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Effect of Water Stress on the yield of Soybean and Maize Grown under Different Intercropping Patterns

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Abstract: Two field experiments were conducted at Giza Agricultural Research Station, Agricultural Research Center, Egypt during 2005 and 2006 growing seasons. The aim of the experiment was to determine the effect of water stress on the yield soybean/maize under different intercropping patterns and their water use efficiency. Intercropping patterns were: 1:1, 1:2, 2:1 and 2:2 soybean/maize. Irrigation treatments consisted of: irrigation using 1.2 pan evaporation coefficient (control), irrigation using 1.0 pan evaporation coefficient (about 7% reduction in irrigation water than the control) and irrigation using 0.8 pan evaporation coefficient (about 14% reduction in irrigation water than the control). The yield of soybean and maize under intercropping was changed to units of cereal to simplify the comparison between different intercropping patterns. Water use efficiency values were calculated for the different treatments by dividing yield in cereal units by consumptive water use. Results showed that the highest yield was obtained under 1:2 soybean/maize intercropping pattern and using irrigation with evaporation pan coefficient equaled to 1.2, compared with either sole maize or sole soybean planting. Furthermore, the highest amounts of irrigation water were applied to 1:2 soybean/maize intercropping pattern for the three irrigation treatments in both growing seasons. Results also indicated that under 1.0 and 0.8 pan evaporation coefficients (7 and 14% reduction in irrigation water than the control, respectively), the lowest reduction in both soybean and maize yield was obtained under 1:2 soybean/maize intercropping pattern. The highest water use efficiency were obtained under 1:2 soybean/maize intercropping pattern and irrigation with 1.0 evaporation pan coefficient. However, water use efficiency was relatively low under irrigation with 0.8 evaporation pan coefficient. Therefore, it could be concluded that to attain high water use efficiency from 1:2 soybean/maize intercropping pattern, irrigation should be applied using 1.0 pan evaporation coefficient, which could save up to 7% of irrigation amounts.

Keywords: water stress, soybean/maize intercropping, irrigation treatments, water use efficiency

INTRODUCTION

Increasing crops productivity and saving irrigation water are two interrelated issues raising a lot of concern these days in Egypt. Legume/cereal intercropping pattern is generally more productive than reference sole crop (Tsubo *et al.,* 2005). Furthermore, the biological basis for intercropping involves complementarily of resources used by the two crops (Barhom, 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 (Willy, 1990) and water (Morris and Garrity, 1993). Under soybean/maize intercropping systems, soybean yield tends to be lower and maize yield tends to be higher (West and Griffith, 1992; Ghaffarzaeh *et al.,* 1994).

Soybean/maize intercropping could be a way of irrigation water saving, especially in situations of limited water resources (Tsubo *et al.,* 2005). Intercrops have been known to conserve water, largely due to early high leaf area index and higher leaf area (Ogindo and Walker, 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 (Barhom, 2001). Similarly, Morris and Garrity (1993) indicated that water utilization efficiency of intercrops was higher by about 18% compared by sole crop.

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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 (Gomma 1981). Moreover, both final maize yield and kernel 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 R1 (beginning bloom) through R5 (seed enlargement), its ability to compensate under stressful conditions decreases and yield losses could increases (Foroud *et al.,* 1993).

In Egypt, previous research on intercropping of soybean and maize have been emphasized on economic aspects i.e. yield and profit gain (Boyoumi, 1981; Abed El-Gwad *et al.,* 1985; El-Hawary, 1993; Barhom, 2001). However, no research was done on the effect of reducing the amount of applied irrigation on soybean and maize yield under different intercropping patterns.

The objectives of this research were: (i) to determine the effect of water stress on the yield of soybean and maize grown under different intercropping patterns; (ii) to determine the highest water use efficiency of different intercropping patterns of soybean/maize under water stress.

MATERIALS AND METHODS

Two field experiments were conducted at Giza Agricultural Research Station, Agricultural Research Center, Egypt during 2005 and 2006 growing seasons. The aim of the experiment was to determine the effect of water stress on the yield of different intercropping patterns of soybean/maize and on their water use efficiency. 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 solo 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. Soybean seeds were inoculated before sowing and planted on May 18th in both growing seasons. Super phosphate (54 unit/ha, 15.5% P_2O_5) was added, in addition to ammonium nitrate (36 unit/ha, 33.5% N) before the second irrigation. Furthermore, potassium sulfate (58 unit/ha, 48% KO2) was added before the third irrigation. The second irrigation (after planting irrigation) was applied to soybean on June, 9th in both growing seasons. Maize seeds were sown on June 9th in both growing seasons. Nitrogen fertilizer was applied in the form of ammonium nitrate (288 unit/ha, 33% N) and was added before the 2nd irrigation. Phosphorus fertilizer was applied in the form of single super phosphate (72 unit/ha, 15.5% P_2O_5) and was incorporated into the soil during land preparation. Potassium sulfate was applied before the second irrigation (58 unit/ha, 48% KO2). Surface irrigation was used. 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):

$$I = Epan * Kp \qquad (1)$$

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. Irrigation treatments consisted of: Irrigation using 1.2 pan evaporation coefficient (control), irrigation using 1.0 pan evaporation coefficient (about 7% reduction in irrigation water than the control) and irrigation using 0.8 pan evaporation coefficient (about 14% reduction in irrigation water than the control). Whereas, intercropping using 1:1 of soybean/maize pattern, intercropping using 1:2 of soybean/maize pattern, intercropping using 2:1 of soybean/maize pattern and intercropping at 2:2 of soybean/maize pattern. Weed control was done by hand. Harvest took place on October 10th and 17th in 2004 and 2005 seasons, respectively, Yield data were collected from five plants (randomly selected) located at the middle three rows in each plot. These data were taken on the different treatments, in addition to sole soybean and sole maize. To ease comparison between the yields of intercrops and sole soybean and maize, relative yield of either sole maize or sole soybean to the area of its corresponding intercropping pattern was calculated. 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

Table 2: Soil moisture constants of the experimental field at Giza Agricultural Station

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

Table 3: Meteorological data for Giza region in 2005 and 2006 seasons

Season	2005						
Month	Tmax (ºC)	Tmin (ºC)	WS (m/s)	RH(%)	SS (h)	SR (cal/cm^2/day)	Epan (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	4.0
Season	2006						
Month	Tmax (ºC)	Tmin (ºC)	WS (m/s)	RH(%)	SS (h)	SR (cal/cm^2/day)	Epan(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	4.3

Tmax=Maximum temperature; TMin=Minimum temperature; WS=Wind speed; RH=Relative humidity; SS=Actual sunshine duration; SR= Solar radiation; Epan=Evaporation pan.

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

Metrological data were collected for Giza Agricultural Research Station and are included in Table (3).

Actual evapotranspiration (ET) was estimated by soil sampling before and after 48 hours of each irrigation, and before harvest and calculated according to the equation of Israelsen and Hansen (1962) as follows:

$$CU = (\Theta_2 - \Theta_1) * Bd * RD \qquad (2)$$

Where: CU is water consumptive use (mm), Θ_2 is soil moisture percentage by weight 48 hours after irrigation, Θ_1 is soil moisture percentage by weight 48 hours before following irrigation, Bd is bulk density in (g/cm^3) and RD is root depth.

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. Water use efficiency values were calculated for the different treatments by dividing yield in cereal units by consumptive use. Data were statistically analyzed according to Snedecor and Cochran (1980) and treatment means were compared by least significant difference test (LSD) at 0.05% level of significance.

RESULTS AND DISCUSSIONS

Results:

Effect of Irrigation and Intercropping Patterns on Maize Yield:

The yield of both intercropped maize and the sole maize was the highest under irrigation with evaporation pan coefficient equaled to 1.2, compared with the other to irrigation treatments in both 2005 and 2006 growing seasons (Table 4). Furthermore, under the three irrigation treatments, maize plants grown under the

Table 4: Maize yield under different irrigation treatments and intercropping patterns and relative sole maize yield in 2005 and 2006 growing seasons.

		2005			2006		
I	IC	Maize yield under intercropping (ton)	Relative sole maize yield (ton)	% increase	Maize yield under intercropping (ton)	Relative sole maize yield (ton)	% increase
1.2	1:1	4.89^{b}	3.90^{b}	25.34	5.53^{a}	3.91^{b}	41.31
	1:2	7.20^{a}	5.23^{a}	37.60	7.02^{a}	5.24^{a}	33.78
	2:1	3.30^{c}	2.60^{c}	27.03	3.75^{b}	2.61^{c}	43.70
	2:2	5.02^{b}	3.90^{b}	28.54	5.70^{a}	3.91^{b}	45.54
1.0	1:1	4.35^{bc}	3.66^{b}	18.89	5.01^{b}	3.66^{b}	36.85
	1:2	6.83^{a}	4.90^{a}	39.27	6.69^{a}	4.90^{a}	36.43
	2:1	2.91^{c}	2.44^{c}	19.31	3.35^{c}	2.44^{c}	37.41
	2:2	4.49^{b}	3.66^{b}	22.75	5.24^{ab}	3.66^{b}	43.21
0.8	1:1	3.24$^{a\ b}$	2.29^{b}	41.15	3.32$^{a\ b}$	2.30^{b}	44.10
	1:2	4.66^{a}	3.07^{a}	51.73	4.50^{a}	3.09^{a}	45.76
	2:1	2.26^{b}	1.53^{c}	48.12	2.23^{c}	1.54^{c}	45.18
	2:2	3.33$^{a\ b}$	2.29^{b}	45.34	3.46^{ab}	2.30^{b}	50.17

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.
a, b, and c letters within each intercropping patterns indicates significant level at $P<0.05$

Table 5: Soybean yield under different irrigation treatments and intercropping patterns and relative sole soybean yield in 2005 and 2006 growing seasons.

		2005			2006		
I	IC	Soybean yield under intercropping (ton)	Relative sole soybean yield (ton)	% increase	Soybean yield under intercropping (ton)	Relative sole soybean yield (ton)	% increase
1.2	1:1	1.31^{b}	0.92^{b}	43.08	1.45^{c}	1.08^{b}	34.26
	1:2	1.46^{a}	1.23^{a}	19.00	1.74^{a}	1.45^{a}	20.23
	2:1	0.90^{c}	0.61^{c}	47.44	0.95^{d}	0.72^{c}	31.94
	2:2	1.33^{b}	0.92^{b}	44.93	1.57^{b}	1.08^{b}	45.37
1.0	1:1	1.09^{b}	0.84^{b}	29.76	1.16^{b}	0.94^{b}	23.93
	1:2	1.32^{a}	1.13^{a}	16.83	1.44^{a}	1.25^{a}	14.81
	2:1	0.62^{c}	0.56^{c}	10.71	0.80^{c}	0.62^{c}	28.21
	2:2	1.10^{b}	0.84^{b}	30.95	1.18^{b}	0.94^{b}	26.07
0.8	1:1	0.70^{b}	0.52^{b}	33.79	0.67^{b}	0.63^{b}	3.08
	1:2	0.78^{a}	0.70^{a}	11.26	1.07^{a}	0.91^{a}	17.57
	2:1	0.38^{c}	0.35^{c}	8.94	0.49^{c}	0.45^{c}	8.22
	2:2	0.72^{ab}	0.52^{b}	37.61	0.72^{b}	0.68^{b}	6.01

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.
a, b, c letters within each intercropping patterns indicates significant level at $P<0.05$

four intercropping patterns out yielded sole maize plants grown in the same land area for both growing seasons. The highest maize yield was obtained from planting one row of soybean with two rows of maize under the three irrigation treatments. Under irrigation with 1.2 evaporation pan coefficient and the highest maize yield was 7.20, and 7.03 ton per 2/3 of a hectare, for both growing seasons, respectively under 1:2 soybean/maize intercropping, respectively and were higher than the relative maize yield of the same previously mentioned area by 37.6 and 33.78% for both growing seasons, respectively (Table 4). Furthermore, under the same intercropping pattern and irrigation using 1.0 evaporation pan coefficient (water stress conditions), percent increase in yield under intercropped maize compared with the sole planting was 39.27 and 36.43%, for the two growing seasons, respectively. This could be an advantage to apply less irrigation water to intercropped maize and still get more yields compared to the yield obtained from sole maize planting (Table 4). Similar trend was observed for using 0.8 evaporation pan and under 1:2 soybean and maize intercropping pattern, where percent increase in yield under intercropping compared with the sole planting was 51.73 and 45.76%, for the two growing seasons, respectively.

Effect of Irrigation and Intercropping Patterns on Soybean Yield:

Regarding to soybean grown under intercropping pattern, the highest yield was obtained under 1:2 soybean to maize intercropping pattern for the three irrigation treatments over the two growing seasons (Table 5). Results also implied that intercropped soybean yield under 1:2 soybean to maize intercropping pattern was higher than relative sole soybean yield (resulted from 2/3 of a hectare) by 19.00, 16.83 and 11.26% under the three irrigation treatments, respectively in 2005 growing season and by 20.23, 14.18 and 17.57% under the three irrigation treatments, respectively in 2006 growing season.

Table 6: Applied irrigation amounts and yield of soybean and maize grown under different irrigation treatments and different planting patterns

		2005			2006		
Irrigation treatments	Planting Patterns	Soybean yield (ton)	Maize yield (ton)	Applied irrigation (m^3/ha)	Soybean yield (ton/ha)	Maize yield (ton/ha)	Applied irrigation(m^3/ha)
1.2	1:1	1.31	4.89	7284	1.45	5.53	7626
	1:2	1.46	7.20	7358	1.75	7.02	7718
	2:1	0.90	3.30	7085	0.95	3.75	7433
	2:2	1.33	5.02	7214	1.55	5.70	7618
	Soybean	1.83	0.00	6898	2.16	0.00	6949
	Maize	0.00	7.80	7073	0.00	7.83	7404
1.0	1:1	1.09	4.35	6817	1.16	5.01	7168
	1:2	1.32	6.83	6903	1.44	6.69	7200
	2:1	0.62	2.91	6480	0.80	3.35	6895
	2:2	1.10	4.49	6754	1.18	5.24	7119
	Soybean	1.68	0.00	6229	1.87	0.00	6443
	Maize	0.00	7.32	6375	0.00	7.20	6823
0.8	1:1	0.70	3.24	6434	0.67	3.32	6584
	1:2	0.78	4.66	6500	1.07	4.50	6661
	2:1	0.38	2.26	5970	0.49	2.23	6428
	2:2	0.72	3.33	6287	0.72	3.46	6526
	Soybean	1.05	0.00	5846	1.36	0.00	6068
	Maize	0.00	4.68	6062	0.00	4.61	6365

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; 1:1 = 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

Table 7: Reduction in soybean and maize yield under 1.0 and 0.8 pan evaporation coefficient and different intercropping patterns averaged over the two growing seasons.

	1.0 pan evaporation coefficient		0.8 pan evaporation coefficient	
Planting pattern	% of soybean yield reduction	% of maize yield reduction	% of soybean yield reduction	% of maize yield reduction
1:1	18.40	10.23	50.18	36.91
1:2	13.82	4.84	42.72	35.54
2:1	23.45	11.24	53.10	36.02
2:2	20.49	9.20	49.65	36.42
Soybean	10.81	0.00	39.83	0.00
Maize	0.00	7.10	0.00	40.56

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.

Amounts of Irrigations and Corresponding Yield Values:

The highest applied irrigation amounts and the highest yield were obtained for 1:2 soybean/maize intercropping pattern for the three irrigation treatments under 2005 and 2006 growing seasons (Table 6). The applied irrigation amounts under 1:2 soybean/maize intercropping pattern were slightly higher than the applied amounts to either sole soybean or sole maize under the three irrigation treatments over all the two growing seasons. However, these applied amounts under different intercropping patterns resulted in producing yield from two crops (soybean and maize), which is more beneficial. Hence, 7358 and 7718 m^3/ha of irrigation water (1.2 pan evaporation coefficient) produced 1.46 and 1.75 ton of soybean plus 7.20 and 7.02 ton of maize under 1:2 soybean/maize intercropping pattern in 2005 and 2006 growing seasons, respectively. Likewise, under water stress conditions (1.0 and 0.8 pan evaporation coefficient), the highest yield was obtained under 1:2 soybean/maize intercropping pattern for both growing seasons (Table 6). An irrigation amount of 6903 and 7200 m^3/ha of irrigation water (1.0 evaporation pan coefficient) produced 1.32 and 6.83 ton of soybean and maize, respectively in 2005 growing season, whereas 1.44 and 6.69 ton of soybean and maize, respectively in 2006 growing season, under irrigation with 1.0 evaporation pan coefficient and under 1:2 soybean/maize intercropping pattern. Furthermore, 0.78 and 1.07 ton of soybean plus 4.66 and 4.50 ton of maize under 1:2 soybean/maize intercropping pattern, when an irrigation amount of 6500 and 6661 m^3/ha of irrigation water (0.8 evaporation pan coefficient) was applied in 2005 and 2006 growing seasons, respectively.

Results in Table (7) indicated that under 1.0 and 0.8 pan evaporation coefficient (7 and 14% reduction in irrigation water than the control, respectively), the lowest reduction in both soybean and maize yield was obtained under 1:2 soybean/maize intercropping pattern. Under 1.0 pan evaporation treatment, the reduction in intercropped maize yield was 4.48, whereas it was 7.10% for sole maize yield. Similarly, the reduction in intercropped maize yield was 35.54%, but it was 40.56% for sole planting under 0.8 pan evaporation coefficient treatment. The opposite was observed for intercropped and sole soybean, where the reduction in soybean yield under 1:2 soybean/maize intercropping pattern was higher than the reduction in the yield of sole soybean. Sole soybean yield was reduced by 10.81 and 39.83% under 1.0 and 0.8 pan evaporation treatments, respectively. Whereas, intercropped soybean was reduced by 13.82 and 42.72% under 1.0 and 0.8 pan evaporation treatments, respectively (Table 7).

Total System Evaluation:

System performance was evaluated on the basis of three items: units of cereal, consumptive water use and water use efficiency. The highest units of cereal, the highest consumptive water use and the highest water use efficiency were obtained under 1:2 soybean/maize intercropping pattern under the three irrigation treatments in 2005 growing season (Table 8). Under that intercropping pattern, the value of units of cereal was 82; the value of consumptive water use was 60.83 cm and the value of water use efficiency was 1.34 unit/cm.

Table 8: Units of cereal, consumptive use (CU) and water use efficiency (WUE) under different soybean/maize intercropping patterns in 2005 growing seasons.

Irrigationtreatments	PlantingPatterns	Units of cereal			CU (cm)	WUE(unit/cm)
		Soybean	Maize	Sum		
1.2	1:1	9	49	58	60.21	0.96
	1:2	10	72	82	60.83	1.34
	2:1	6	33	39	58.57	0.67
	2:2	9	50	59	59.64	0.99
	Soybean	12	0	12	57.02	0.21
	Maize	0	78	78	58.48	1.33
1.0	1:1	7	44	51	56.36	0.90
	1:2	9	68	77	57.07	1.35
	2:1	4	29	33	53.57	0.62
	2:2	7	45	52	55.83	0.94
	Soybean	11	0	11	51.50	0.22
	Maize	0	73	73	54.36	1.34
0.8	1:1	5	32	37	53.19	0.70
	1:2	5	47	52	53.74	0.96
	2:1	3	23	25	49.36	0.51
	2:2	5	33	38	51.98	0.73
	Soybean	7	0	7	48.33	0.14
	Maize	0	47	47	50.12	0.93

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; 1:1 = 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

Table 9: Units of cereal, consumptive use (CU) and water use efficiency (WUE) under different soybean/maize intercropping patterns in 2006 growing seasons.

Irrigation treatments	Planting Patterns	Units of cereal			CU (cm)	WUE(unit/cm)
		Soybean	Maize	Sum		
1.2	1:1	10	55	65	63.05	1.03
	1:2	12	70	82	63.81	1.28
	2:1	6	37	44	61.45	0.71
	2:2	10	57	67	62.98	1.07
	Soybean	14	0	14	57.45	0.25
	Maize	0	78	78	61.21	1.27
1.0	1:1	8	50	58	59.26	0.98
	1:2	10	67	77	59.52	1.29
	2:1	5	34	39	57.00	0.68
	2:2	8	52	60	58.86	1.02
	Soybean	12	0	12	53.26	0.23
	Maize	0	72	72	56.40	1.28
0.8	1:1	4	33	37	54.43	0.69
	1:2	7	45	52	55.07	0.95
	2:1	3	22	26	53.14	0.48
	2:2	5	33	39	53.95	0.37
	Soybean	9	0	9	50.17	0.18
	Maize	0	46	46	52.62	0.88

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; 1:1 = 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

Furthermore, under irrigation with 1.0 evaporation pan coefficient (water stress treatment), water use efficiency was higher than the one under irrigating with 1.2 pan evaporation coefficient (control treatment). Water use efficiency were 1.34 and 1.35 unit/cm under irrigation with 1.2 pan evaporation coefficient and irrigation with 1.0 pan evaporation coefficient, respectively. However, under irrigation with 0.8 pan evaporation coefficient, water use efficiency was relatively low.

In 2006 growing season, the value of units of cereal, consumptive water use water use efficiency took similar trend to 2005 growing season under 1:2 soybean/maize intercropping pattern for the three irrigation treatments (Table 9). Furthermore, water use efficiency was the highest under water stress treatment (1.0 evaporation pan coefficient), compared with control irrigation treatment (1.2 evaporation pan coefficient). Whereas, it was the lowest under 0.8 evaporation pan coefficient. Water use efficiency was 1.28, 1.29 and 0.95 unit/cm under irrigation with 1.2, 1.0 and 0.8 evaporation pan coefficient.

Discussion:

Intercropping involves planting two crops that differed in growth habits, phenological characteristics and productivity on the same unit of land (IITA, 1980). Typically, C4 cereal crop, such as maize is the dominant plant species, whereas C3 legume crop, such as soybean is the associated or secondary species. Canopy structures and rooting systems of cereal crops are generally different from those of legume crops. Maize roots can penetrate deeper in the soil (up to 1.7 m) than soybean roots (up to 1.3 m) (Allen *et al.,* 1998). Furthermore, maize can form higher canopy structures than soybean. This suggests that the component crops probably have differing spatial and temporal use of environmental resources. Intercrops may make use of environmental resources such as radiation, water and nutrients more efficiently than monocrops (Willey, 1990). Pervious research done in Egypt on intercropping has focused on the effect of intercropping on land equivalent ratio and gross return/land area. In our research we focused on the effect of water stress on soybean and maize yield under intercropping and its relationship with water use efficiency. Our results showed that the amount of applied irrigation water to 1:2 soybean/maize intercropping pattern (gave the highest yield) was higher by about 4-7% (averaged over the three irrigation treatments) than the applied amount to sole maize planting (Table 6). Whereas, the applied amount to that intercropping pattern was higher by 6-11% than the amount applied to soybean (Table 6). 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 (Table 4 and 5).

Under saving the applied irrigation water by 7 %, reduction in maize yield was under intercropping (1:2 soybean/maize) was less than under sole planting (Table 7). This could be attributed to that soybean/maize intercropping caused the plants to extract soil water in a higher rate compared with sole planting and that resulted in the higher ability to convert water to biomass (Ogindo and Walker 2005). On the contrary, the reduction in soybean yield was under intercropping (1:2 soybean/maize) was higher than under sole planting (Table 7). This could be attributed to the ability of maize roots to penetrate deeper in the soil than soybean roots (Allen *et al.,* 1998), which helped in reducing maize yield losses under water stress. Furthermore, water use efficiency was the highest under 7% of saving in irrigation water, compared with control treatment and 14% reduction in applied irrigation water (Table 8 and 9). Therefore, applying irrigation water at 1.0 pan evaporation coefficient under 1:2 soybean/maize intercropping pattern could be practice to save irrigation water. However, under saving 14% of applied irrigation water (0.8 pan evaporation coefficient) yield losses was high for either intercrops or sole planting (Table 7). Under 1:2 soybean/maize intercropping pattern, yield losses were 42.72 and 35.54%, respectively. Whereas, for sole plantings of soybean and maize, yield losses were 39.83 and 40.56%, respectively under the same intercropping pattern. Moreover, water use efficiency was the lowest, compared with the other to irrigation treatments (Table 8 and 9).

Conclusion:

Four soybean/maize intercropping patterns were tested for its productivity and three irrigation treatments tested for its water use efficiency. Results showed that intercropping at 1:2 soybean/maize pattern is the most productive system, compared with the other three. Furthermore, the highest water use efficiency was obtained under irrigation with 1.0 pan evaporation coefficient (7% saving irrigation water). Therefore, it could be concluded that to attain high water use efficiency from 1:2 soybean/maize intercropping pattern, irrigation should be applied using 1.0 pan evaporation coefficient

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