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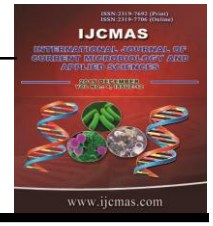

Original Research Article

Effect of deficit irrigation and soybean/maize intercropping on yield and water use efficiency

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A B S T R A C T

The present study aimed to evaluating the yield and water use efficiency (WUE) of intercropping soybean and maize under deficit irrigation and carried out at the experimental farm of the Faculty of Agriculture, Fayoum University, Egypt in 2013 and 2014. The experimental layout was distributed in split plot arrangement in randomized complete block design with three replicates. The irrigation treatments included three mainly (I_1 =100, I_2 =85 and I_3 =70% of ET_o) with three cropping systems (sole soybean, sole maize and soybean/ maize intercropping) were occupied the main and sub.plots, respectively. Surface irrigation using spiles was used and crops were planted in rows within each plots (10.5 m^2 for each).Data obtained showed that plant leaf relative water content, chlorophyll fluorescence and performance index were significantly decreased with deficit irrigation and grater values were observed with intercropping in comparison with sole system. Under intercropped system and both sole maize and soybean, the maximum values of grain yield (GY) was obtained when plants were irrigated with I_1. The results demonstrated that intercropping soybean with maize significantly reduced soybean and maize crop yields in both seasons, however the total intercropped yield was greater than that of sole crops. Land equivalent ratios (LER) of all intercrops were greater than unity; denoting that higher productivity per unit area was obtained by growing maize and soybean crops together than by growing them sole. The maximum values of LER were recorded with crops irrigated using (I_1) treatment (1.47 and 1.45), whereas the lowest LER values were obtained when crops were irrigated with I_3 treatment (1.29 and 1.28). The greatest WUE was found under soybean/maize intercropping and irrigated with I_1 treatment. However, WUE was relatively low under irrigation with I_3. Based on the results of the present work, it could be concluded that soybean/maize intercropping provide to be better.

Keywords

Deficit irrigation, intercropping, Soybean, Maize

Introduction

The declining availability of fresh water has become a worldwide problem, especially in arid and semi-arid regions as Egypt, where more than 80% of water resources have been exploited for agricultural irrigation (Wang et al., 2001). Nowadays in Egypt, increasing crops productivity and saving irrigation water are two interrelated issues raising a lot of concern (Gaballah and Ouda, 2008).In order to tackle this challenge, adoption of practices that help to improving water management is the must. Regulated deficit irrigation and intercropping system are very promising.

Irrigation schedules can be classified as full and deficit irrigation, on basis of plant, soil, and climatic conditions (Martin et al., 1990). Deficit irrigation provides means of reducing water consumption and minimizing adverse effects on yield (Zhang et al., 2004). Intercropping system is an agricultural practice of culturing two or more crops in the same place of field at the same time which is commonly practiced in many parts of the world (Bhupinder, et al. 2003). Intercropping system is generally more productive than sole crop (Tsubo et al., 2005, Zhang et al., 2007 and Ijoyah et al, 2013) and also, could be a way of irrigation water saving (Tsubo et al., 2005).Some researchers found that greater use efficiency of nutrients (Li et al., 2001and Rowe et al., 2005), water (Borham, 2001and Walker and Ogindo, 2003) radiation (Awal et al., 2006) and land (Dhima et al., 2007 and Ariel et al., 2013) may be achieved with intercropping. Ijoyah (2012) and Matusso et al., (2014) reported that reasons for applying intercropping system include insurance against total crop failure, yield increment, weed control and high monetary returns. Moreover intercropping system aimed to adopt improved and sustainable technologies in order to guarantee improvements in food productivity and thereby food security (Gruhn et al., 2000 and Landers, 2007).

Corn crop (*Zea* mays) is ranked the third important crop after wheat and rice in many countries. All over the world, the total sowing area was 184,239,959 ha which produced 1,016,431,783 t with an average yield of 5.52 t ha^{-1} (FAO Statistical Yearbook, 2014). Corn is desired for its multiple purposes as human food, animal feed, and pharmaceutical and industrial manufacturing. It is grown for its grain which contains 65 % carbohydrates, 10-12 % protein and 4-8 % fat (Iken and Amusa, 2004). It is consumed in some countries as, cornflakes, corn syrup and oil. For animal feed, it is highly desirable because of its high yield and feed value of grain, leaf and stem. For industrial and pharmaceutical applications, it can be used to produce starch, ethanol, plastics and as a base for antibiotic production.

According to FAO Statistical Yearbook (2014) the total sowing area of soybeans for all over the world was 111,273,135 ha which produced 276,396,011 t at an average yield of 2.48 t ha^{-1}. Soybean has a high protein content of about 40 % by weight, 32 % carbohydrates, 20 % fat, 5 % minerals and 3 % fiber and other trace substances. It is also used in industries as a source of edible oil and the by-product of the oil extraction .i.e., soybean cake used as animal feed. It is used as sources of protein in human food and animal feed (Atungu and Afolabi, 2001).

Objectives of this research were: 1) to determine the effect of deficit irrigation on the yield of soybean and maize grown sole and under intercropping soybean/maize, 2) to determine water use efficiency of soybean and maize grown sole and under intercropping soybean/maize.

Materials and Methods

Experimental location

Two field experiments were conducted during the two growing seasons (2013 and 2014) in a sandy loam soil at the experimental farm of the Faculty of

Agriculture, South-east Fayoum, Egypt. The work aimed to study the effects of deficit irrigation and intercropping soybean/maize on yield and yield components and water use efficiency of soybean and maize yields under sole and intercropping system. Fayoum co-ordinates are Longitude: 30^{o} 85' E, Latitude: 29^{o} 30' N, Altitude: -25 m and the fetch (F) of short vegetation around the evaporation pan is 1000 m. Some physical and chemical properties of the experimental soil are given in Tables (1 and 2), respectively.

Table.1 Some physical properties of the experimental soil.

Soil depth, cm	Particle size distribution				Bulk density, Mgm^{-3}	F.C %	W.P %	A.W %
	Sand, %	Silt, %	Clay, %	Texture class				
0-20	72.50	12.90	14.60	S L	1.46	19.79	6.69	13.10
20-40	74.60	12.00	13.40	SL	1.57	19.42	3.64	15.78
40-60	74.20	12.10	13.70	S L	1.58	18.62	4.37	14.25

SL: Sandy loam, FC: Field Capacity, WP: Wilting Point and AW: Available water.

Table.2 Some chemical properties of the experimental soil

Soil depth, cm	ECe, dSm^{-1}	pH	$CaCO_3$ %	OC*	Total N mg kg^{-1}	Available Nutrients (mg kg^{-1})				
						P	K	Fe	Mn	Zn
0-20	3.7	7.86	17.5	0.9	14.81	3.25	42.57	4.45	1.25	0.87
20-40	3.40	7.78	18.6	0.82	13.24	3.28	39.87	4.35	1.08	0.79
40-60	3.10	7.92	21.4	0.65	13.21	3.15	39.24	4.21	0.88	0.82

*OC, organic content.
P: extracted with NaHCO3, pH8.5
K: extracted with Ammonium Acetate, pH7
Fe, Mn, Zn: P: extracted with DTPA

Experimental design and treatments

The experimental layout was distributed in a split plot arrangement in randomized complete block design with three replicates. The irrigation treatments and cropping systems were allocated in main-plots and sub-plots, respectively. The sub-plot area was 10.5 m^2.

Three deficit irrigation treatments applied as a percentage of the reference evapotranspiration (ET_o) were100 (I_1), 85

(I_2) and 70% (I_3) of ET_o. The cropping system treatments were sole soybean (SS), sole maize (SM) and soybean/ maize intercropping (SMI).

Planting and fertilization

Soybean, maize and soybean / maize intercropping were sown at1st June 2013 and 5th June 2014 in rows by 60 cm apart. One ridge of soybean (var. Giza 22) was intercropped with one ridge of maize (hybrid 3020).Planting of maize was practiced on one side of ridges in hills, 25 cm apart i.e. the same distance of maize hills in the intercropping system. Planting of soybean was practiced on middle ridges in hills at 5 cm distance i.e. the same distance of its hills in the intercropping system. Two seeds of each crop were sown manually. The seedlings were thinned to one plant per stand two weeks after sowing.

Phosphorus in the form of calcium superphosphate (15.5 % P_2O_5), at the rate of 375 Kg ha^{-1} was applied to the soil during seed bed preparation. Nitrogen in the form of ammonium nitrate (33.5 % N) at the rate 300 kg $ha^{-1}$was applied for maize-soybean intercropping systems and solid maize and at the rate 75 kg ha^{-1} for solid soybean. The above mentioned N rates were added in two equal portions, before the first and second irrigation.

Irrigation water applied

The actual amount of water applied to plants of each irrigation treatments depended mainly upon the reference evapotranspiration (ET_o) computed by equation (1) according to Doorenbos and Pruitt(1992):

$$ETo = Kpan \times Epan \dots\dots\dots (1)$$

Where:

E*pan* Is evaporation from the Class A pan (mm/day),

K*pan* Is the pan evaporation coefficient.

Monthly mean weather data for a 16-year (January 1997– December 2012) were obtained from Attsa weather station, Fayoum Governorate. Monthly mean maximum (Tmax) and minume (Tmin) temperate, relative humidity (RH), wind speed (U) and class A pan evaporation (E-pan) for Attsa weather station are shown in Table 3.

Table.3 Monthly mean maximum and minimum temperate, relative humidity, wind speed and class A pan evaporation for Attsa Station

Monthes	Tmax (C°)	Tmin (C°)	RH (%)	U (m^{s-1})	E-pan (mm d^{-1})
January	21.44	7.96	61.74	3.30	1.69
February	22.01	7.93	59.22	3.67	2.37
March	25.20	9.67	56.66	4.23	3.74
April	31.37	13.90	53.19	5.04	5.22
May	35.63	18.29	51.84	5.55	6.94
June	37.63	21.05	54.09	5.54	7.65
July	39.11	22.31	54.99	5.16	7.51
August	38.78	22.85	57.04	4.84	7.07
September	35.98	21.40	57.93	4.84	6.33
October	31.88	17.94	59.09	4.41	4.69
November	27.68	14.30	62.95	3.77	3.07
December	23.90	10.23	60.44	2.94	2.37

The average daily Epan was 7.65, 7.51, 7.07 and 6.33 mmd^{-1} for June, July, August and September months, respectively.

Surface irrigation using spiles was applied to plants of the three studied cropping systems. The plots involving irrigation treatments were isolated with 2m fallow land to avoid the lateral movement of water from one plot to another. Subplots within each irrigation treatment were isolated by a distance of 0.5 m fallow land. Each experimental plot was 10.5 m^2 (3 m× 3.5 m). Irrigation treatments were started after the first irrigation.

The plants in all plants were irrigated at ten days intervals by different amounts of water. The amount of irrigation water applied to each plot during the irrigation regime was determined by using equation (2):

$$IWA = \frac{A \times ETo \times Ii}{Ea \times 1000} + LR \ldots \ldots (2)$$

Where:

IWA = irrigation water applied, (m^3),
A = plot area, (m^2),
ET_o = reference evapotranspiration, (mmd^{-1}),
Ii = irrigation intervals, (day),
E_a = application efficiency, (%),and
LR = leaching requirements (m^3).

The amount of irrigation water applied (IWA) was controlled through plastic pipe (spiles) of 50mm diameter. One spile per plot was used to convey water for each plot. The amount of water delivered through a plastic pipe was calculated using equation (3) according toIsraelsen and Hansen(1962).

$$Q = CA\sqrt{2gh} \times 10^{-3} \ldots \ldots \ldots (3)$$

Where:
Q = discharge of irrigation water, (l. sec^{-1}),
C = coefficient of discharge,
A = cross section area of irrigation pipe, (cm^2),
g = gravity acceleration, (cm. sec^{-2}),
h = average effective head of water, (cm).

Measurements

Methods of soil analysis

Physical and chemical properties of the experimental soil were conducted according to the methods and procedures outlined and described by Klute (1986) and Page et al. (1982).

Plant analysis

Relative water content (RWC)

Relative water content (RWC) was estimated using 2 cm-diameter fully-expanded leaf discs (Hayat et al., 2007). The discs were weighed (fresh mass; FM) and immediately floated on double-distilled water in Petri dishes for 24 h, in the dark, to saturate them with water. Any adhering water was blotted dry and the turgid mass (TM) was measured. The dry mass (DM) was recorded after dehydrating the discs at 70°C until the constant weight. The RWC was then calculated using the equation (4):

$$RWC(\%) = \frac{(FM-DM)}{(TM-DM)} \times 100 \ldots \ldots \ldots (4)$$

Chlorophyll fluorescence

Chlorophyll fluorescence was measured through two different sunny days, using a portable fluorometer (Handy PEA, Hansatech Instruments Ltd, Kings Lynn, UK). One leaf (at the same age) was chosen per plant to conduct the fluorescence measurements. Maximum quantum yield of PS II F_v/F_m was calculated using the formulae; $F_v/F_m = (F_m - F_0) / F_m$ (Maxwell and Johnson, 2000). F_v/F_0 reflects the efficiency of electron donation to the PSII RCs and the rate of photosynthetic quantum conversion at PSII RCs. F_v/F_0 was calculated using the formulae; $F_v/F_0 = (F_m - F_0) / F_0$ (Spoustová et al., 2013). Performance index of photosynthesis based on the equal absorption (PI_{ABS}) was calculated as reported by Clark et al. (2000).

At harvest time (25 September 2013 and 29 September 2014 for the two growing seasons, respectively) three individual plants were randomly chosen from each experimental plot to evaluate growth characteristics Shoot lengths were measured, from the cotyledonary node to the terminal bud of the stem, using a meter scale. Number of leaves was counted per plant, and leaf area per plant was measured using digital planometer (Planix 7). Shoots of plants were weighed to record their fresh weights, and then placed in an oven at 70 ± 2 °C till a constant weight to measure their dry weights.

Harvest index (HI)

Harvest index (HI) was determined as a ratio of seeds yield to total biomass production on dry mass basis**.**

Seed yield

Seed yield (t ha^{-1}) was estimated by converting seed or green yield of two central ridges in each sub-plot to seed yield (t ha^{-1}) by the equation (5).

$$\text{Yield}\ (\text{t ha}^{-1}) = \frac{\text{Yield /row}}{1000 \times 1000} \times \text{Number of rows of crop/plot} \times \frac{10000\ \text{m}^2}{\text{plot area m}^2} \quad \ldots\ldots..(5)$$

Evaluation of intercropping system

Land equivalent ratio (LER)

Land equivalent ratio (LER) is the most common index adopted in intercropping to measure the land productivity. It is often used as an index to determine the efficacy of intercropping (Brintha and Seran, 2009). To evaluate yield performance of intercropping system and monoculture, LER was used and determined as shown in equation (6) (Vandermeer, 1989 and Willey, 1985):

$$\text{LER} = \frac{\text{Ymi}}{\text{Yms}} + \frac{\text{Ysi}}{\text{Yss}} \ldots\ldots (6)$$

Where Y_{ms} and Y_{mi} are grain yields of maize insole and intercropping (t ha^{-1}), respectively; Y_{ss} and Y_{si} are grain yields of soybean in sole and intercropping, (t ha^{-1}) respectively.

The percentage land saved

Land saved calculations was another index used to assess the advantage of the intercropping system. It indicates the amount of land saved from intercropping, that could be used for other agricultural purposes. Land saved was calculated using equation (7) according to Willey (1985):

$$\text{Land saved}\ (\%) = 100 - \frac{1}{\text{LER}} \times 100 \ldots\ldots (7)$$

Water use efficiency (WUE)

Water use efficiency values as kg grain or seedsm^{-3} of applied water were calculated for different treatments after harvest using equation (8) according to Jensen(1983).

$$\text{WUE} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{water applied (m}^3\ \text{ha}^{-1})} \ldots\ldots\ldots (8)$$

Statistical analysis

The obtained data were subjected to analysis of variance as described by Gomez and Gomez (1984).The homogeneity test was done using the method described by Snedecor and Cochran (1980). The combined analysis was done for irrigation system to study the effect of this variable and the interactions involved. Means were compared using Dancan method at 5 % level of probability in both seasons.

Results and Discussion

Effect of irrigation treatments and intercropping system on plant leaf relative water content (RWC), Chlorophyll fluorescence and performance index (PI-1) of sole and intercropping maize and soybean

Relative water content (RWC)

Data presented in Table (4) show that irrigation treatments had significant effect on RWC, where it was significantly decreased with increasing deficit irrigation. The trend of results obtained in the sole maize and soybean is in accordance with that of those obtained in the intercropping system in both growing seasons. These results were in track with Hassan, et al., (2013) and Maralian, et al. (2014).

The RWC of sole maize and intercropping system under treatments I_1 were greater by 7.7 and 21.2 % and 3.4 as well as 16.0% than the I_2 and I_3 treatment, respectively, in 2013 and 4.9 and 13.0 % as well as 5.5 and 12.0%, respectively, in 2014. In addition, the RWC of sole soybean and intercropping system under treatments I_1were greater than the I_2 and I_3 treatment by 5.1 and 19.9 % as well as 4.3 and 18.0% in the first season and 4.0 and 18.9 % as well as 2.2 and 16.9% in the second season, respectively.

Table.4 Effect of irrigation treatments and intercropping system on RWC, chlorophyll fluorescence and Performance index (PI-1) of sole and intercropping maize and soybean

Treatments		RWC		F_v/F_m		F_v/F_o		PI-1	
Irrig.	Cropp. system	2013	2014	2013	2014	2013	2014	2013	2014
Maize crop									
I_1	Sole	$79.90^{A\Gamma}$	73.61^{B}	0.78^{A}	0.81^{A}	2.28^{AB}	2.47^{A}	4.25^{B}	3.94^{B}
	Inter.	80.71^{A}	77.72^{A}	0.81^{A}	0.80^{A}	2.71^{A}	2.80^{A}	4.86^{A}	4.38^{A}
I_2	Sole	73.76^{B}	70.01^{B}	0.75^{B}	0.73^{B}	1.61^{BC}	1.66^{B}	2.62^{C}	2.64^{D}
	Inter.	77.94^{A}	73.41^{B}	0.81^{A}	0.81^{A}	2.85^{A}	2.54^{A}	2.83^{C}	3.01^{C}
I_3	Sole	63.00^{D}	64.01^{D}	0.72^{B}	0.72^{B}	1.16^{C}	1.49^{B}	1.55^{E}	1.57^{E}
	Inter.	67.78^{C}	68.38^{C}	0.79^{A}	0.79^{A}	1.86^{C}	2.22^{A}	1.96^{E}	1.90^{E}
Soybean crop									
I_1	Sole	75.44^{BC}	73.14^{A}	0.79^{B}	0.80^{AB}	5.95^{AB}	5.22^{B}	4.82^{B}	4.47^{AB}
	Inter.	81.24^{A}	77.71^{A}	0.84^{A}	0.84^{A}	6.24^{A}	6.25^{A}	5.50^{A}	5.11^{A}
I_2	Sole	71.56^{C}	70.19^{B}	0.78^{B}	0.77^{BC}	4.57^{BC}	4.00^{C}	4.24^{B}	4.03^{BC}
	Inter.	77.74^{AB}	76.00^{A}	0.83^{AB}	0.83^{AB}	5.69^{AB}	5.77^{AB}	5.07^{A}	4.78^{AB}
I_3	Sole	60.46^{E}	59.33^{D}	0.73^{C}	0.75^{C}	2.86^{D}	3.02^{D}	2.68^{D}	2.82^{D}
	Inter.	66.64^{D}	64.54^{C}	0.81^{AB}	0.82^{AB}	3.35^{CD}	4.45^{C}	3.88^{C}	3.92^{C}

$^{\Gamma}$Treatment means with the same letter are not significant at the p≤0.05 level in the same column for each crop.

In this regard, Sinclair and Ludlow (1986) reported that RWC considers a measure of plant water status, reflecting the metabolic activity in plant tissues and used as a most meaningful index to identify the legumes with contrasting differences in dehydration tolerance. This parameter (RWC vs. plant biomass or growth) could be used as a convenient evidence to distinguish between the specific and non-specific traits for drought tolerance in squash plants, similar to what has been reported for other crops in semi-arid environment and drip irrigation (Debashis et al 2008).

Chlorophyll fluorescence and performance index

Data presented in Table (4) show that the irrigation treatment at (I_3) significantly decreased the value chlorophyll fluorescence comparing to (I_1) in both seasons. This result supports that of Munne-Bosch and Alegre, (2000)who found that the chlorophyll was decreased with decreasing the irrigation water. Under sole planting the highest values of F_v/F_m (0.78 and 0.81 for maize and 0.79 and 0.80 for soybean) were obtained by the highest irrigation level (I_1) in both seasons, respectively. While its values were (0.72for maize and 0.73 and 0.75 forsoybean) irrigated by I_3treatment (I_3) in both seasons, respectively. Higher chlorophyll fluorescence produced higher grain yields and is thought to also increase sugar content in certain crops. Many reports suggested that using the analysis of chlorophyll 'a' fluorescence considered as a reliable method to determine the changes in the function of PSII under stress conditions (Broetto et al., 2007; Habibi, 2012). Our results reported reductions in F_v/F_m, F_v/F_0 and performance index (PI) under deficit irrigation stress conditions, which were possibly due to the reduction in leaf photosynthetic pigments and RWC needed for photosynthesis. These results are in parallel line with those of Gunes et al. (2007), Boughalleb and Hajlaoui (2011).Water stress may also reduce photosynthesis rate through direct influence on the metabolic and photochemical processes in the leaf, or indirect influence on stomatal closure and cessation of leaf growth which results in decreased leaf surface area (Dejong, 1996).

The maximum chlorophyll fluorescence and Performance index (PI-1) values were obtained in intercropping system compared with sole crop under both two growing seasons and crops (Table 4). These results are in agreement with those found by Ghosh et al. (2006) and Koohi, et al.(2014). They reported that in soybean/ sorghum intercropping, chlorophyll content of sorghum leaf in all treatments of intercropping was higher than sole crops and its reason attributed to the overcast of plants on each other and nitrogen fixation by legume in intercropping. The amount of chlorophyll in plant depends on soil nitrogen availability and the ability of nitrogen adsorption by plant, and these are important factors in farm management (Jongschaap and Booij, 2004).

It was reported that high relative water content is a resistant mechanism to drought, and that resulted in more osmotic regulation or less elasticity of tissue cell wall (Ritchie et al, 1990).Drought stress is a decrease of soil water potential so plants reduce their osmotic potential for water absorption by congestion of soluble carbohydrates and proline and in other words osmotic regulation is performed (Martinet al, 1993). Therefore osmotic regulation will help to cell development and plant growth in water stress (Pessarkli, 1999). It is defined that decrease of relative water content close stomata and also after blocking of stomata will reduce photosynthesis rate (Cornic, 2000).

Effect of irrigation treatments and intercropping system on sole and intercropped yield and yield components

Plant height, weight of 100 grain, harvest index (HI) and grain yield (GY) was significantly affected by the different irrigation treatments and intercropped system (Table 5). Under both intercropped system and the sole maize and soybean, the maximum values of previous traits were obtained when the plants were irrigated with the highest amounts of irrigation water I_1(100% of ET_o), while the minimum values were recorded by the least amount I_3(70% of ET_o), in both growing seasons. Under sole and intercropping maize, the tallest plants were obtained by using (I_1) (255 and 247 as well as 247 and 238 cm) while the treatment (I_3) resulted in the shortest plants (220 and 211 as well as 211 and 194 cm) in both seasons, respectively. The same trend was recorded under sole and intercropping soybean, where the tallest plants were produced by (I_1) (59.1 and 55.8 as well as 71.1 and 74.6 cm) while the treatment (I_3) recorded the shortest plants (38.9 and 41.7 as well as 48.1 and 55.2 cm) in both seasons, respectively.

Similar results have been reported by (Nicola´s et al., 2008; Hassan, et al., 2013). Nicola´s et al., (2008) reported that the first sign of water shortage is the decrease in turgor which causes a decrease in both growth and cell development, especially in the stem and leaves. The growth of cells is the most important process that is affected by water stress and the decrease in the growth of cells leads to decrease the plant height. Otherwise, deficit irrigation had altered the morphology of rosemary plants, reducing plant height and shoot growth. Harvest index (HI) of sole and intercropping system was significantly affected by deficit irrigation (Table 5). In two growing seasons, treatment I_1 and I_3 had the highest and the lowest harvest index, respectively.

As shown in Table (5), the average GY of maize and soybean crop was increased with increasing amounts of applied water. This result is in agreement with those of (Mahfouz and Abd El-Wahed, 2008) and Abd El-Wahed and Ali, 2013). Moreover, decreasing irrigation water by 15 and 30 % from ETo for treatments I_2 and I_3 reduced the sole and intercropping maize by 14.2 and 33.6 % as well as 22.0 and 43.8 % than the I_1 treatment, respectively, in the first season, and by 15.4 and 38.6% as well as 22.1 and 47.6 %, respectively, in the second season. While the sole and intercropping soybean reduced by 11.2 and 23.3 % as well as 19.9 and 33.2% than the I_1 treatment, respectively, in the first season, and by 13.8 and 21.9 % as well as 22.3 and 35.4%, respectively, in the second season. This may be due to the reduction in available soil moisture which consequently resulted in reducing absorption of both water and nutrient elements. In this concern, Tahir (1983) indicated that in arid and semi-arid regions very often moisture stress is the limiting factor for crop growth and yield level.

However, there is a strong interaction between water and plant nutrient availability. In addition, the low GY of the maize under the lower amounts of applied water may be due to several factors; lower soil water content have been shown to delay rooting (Bathke et al., 1992) with a concomitant reduction in leaf area and root shoot dry weight (Masle and Passiour, 1987), a reduction in yield is observed because of low photosynthesis. These morphological changes in growth can be considered as a morphological adaptation of the plant to water and environmental stresses to reduce transpiration and to induce a lower consumption of water (Banon et al., 2003).

Table.5 Effect of irrigation treatments and intercropping system on plant height, weight of 100 grain, HI and grain yield of maize and soybean crops.

Treatments		Plant height, cm		HI		weight of 100 seed, g		Yield, t ha^{-1}	
Irrig.	Inter. syste	2013	2014	2013	2014	2013	2014	2013	2014
Maize crop									
I_1	Sole	$255^{A\Gamma}$	247^{A}	0.35^{A}	0.37^{A}	40.27^{A}	39.27^{A}	9.90^{A}	9.78^{A}
	Inter.	247^{A}	238^{AB}	0.33^{A}	0.34^{AB}	35.53^{AB}	32.4^{BC}	7.83^{B}	7.64^{B}
I_2	Sole	243^{AB}	240^{AB}	0.24^{B}	0.25^{B}	35.27^{AB}	34.53^{B}	8.49^{AB}	8.28^{C}
	Inter.	236^{AB}	229^{AB}	0.22^{B}	0.23^{B}	32.07^{B}	30.07^{C}	6.11^{C}	5.95^{D}
I_3	Sole	220^{BC}	211^{B}	0.22^{B}	0.24^{B}	33.80^{AB}	32.53^{BC}	6.57^{C}	6.01^{D}
	Inter.	211^{C}	194^{B}	0.20^{B}	0.21^{B}	31.20^{B}	29.13^{C}	4.40^{D}	4.00^{E}
Soybean crop									
I_1	Sole	59.1^{BC}	55.8^{AB}	0.33^{A}	0.35^{A}	19.25^{A}	19.63^{A}	3.97^{A}	3.80^{A}
	Inter.	71.1^{A}	74.6^{A}	0.38^{A}	0.39^{A}	18.27^{A}	18.00^{AB}	2.44^{D}	2.37^{C}
I_2	Sole	55.8^{BC}	46.6^{B}	0.29^{B}	0.30^{B}	18.52^{A}	18.31^{AB}	3.52^{B}	3.28^{B}
	Inter.	66.0^{AB}	67.3^{A}	0.33^{A}	0.37^{AB}	18.07^{A}	17.07^{AB}	1.96^{E}	1.84^{D}
I_3	Sole	38.9^{D}	41.7^{B}	0.22^{B}	0.23^{C}	15.99^{B}	15.53^{B}	3.04^{C}	2.97^{B}
	Inter.	48.1^{CD}	55.2^{AB}	0.29^{B}	0.30^{BC}	15.14^{B}	14.30^{B}	1.63^{F}	1.53^{D}

$^{\Gamma}$Treatment means with the same letter are not significant at the $p \leq 0.05$ level in the same column for each crop.

Regarding the effect of intercropping treatment (Table 5) it was found that it had significant effect on plant height, HI, weight of 100 grain and grain yield. Under intercropped system, also, the maximum values of previous traits were obtained when the plants were irrigated with the highest amounts of irrigation water (I_1), while the minimum values were recorded for the least amount I_3 in both growing seasons.

Data presented in Table (5) clearly show that the plant height of maize and soybean crops was significantly affected by irrigation treatments. The plant height was increased with increasing irrigation levels in the two seasons. Under sole and intercropping maize, the tallest plants were obtained by(I1) (255 and 247 as well as 247 and 238 cm) while the treatment (I3) recorded the shortest plants (220 and 211 as well as 211 and 194 cm) in both seasons, respectively. The same trend was observed under sole and intercropping soybean, where the tallest plants were obtained by (I1) treatment(59.1 and 55.8 as well as 71.1 and 74.6 cm) while the (I3) treatment resulted in the shortest plants (38.9 and 41.7 as well as 48.1 and 55.2 cm) in both seasons, respectively. It was noticed that in the two growing seasons, maximum plant height values were observed in sole maize, while the minimum plant height values were recorded in intercropped maize. Similar results have been reported by Karamullah (1989)and Zaman and Malik (2000). Reduction in plant height may be due to intense intercrop competition for various growth resources. On the other hand, the maximum plant height values were observed in intercropping soybean, while the minimum plant height values were recorded in sole soybean. The obtained results are in agreement with those obtained by Undie et al. (2012), Ijoyah, et al (2013) and Hirpa (2014). They reported intercropping system yielded taller.

Intercropping system significantly reduced weight of 100 seed compared to those produced by sole soybean and maize (Table 5). This result is in line with obtained by Olufajo (1992), Muneer et al., (2004) Undie, et al., (2012) and Ijoyah, et al (2013). A reduced weight of 100 seed of soybean may be due to shade by taller maize crop and could have contributed in the reduction of soybean yield.

Intercropping system significantly affected its harvest index (Table 5). In both growing seasons, the sole maize produced significantly higher harvest index (HI) than intercropping system. The obtained result is in agreement with that obtained by Undie, et al (2012), who reported that the sole maize produced significantly higher harvest index than intercrop system.

The HI produced from sole maize was greater by 5.7, 8.3 and 9.1as well as8.1, 8.0 and 12.5 % respectively, in years 2013 and 2014 compared to that obtained from intercropped maize.In the other hand, the sole soybean produced significantly lower harvest index than intercropping system. The highest HI values (0.38, 0.33 and 0.29 as well as 0.39, 0.37 and 0.30, respectively, in two growing seasons) were observed from soybean intercropping, while the least HI values (0.33, 0.29 and 0.22 as well as 0.35, 0.30 and 0.23, respectively, in two growing seasons) were yielded from sole soybean.

A reduction in grain yields of intercropping soybean and maize as compared to sole soybean and maize was recorded (Table, 5). The obtained results were in agreement with those obtained by Khalil (1990) and Ijoyah et al. (2013). These results could be due to the weight of 100 grain of intercropping maize was lower than those obtained from sole maize.

The yield reduction from sole maize under treatments I_1, I_2 and I_3 were greater by 20.91, 28.1and 33.0%, respectively, in 2013 and 21.9, 28.2 and 33.41% in 2014 compared to those obtained from intercropping maize. Whereas, the yield reduction from sole soybean under treatments I1, I2 and I3 were greater by 38.4, 44.5 and 46.3 %, respectively, in 2013 and 37.7, 43.9 and 48.4 % in 2014 compared to those obtained from intercropping soybean.

As shown in Fig. (1), the yield reduction of soybean was greater than that of maize in the two growing seasons. This is mainly due to the soybean when intercropped with maize had inter specific competition and depressive effects on maize crop. This result is in agreement with that obtained by West and Griffith, (1992) and Ghaffarzaeh et al., (1994). They reported that, under soybean and maize intercropping systems, soybean yield tends to be lower and maize yield tends to be higher.

Effect of irrigation treatments and intercropping system on water use efficiency (WUE)

Data presented in Table (6) demonstrate that, WUE was affected by irrigation treatments. Under maize crop, the highest and lowest values of WUE were recorded under I_1 and I_3 treatment, respectively, in two seasons. The obtained result is in agreement with that of Abd El-Wahed and Ali (2013), who reported that the highest yield was obtained from I_1 treatment which compensated the highest amount of water used in both seasons of this study.

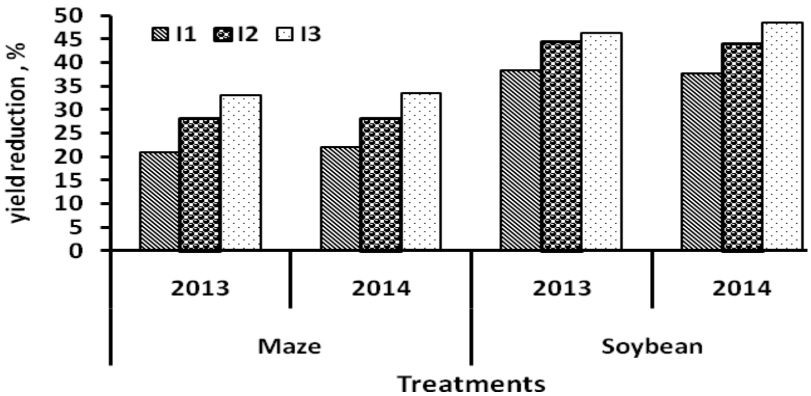

Fig.1 Reduction in soybean and maize yield irrigation treatments and intercropping system under two growing seasons

Table.6 Effect of irrigation and intercropping treatments on water use efficiency

Treatments	Sole maize	Sole soybean	Inter	Sole maize	Sole soybean	inter
	2013			2014		
I_1	1.08	0.43	1.12	1.07	0.42	1.09
I_2	1.09	0.45	1.04	1.07	0.42	1.00
I_3	1.03	0.48	0.94	0.94	0.46	0.86

Data in Table (6) show that the average of WUE value under I_1 and I_2 (1.08 kg m^{-3}) was higher than that average I_3 (0.98 kg m^{-3}) at the two seasons. It was observed that the I_1 and I_2 treatment used the water more efficiently as compared to other treatment (I_3). This result may be attributed to decrease in both seed yield and water use for I_3 treatment.

On the other hand, WUE values of soybean crop are increased by increase deficit irrigation treatments. The values of WUE for irrigation treatments I_1, I_2 and I_3 were 0.43, 0.45 and 0.48 kg m^{-3}, respectively, in the first season. Meanwhile, in the second one, these values were 0.42, 0.42 and 0.46 kg m^{-3} for the same irrigation treatments, respectively. These results are in agreement with those of Al-Mefleh et al. (2012) and Yaseen, et al., (2014) who mentioned that increasing irrigation levels did not increase the WUE.

The data in Table (6) also, clearly show that the values of WUE for maize crop were greater than those obtained from soybean crop in both seasons. The same trend was observed by Borham (2001). Who reported that this trend is mainly due to increase grain yield of maize crop as compared with seed yield of soybean. Regarding the intercropping system, the WUE values were 1.12, 1.04 and 0.94 kg m^{-3} for irrigation treatments I_1, I_2 and I_3, respectively, in the first season. Meanwhile, in the second season, these values were1.09, 1.00 and 0.86 kg m^{-3} for the same irrigation treatments, respectively. These values clearly show that the WUE values for intercropping system were higher than the WUE values yielded from sole maize and sole soybean crops in the two growing seasons and under irrigation treatments. These results are due to increase grain yield of intercropping system as compared with seed yield of sole maize and sole soybean crop.

Effect of irrigation and intercropping treatments on land equivalent ratio (LER)

In the two growning seasons, the maximum values of partial LER (0.79 and 0.78) were recorded when maize irrigated with highest amount of irrigation water (I_1) treatment. Whereas the lowest ones (0.67 and 0.67) were obtained when plants irrigated with the least amount of irrigation water (I_3) one (Table 7). The same trend was recorded under soybean, where the highest partial LER values (0.62 and 0.62) were recorded for soybean plants when irrigated with (I_1) treatment. Whereas the lowest ones (0.54 and 0.52) were obtained for soybean irrigated with (I_3).

Table.7 Effect of irrigation and intercropping treatments on partial and total land equivalent ratio

Irrig.	Partial				Total		Land saved (%)	
	Mize		Soybean					
	2013	2014	2013	2014	2013	2014	2013	2014
I_1	0.79	0.78	0.62	0.62	1.41	1.40	28.92	28.74
I_2	0.72	0.71	0.56	0.56	1.28	1.27	21.55	21.86
I_3	0.67	0.67	0.54	0.52	1.21	1.18	17.11	15.37

The reduction of partial LER values of soybean crop was greater than obtained from maize crop. This result attributed to increase reduction of soybean crop than maize crop (Fig. 1). The partial LER values of maize under I_1, I_2 and I_3 treatments were 22.12, 22.80 and 19.86 % higher than those obtained from soybean treatments, respectively, in the first season. Whereas in the second season, partial LER values of maize were 20.21, 21.81 and 22.55% higher than those obtained from soybean treatments, respectively. The total LER of intercropping system was greater than the sole crops (Table 7). In both seasons, the total LER under irrigation treatments were greater than one, indicating that all treatments had an advantage in land use. This result supports that of Hirpa (2014). Intercropping system recorded the total LER values ranged from1.21to 1.41in years 2013 and from 1.18to 1.40 in year 2014.This means that higher productivity per unit area was yielded by growing maize and soybean crops together than by growing them sole. In both seasons, as average, the total LER values were 1.41, 1.28 and 1.19 under I_1, I_2 and I_3 treatments, respectively. This result indicating that, under I_1, I2 and I3 treatments, the area planted with sole crop would need to be 41, 28 and 19 % greater than the area planted with intercropping system to produce the combined yield. As shown in Table (7), as average, under I_1, I_2 and I_3 treatments, 28.83, 21.71 and16.24 % of land was saved respectively, which could be used for other agricultural purposes.

In conclusion, three cropping systems were tested for crop productivity in relation to three irrigation treatments tested for its water use efficiency. Results showed that the intercropping system soybean/ maize is the most productive, compared with the sole maize or soybean crops. Furthermore, the highest water use efficiency was obtained under irrigation with I_1 (100% of ET_o). Land equivalent ratio in all treatments was more than unity. Irrigation of intercropping soybean/maize on basis ofI_1 proved to be the most effective on grain yield and water use efficiency.

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