evaporation coefficients, respectively. With regard to the value of water use efficiency, it was 0.37 and 0.29 cereal unit /cm (Table 11).

Similar trend was obtained in the 2009growing season, where the highest unit of cereals, water consumptive use and water use efficiency were obtained under irrigation at 1.2 pan evaporation coefficient and the lowest values were obtained under irrigation at 0.8 pan evaporation coefficient (Table 11). From these results it could be concluded that increasing irrigation frequency accelerated the vegetative growth of maize and soybean and therefore encouraged cell division and meristmatic activity by good absorption of nutrients with high level of available moisture.

5.2. Effect of soybean/maize intercropping patterns

Regarding to the intercropping patterns, the highest unit of cereals was obtained from 1:2 soybean/maize, i.e. 25 units. Furthermore, this intercropping pattern resulted in the highest water consumptive use (57.2cm) and water use efficiency (0.43 (/cereal unit /cm). The lowest value of unit of cereals (14 unit), water consumptive use (53.8 cm) and water use efficiency (0.25 cereal unit /cm) was obtained 2:1 soybean/maize intercropping pattern (Table 11).

Regarding to 2009 growing season, similar trends was observed, where the highest unit of cereals, water consumptive use, and water use efficiency for all soybean and maize intercropping patterns and for sole soybean and sole maize were obtained under 1:2 soybean/maize intercropping pattern were 25 unit, 59.5 cm and 0.42 cereal unit /cm. While the lowest values were obtained under 2:1 soybean/ maize (Table 12).

Table (11): Water consumptive use and water use efficiency under different soybean/maize intercropping patterns in 2008 growing seasons.

Irrigation Treatments	Intercropping patterns	Cereal units			WCU (cm)	WUE (cereal unit/cm)
		Soybean	Maize	Total		
1.2	1:1	4	20	24	60.21	0.41
	1:2	5	26	31	60.83	0.51
	2:1	2	14	16	58.57	0.27
	2:2	4	21	25	59.64	0.42
	Sole soybean	7	--	7	57.02	0.13
	Sole maize	--	38	38	58.48	0.65
Mean		4	20	24	59.13	0.45
1.0	1:1	3	18	21	56.36	0.38
	1:2	4	21	25	57.07	0.45
	2:1	2	12	14	53.57	0.27
	2:2	3	19	22	55.83	0.39
	Sole soybean	6	--	6	51.50	0.11
	Sole maize	--	34	34	54.36	0.63
Mean		3	17	20	54.78	0.37
0.8	1:1	2	13	15	53.19	0.29
	1:2	3	16	19	53.74	0.34
	2:1	1	9	10	49.36	0.22
	2:2	2	14	16	51.98	0.30
	Sole soybean	4	--	4	48.33	0.08
	Sole maize	--	24	24	50.12	0.48
Mean		2	13	15	51.12	0.29
General mean of intercropping pattern	1:1	3	17	20	56.60	0.36
	1:2	4	21	25	57.20	0.43
	2:1	2	12	14	53.80	0.25
	2:2	3	18	21	55.80	0.37
	Soybean	6	--	6	52.30	0.11
	Maize	--	32	32	54.32	0.59
Mean		3	17	20	55.0	0.36

5.3. Effect of interaction between irrigation treatments and soybean/maize intercropping patterns

The highest value of unit of cereals, water consumptive use and water use efficiency was obtained under irrigation at 1.2 pan evaporation coefficient and 1:2 soybean/maize intercropping pattern. The lowest value of unit of cereals, water consumptive use and water use efficiency was obtained under irrigation at 0.8 pan evaporation coefficient and 2:1 soybean/maize intercropping pattern (Table 12).

With respect to the interaction between irrigation treatments and soybean/maize intercropping patterns in 2009 growing season, the same trend was observed, where the highest value of unit of cereals, water consumptive use and water use efficiency was obtained under irrigation at 1.2 pan evaporation coefficient and 1:2 soybean/maize intercropping pattern (Table 12).

Table (12): Water consumptive use and water use efficiency under different soybean/maize intercropping patterns in 2009 growing seasons.

Irrigation Treatments	Intercropping patterns	Cereal units			WCU (cm)	WUE (cm/cereal unit)
		Soybean	Maize	Total		
1.2	1:1	4	23	27	63.05	0.42
	1:2	2	27	29	63.81	0.47
	2:1	4	16	20	61.45	0.32
	2:2	4	24	28	62.98	0.44
	Soybean	6	---	6	57.45	0.10
	Maize	---	40	40	61.21	0.65
Mean		3	22	25	61.66	0.41
1.0	1:1	3	21	24	59.26	0.40
	1:2	1	26	27	59.52	0.46
	2:1	4	14	18	57.00	0.31
	2:2	3	22	25	58.86	0.42
	Soybean	5	---	5	53.26	0.10
	Maize	---	37	37	56.40	0.65
Mean		3	20	23	57.38	0.40
0.8	1:1	2	16	18	54.43	0.32
	1:2	1	17	18	55.07	0.32
	2:1	2	12	14	53.14	0.27
	2:2	2	16	18	53.95	0.33
	Soybean	3	---	3	50.17	0.06
	Maize	---	23	23	52.62	0.44
Mean		1.7	14	16	53.23	0.30
General mean of intercropping pattern	1:1	3	20	23	58.9	0.38
	1:2	1	24	25	59.5	0.42.
	2:1	3	14	17	57.2	0.30
	2:2	3	21	24	58.6	0.40
	Soybean	5	-	5	53.6	0.09
	Maize	-	33	33	56.7	0.58
Mean		3	19	21	57.4	0.37

CONCLUSION

1. Intercropping involves planting two crops that differed in growth habits, phonological characteristics and productivity on the same unit of land **(IITA, 1980).**
2. Intercropping may do the environmental resources such as radiation, water and nutrients more efficiently than monocrops **(Willey, 1990).**
3. The results showed that the amount of applied irrigation water under 1:2 soybean/maize intercropping pattern gave the highest yield than the

applied amount to sole maize planting whereas, the applied amount to that intercropping pattern was higher by 6-11% than the amount applied to soybean. However, the advantage is coming from producing high yields from two crops by a little increase in the applied amount of irrigation water, compared with sole planting.

REFERENCES

Abd El-Gawad, A.A.; A.S. Edris and A.M. Abo-Shetaia (1985). Intercropping soybean with maize: 3. Competitive relationships and yield advantages. Ann. Agric. Sci. Fac. Agric., Ain Shams Univ. 30(1): 237-248.

Ashoub, M.A.; M.S. Hassanein and I.M. Abedel-Azize; M.M. Shahin and M.N. Gohar (1996). Influence of irrigation, nitrogen, zinc and manganese fertilization on yield and yield components of maize. Ann. Agric Sci. Ain Sham. Univ. 41(2): 697-711.

Borhom, T.I.H. (2001). Studies on water requirements for some crops under different cropping systems. M. Sc. Thesis. Fac Agric. Cairo Univ.

Brockhaus, F.A.(1962). ABC der Landwirtschaft, Band I: A-K. 2nd Edit. VEB, Brock Haus Verlag, Leipzig. 488-489.

Cassel, D.K., C.K. Martin and J.R. Lambert (1985). Corn irrigation scheduling in humid regions on sandy soil with tillage pans. Agron. J. 77(6):851-855.

Doorenbos, J. and W.O. Pruitt (1992). Guidelines for predicting crop water requirements. FAO Irrigation and Drainage. No.: 24,Rom

El-Shenawy, A.A. (1990). Effect of water stress and plant population on single and double crosses in maize (Zea mays L.). M.Sc. Thesis Fac. of Agric. Kafr El-Skeikh, Tanta Univ.

Foroud, N.; Mundel, H.H.; Saindon, G. and T.Entz, (1993). Effect of level and timing of moisture stress on soybean yield components. Irri. Sci. 13, 149–155.

Galal, S.L.; M.M. Hindi; Abdalla and A.A. Metwally (1984). Intercropping corn and soybean under different patterns of intercropping. 1st Conf. Agric. Bot. Mansoura. 170-179.

Gardner, F.P.; R.B Pearce and R.L. Mitchell. (1985). Physiology of Crop Plants. Iowa State University Press. Ames.

Hall, R.L. (1974). Analysis of the nature of interference between plants of different species. Aust. J. Agric. Res. 25:749-756.

International Institue of Tropical Agriculture (IITA) (1980). Annual Report, Ibadan, Nigeria. pp10-15.

Israelsen, O.W. and V.E. Hansen. (1962). Irrigation Principles and Practices. John Wiley & Sons, Inc. New York.

Keating, B.A. and P.S. Carberry, (1993). Resource capture and use in intercropping: solar radiation. Field Crops Research. 34:273-301.

Khedr, P.J.: S.E.G. Matta; M.F. Wahba and M.M. El-Koliey (1996). Effect of water regime on yield of some maize cultivar and water relations. Bull. Of Agric. Cairo Univi. 47(1): 87-98.

Kranz, W.L.; R.W. Elmore and J.E. Specht. (1998). Irrigating Soybean. University of Nebraska–Lincoln Extension educational programs.

Morris, R.A. and D.P. Garrity, (1993). Resource capture and utilization in intercropping: water. Field Crops Research. 34:303-317.

Piper, C. S. (1950). Soil and plant analysis. Univ. of Adelaid. Australia.

Ritchie, S.W.; J.J. Hanway, and G.O. Benson. (1993). How corn plant develops. Iowa State Univ. Sci. Tech. Cooperative Ext. Services. Report No. 48. Iowa State University, Ames.

Shalaby, Y.Y. and S.M. Mekhail (1979). Effect of planting date, watering intervals and nitrogen rates on maize. Ann. Agric. Sci., Moshtohor, 11:25-34.

Sherif, A.E.M. (1984). Studies on the intercropping of soybean with maize on the growth and yield parameters. M. Sc. Thesis Fac. Agric. Mansoura Univ.

Snedcor, G.W. and Cochran (1980). Statistical Methods. 7th Edition, Iowa Stat. Univ. Press, Ames., Iowa, USA.

Tsubo, M.S. Walker and H.O. Ogindo. (2005). A simulation model of cereal-legume intercropping system for semi-arid regions. Field crops Res., 93(1):10-22.

Vites, F.G.Jr. (1965). Increasing water efficiency by soil management. Amer. Soci. Agron., 26:259-274.

Willey, R.W. (1990). Resource use in intercropping systems Agricultural Water Management, 17:215-231.

Willey, R.W. and D.S.Osiru. (1972). Studies on mixtures of maize and beans with particular reference to plant population. J. Agric. Sci., 79:517-529.

تأثير معاملات الرى على محصول فول الصويا والذرة الشامية تحت نظم تحميل مختلفة

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أجريت تجربتان حقليتان بمزرعة محطة البحوث الزراعية بالجيزه خلال موسمى ٢٠٠٨، ٢٠٠٩ لدراسة أثر جدولة الرى بإستخدام البخر التراكمى للوعاء تحت نظم مختلفة من تحميل محصولى فول الصويا والذرة لاشامية على المحصول ومكوناته وبعض العلاقات المائية وكذا بعض المقاييس الخاصة بنظم التحميل وهما معدل استغلال الارض وكذلك معدل التزاحم النسبى. وقد استخدم ثلاثة معاملات رى (١.٢، ١.٠، ٠.٨ معامل بخر الوعاء) مع اربعة معاملات لنظم التحميل بين فول الصويا والذرة الشامية وهى (١:١، ١:٢، ٢:١، ٢:٢) لكل من فول الصويا والذرة الشامية على الترتيب ويمكن تلخيص النتائج الرئيسية فى الأتى:

١- تأثر محصول الذرة الشامية ومكوناتة بمختلف معاملات الرى خلال موسمى الزراعة وقد كانت اعلى القيم لمحصول الذرة الشامية ومكوناتة عند الرى ١.٢ من بخر الوعاء. وكانت النتائج مشابهة لمحصول فول الصويا.أدى الرى عند (١.٢ معامل بخر الوعاء) ألى زيادة محصول الحبوب ومكوناته لمحصول الذرة الشامية خلال موسمى الدراسة وقد سلك محصول فول الصويا نفس الاتجاه.

٢- تأثر محصول الذرة الشامية معنوياً بنظام التحميل ١:٢ بتبادل صف من فول الصويا مع صفين من الذرة الشامية.

٣- كان اعلى محصول لفول الصويا تحت نظام التحميل ٢:١ حيث يتبادل صفين من فول الصويا مع صف من الذرة الشامية.

٤- كانت قيم معدل كفاءة استغلال الارض (L.E.R) ومعامل التزاحم النسبى (R.C.C) عالية تحت نظام التحميل ٢:١، ١:٢ فول صويا وذرة مع معاملة الرى عند ٠.٨، ١.٢ معامل بخر الوعاء.

٥- بلغ أعلى استهلاك مائى (٦٠.٨٣,٦٣.٨١ سم) وأعلى كفاءة لاستخدام المياة (٠.٥١، ٠.٤٧ وحدة/سم) خلال موسمين الزراعة وتحت نظام تحميل ٢:١ فول صويا وذرة شامية على الترتيب.