Alinteri J. of Agr. Sci. (2021) 36(1): 169-180
e-ISSN: 2587-2249
info@alinteridergisi.com

http://dergipark.gov.tr/alinterizbd
http://www.alinteridergisi.com/
DOI:10.47059/alinteri/V36I1/AJAS21025

RESEARCH ARTICLE

Response of Maize to Different Intercropping Systems and Different Sowing Dates of Cowpea

Moshira A. El-Shamy[1*] • Mona A.M. El-Mansoury[2] • Maha A. El Bialy[3] • Mohamed H. Helmy[4] • A.F. Hassan[5]

[1]Crop Intensification Research Department, Field Crops Research Institute, A.R.C. Giza, Egypt.*

[2]Soil, Water and Environment Research Institute, A.R.C., Giza, Egypt.

[3]Water Management Research Institute, National Water Research Center, Delta Barrage, Qalubia, Egypt.

E-mail: Mahaaly000@gmail.com

[4]Water Management Research Institute, National Water Research Center, Delta Barrage, Cairo, Egypt.

[5]Water Management Research Institute, National Water Research Center, Delta Barrage, Cairo, Egypt.

A R T I C L E   I N F O

Article History:
Received: 10.02.2021
Accepted: 28.02.2021
Available Online: 08.04.2021

Keywords:
Intercropping
Water Relations
Water & Land Equivalent Ratios
Gross Return

A B S T R A C T

The recent challenge in agriculture is producing more yields by consuming less water, especially in areas with limited resources of land and water. The study was carried out at Sakha Agricultural Research station., kafr el- sheikh governorate, Egypt, during the 2018 and 2019 summer seasons to evaluate productivity and economic profitability of cowpea intercrop with maize under different sowing dates of cowpea as well as evaluate the efficiency of the system using the land equivalent ratio (LER), water equivalent ratio (WER), some water relations also Gross return. The split-plot design with three replications was used. The main plots were assigned to the cowpea sowing date (D1-1st May, D2 - 20th May, and D3- 9th June), the sub-plot was contained to the intercropping pattern (P1-(1:1), P2-(1:2) and P3-(2:4)). The highest values of irrigation water use efficiency (IWUE) and crop water use efficiency (CWUE) were given with the first sowing date under the intercropping system (1:2). The cowpea sowing dates had no significant differences in yield and some components of maize and on its interaction with intercropping patterns. The highest LER was found with the third sowing date for cowpea under intercropping system (1:2) treatment in two seasons, respectively. In economic viewpoint high additional increase in profits over each cost for all intercropping patterns especially the third sowing date for cowpea under the intercropping system (1:2).

Please cite this paper as follows:

El-Shamy, M.A., El-Mansoury, M.A.M., El Bialy, M.A., Helmy, M.H. and Hassan, A.F. (2021). Response of Maize to Different Intercropping Systems and Different Sowing Dates of Cowpea. *Alinteri Journal of Agriculture Sciences*, *36*(1): 169-180. doi: 10.47059/alinteri/V36I1/AJAS21025

Introduction

In Egypt, capital share from water is decreasing to less than 650 m^2 and this decreasing is continuous under the increasing national population. Water supply considers a limiting factor for crop production and food security. **Fereres and Soriano (2007)** stated that the recent challenge in agriculture is producing more yields by consuming less water, especially in areas with limited resources of land and water,

* Corresponding author: Moshira A. El-Shamy

Many researchers have been previously worked on the water use efficiency of intercrop systems, but with controversial results and many of them showed that greater yields achieved by the intercrops only as a consequence of higher water consumption (**Yang et al, 2012 and Wang et al., 2015**).

Cowpea (Vigna unguiculata. L.) has been introduced to Egyptian agriculture as a promising double purpose forage and seed crop for a green canopy or using it in animal diets as dry seed as well as it is a primary source of protein for humans and animals. **Darwesh et al. (2016)** study results showed that moderate water scheduling (irrigation at 65% of `accumulated pan evaporation) in sole crop and intercropping pattern not only does not reduce sunflower and forage cowpea yield. Given these findings, sunflower and cowpea mixed culture in the 1:2 intercropping pattern is enforceable.

Maize is one of the most important crops for the Egyptian national economy because it is the main source of human food. The total cultivated area in 2012 was 679,508 hectares with an average productivity of 6.87 tons/ha (***MLAR*, *2013***). ***Nofal and Attalla (2006)*** indicated that the highest pods yield was found when the yellow maize hybrid was planted in a 1:2 pattern and the highest values of land equivalent ratio LER of maize and soybean. In general, LER increased by both crops. ***Ouda et al (2007)*** concluded that intercropping of 1:2 soybean- maize is the most productive system and has attained high water productivity especially when applied irrigation water using 1.0 pan evaporation coefficient.

The aim of this study; obtain initial results on the possibility of different cowpea sowing dates on maize and intercropping systems, growth, yield parameters, and computing maize and cowpea water relations.

Materials and Methods

A field experiment was conducted at Sakha Agricultural Research Station Farm, during the two growing seasons of 2018 and 2019 to study the three sowing dates for cowpea with one sowing date for maize and three intercropping systems 1:1, 1:2, and 2:4) rows of maize cv. S.C 122 and Cowpea cv. Balady was used along with the sole planting of each crop. maize and cowpea seeds were obtained from Agric. Res. Center (ARC), Giza, Egypt.

Data presented in Table 1 which showed some meteorological parameters during the studied period 2018 and 2019, recorded from Sakha Agrometeorological Station.

Table 1a. Some agro-meteorological parameters in the 2018 season seasons

Month	T (C0)			RH (%)			WS, m sec-1	Pan Evap., mm day-1	Rain, mm
	Max.	Min.	Mean	Max.	Min.	Mean			
May	31.2	23.9	27.6	75.6	43.3	59.4	1.10	6.34	0.00
June	34.6	25.3	29.0	29.0	48.2	61.9	1.14	7.72	0.00
July	34.2	25.4	29.8	29.8	51.0	66.8	1.03	7.90	0.00
Aug.	33.9	25.3	29.6	29.6	51.9	65.7	0.87	6.42	0.00
Sep.	32.8	23.5	28.2	28.2	48.3	65.7	0.79	4.99	0.00
Oct.	29.5	20.6	25.1	25.1	49.6	66.1	0.66	3.24	10.5

Table 1b. Some agro-meteorological parameters in the 2019 season

Month	T (C0)			RH (%)			WS, m sec-1	Pan Evap., mm day-1	Rain, mm
	Max.	Min.	Mean	Max.	Min.	Mean			
May	31.9	25.4	28.7	76.4	37.9	57.2	0.79	6.83	0.00
June	33.0	28.0	30.5	81.5	50.0	65.8	1.19	8.46	0.00
July	33.5	28.4	31.0	85.3	54.4	69.9	0.97	8.08	0.00
Aug.	34.2	25.9	30.1	89.7	55.6	72.7	0.80	6.82	0.00
Sep.	32.4	27.9	30.2	83.4	52.9	68.2	0.89	5.90	0.00
Oct.	30.3	26.7	28.5	87.3	54.3	70.8	0.66	3.84	57.3

T= Air temperature, RH= Relative humidity, Ws = Wind speed, and pan evapotranspiration

Source: Meteorological Station at Sakha Agricultural Research Station 31°-07' N latitude, 30°-57' E longitude with an elevation of about 6 meters above mean sea level.

Soil particle size distribution and bulk density were determined as described by **Klute (1986**). Field capacity, permanent wilting point, and available water characters were determined according to **James (1988)**. Chemical characteristics of soil were determined as described by **Jackson (1973)** and all data are presented in Table 2 (a&b).

Table (2a). The mean values of some physical properties of the experimental site (mean of 2018 and 2019 seasons)

Soil Depth, cm.	Particle Size Distribution			Texture Class	F.C %	P.W.P %	AW (%)	Bd, Mg/m^3
	Sand%	Silt %	Clay %					
0 – 15	15.7	31.0	53.3	Clay	44.61	26.56	18.05	1.04
15 – 30	22.4	33.1	44.5	Clay	40.20	21.44	18.76	1.09
30 – 45	20.7	40.3	39.0	Clay loam	38.70	20.60	18.10	1.11
45 – 60	22.9	40.9	36.2	Clay loam	36.30	19.83	16.47	1.16
Mean	20.4	36.3	43.3	Clay loam	39.95	22.11	17.85	1.10

Where:- F.C % = Soil field capacity, P.W.P % = Permanent wilting point, AW % = Available water and Bd, Mg/m^3 = Soil bulk density.

Table (2b). The mean values of some chemical properties of the studied experimental site

Soil Depth, Cm	Ec, ds/m	PH (1: 2.5) soil water suspension	Soluble ions, meq/l							
			Ca++	Mg++	Na+	K+	CO3--	HCO3-	Cl-	SO4 --
0-15	3.24	8.65	11.29	5.20	14.31	0.43	0.00	4.70	14.96	11.57
15-30	3.51	8.54	11.45	7.61	15.17	0.37	0.00	4.20	14.87	15.53
30-45	3.80	8.49	12.61	8.27	16.52	0.31	0.00	3.90	13.00	20.81
45-60	4.10	8.37	13.92	9.46	16.34	0.28	0.00	3.60	12.49	23.91
Mean	3.66	----	12.32	7.64	15.59	0.35	0.00	4.10	13.83	17.96

All recommended agronomic practices were performed according to the crop and the studied site except the studied treatments. Maize (Zea mays L.) cv. S.C 122 and cowpea (Vigna unguiculata, L.) cv. Balady, the summer crops were planted on 1st May - 20th May and 9th June for cowpea crop and 20th May for maize crop in two seasons and harvested 20th August - 18th September and 13th October for cowpea and 15th September for maize in the first season of 2018, while in the second season of 2019 harvesting dates were on 22th August - 19th September and 15th October for cowpea and 13th September for maize, respectively.

The experimental field has been well prepared by plowing it twice perpendicular leveling, and then divided into the experimental unit which its area was 42 m^2 consisting of 14 ridges, each of 5 m in length and 60 cm in width (1/167 fed). The preceding winter crop was wheat (Triticum aestivum, L.) in both seasons. Calcium superphosphate (15 % P_2O_5) was applied during soil preparation at the rate of 63 kg ha^{-1}, Potassium Sulphate (48% K_2O) at the rate of 10.08 kg ha^{-1} was applied before the third irrigation, and Nitrogen in form of ammonium nitrate (33.5%) was added in two equal doses, the first was applied before the second irrigation and the second dose was added before the third irrigation.

Experimental Design

Agricultural practices for two crops were performed according to the technical recommendations of A.R.C. A split-plot design was used in combination with three sowing dates (D_1, $D_2$and D_3) on the main plots and three intercropping patterns of maize-cowpea as following:

D_1- 1st May for Cowpea crop,
D_2- 20th May for Cowpea crop, and
D_3 - 9th June for Cowpea crop.

Under sowing date of 20th May for maize crop
With three intercropping systems (P_1, P_2, P_3, Sole maize, and Sole cowpea) in sub-plots:

P_1- Growing (1:1) ridge of maize and cowpea respectively, by growing maize in hills 30 cm apart 2 plants in a hill and growing cowpea in hills 10 cm apart from one plant in a hill on both sides. This provides 150% total population i.e. 100% component population of maize plus 50% component population of cowpea.

P_2 - Growing (1:2) ridge of maize and cowpea respectively, by growing maize in hills 40 cm apart 2 plants in the hill and growing cowpea in hills 15 cm apart 2 plants in a hill in both sides. This provides 130% total population i.e. 75% component population of maize plus 55% component population of cowpea.

P3- Growing (2:4) ridge of maize and cowpea respectively, by growing maize in hills 40 cm apart 2 plants in the hill and growing cowpea in hills 15 cm apart two plants in a hill in both sides. This provides 135% total population i.e. 50% component population of maize plus 85% component population of cowpea.

Sole maize: grown in ridge 60 cm width in hills 30 cm apart, one plant in the hill (optimum density).

Sole cowpea: grown in ridge 60 cm width in hills 10 cm apart, one plant in a hill in both sides (optimum density).

Irrigation Practices

- ### *Irrigation Water Applied (I.W)*

Irrigation water was measured and controlled by a rectangular weir. Irrigation water discharge was determined according to **Michael, (1978)** as follows:

$$\boldsymbol{Q = 1.84LH^{3/2}}$$

Where:
Q = Water discharge, m^3sec^{-1},
L = width of weir, cm
H = the head above weir crest, cm

- ### *Water Consumptive Use*

Percentage of soil moisture was determined (on a weight basis) just before and 48 hrs after irrigation as well as at harvest to compute the actual consumed water as stated by **Hansen et al., (1979)** as follows:

$$\mathrm{CU} = \frac{\theta_2 - \theta_1}{100} \mathrm{x}\rho_d\mathrm{xD}$$

Where:

CU = Water consumptive use in the effective root zone (60 cm.),
θ_2 = Gravimetric soil moisture percentage after irrigation,
θ_1= Gravimetric soil moisture percentage before irrigation,
$\boldsymbol{\rho_d}$ = Soil bulk density (Mg/m^3), and
D = Soil layer depth.

Studied Plant Parameters

- ### *Maize*

At harvest a sample of 10 plants was chosen at random, from each plot to study:

1- Plant height (cm) 2- Stem diameter (cm) 3- Ear length (cm).

4- Ear diameter (cm) 5- Ear weight (g) 6- Weight of grains/plant (g)

7- Grain yield (t/ha) 8- N Content. 9- Oil %.10-Protein (%).

- ***Cowpea***

At harvest, a sample of 10 plants was chosen at random from each plot to calculate the following characters:

1- Plant height (cm) 2- Stem diameter (cm)

3- Number of leaves/plant 4- Dry matter (kg)

The plants in two ridges of each experimental unit were harvested, collected together, labeled, thrashed and the seeds were separated. The seed yield was recorded in kg/ square meter, then it converted to record:

5- Dry seed yield (ton fed-1) 6- Dry matter % 7- Crude protein %

8- Crude fiber % 9-Seed yield (kg).

Irrigation Water Use Efficiency (IWUE, Kg m^{-3})

Water Use Efficiency of irrigation water (IWUE) was calculated according to **Zhang et al., (1998)**

$$IWUE = \frac{Y}{IW}$$

Where :

IWUE = Water Use Efficiency of irrigation water (Kg m^{-3}),

Y= yield, kg ha^{-1} and

IW = irrigation water applied ($m^3\ ha^{-1}$).

Crop Water Use Efficiency (CWUE, Kg m^{-3})

Crop Water Use Efficiency is generally defined as crop yield per cubic meter of water consumption. Concept of Crop Water Use Efficiency in the agricultural production system is focused on producing the same amount of food with fewer water resources. Water productivity was calculated according to **Zhang et al., (1998**).

$$CWUE = \frac{Y}{WCU}$$

Where:

CWUE= Crop Water Use Efficiency (kg m^{-3}),

Y= yield, kg ha^{-1} and

WCU=actual water consumption of the growing season m^3ha^{-1}.

The Water Equivalent Ratio, (WER)

The advantage of water use for intercropping can be articulated by The Water Equivalent Ratio, WER **(Mao et al., 2012).** WER reveals the amount of water required by sole crops to produce the yields that are obtained in an intercrop with one unit of water. A water equivalent ratio larger than 1 reflects the efficient use of water in intercropping than in the sole crops. To calculate the WERs of different treatments in maize-cowpea intercrop systems, it can be used the following formula:

$$WER = WER_M + WER_C = \frac{(Y_{Int.M}/WU_{Int.M})}{(Y_{mono,M}/WU_{mono,M})} + \frac{(Y_{Int.C}/WU_{Int.C})}{(Y_{mono,C}/WU_{mono,C})} = \frac{WUE_{IM}}{WUE_{Mono,M}} + \frac{WUE_{Int,C,}}{WUE_{Mono,C}}$$

Where:

$WUE_{mono\ M}$ and $WUE_{mono\ C}$ = The Water Use Efficiencies of Monocultures of Species Maize and Cowpea.

$WUE_{int,M}$ and $WUE_{int,C}$ = The Water use efficiencies of Species Maize and Cowpea in the intercrop. These Water use efficiencies are calculated as the yield of crop maize or cowpea per unit of the total water used in the intercrop.

Land Equivalent Ratio (LER)

This was determined according to **Willey (1979):**

$$LER = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where:

Yab = Mixture yield of a (when combined with b).

Yaa = Pure stand yield of the crop (a).

Yba = Mixture yield of b (when combined with a).

Ybb = Pure stand yield of the crop (b).

Gross Return ($\$.ha^{-1}$)

Gross return from each treatment was calculated in dollars ($) ton of maize and ton of cowpea seeds in both seasons as follows:-

Kg of maize = 0.1 $ and kg of cowpea seeds = 1.56 $. for first season, and

Kg of maize =. 0.24$. and ton of cowpea seeds = 1.88$ for second season.

The price of maize and cowpea seeds was obtained by the market search.

Statistical Analysis

The collected data on maize and cowpea were performed with Costat (version 6.3030 and Microsoft Office Excel 2010 programs). The experimental design was a split-plot design with three replications.

Results and Discussion

Irrigation Water (IW) and Water Consumptive Use (CU)

Irrigation water applied (IW) data presented in Table (3) clearly showed that the highest average value of water applied (9830.00 $m^3\ ha^{-1}$ i.e. 98.30 cm) was recorded with the third sowing date of cowpea. While, the lowest average value of IW was obtained from the first planting date (D1, 8830.00 $m^3\ ha^{-1}$ i.e. 88.30cm). There were no differences in IW values between intercropping patterns of P_1, P_2, and P_3. It is clear from Table 3 showed that regarding the planting dates, the water consumptive use which computed based on soil moisture depletion in the effective root zone can be descended in this order D_3, 76.4 > D_2, 70.6 > D_1, 68.5 cm. On the other hand, the corresponding values of intercropping patterns showed no big differences in the values. The over means of the two seasons under intercropping patterns can be arranged in descending order as 73.9 > 72.1 > 69.5 cm for P_2, P_1, and P_3, respectively. Given the effect of the interaction between treatments under all sowing dates, the highest mean value 78.7 cm was under intercropping system treatment P_2 (1:2) under the third sowing date D_3. This might be attributed to increasing soil moisture of the surface layer under the conditions of this treatment resulted in increasing the shading conferred by the greater canopy that minimized the soil evaporation losses, increasing transpiration for plant surface which considers one of the main components of water consumptive use. These results are similar to finding by **Nyawade et al. (2019a, 2019b).**

Table 3. Effect of Cowpea Sowing Date and Intercropping Patterns on Seasonal Amount of Irrigation Water (IW) and Consumptive Use (CU) for Cowpea Intercropped on Maize in the Two Growing Seasons

Sowing date	Intercropping systems	I W, cm			C U, Cm		
		1st growing season	2nd growing season	Mean	1st growing season	2nd growing season	Mean
D1	P1	86.9	89.7	88.3	67.3	67.2	68.7
	P2	86.9	89.7	88.3	69.4	71.8	70.6
	P3	86.9	89.7	88.3	65.3	67.2	66.3
Mean		86.9	89.7	88.3	67.3	69.7	68.5
D2	P1	89.5	92.6	91.1	69.8	72.2	71.0
	P2	89.5	92.6	91.1	70.1	74.1	72.4
	P3	89.5	92.6	91.1	67.0	69.5	68.3
Mean		89.5	92.6	91.1	69.2	71.9	70.6
D3	P1	96.4	100.2	98.3	75.1	78.2	76.7
	P2	96.4	100.2	98.3	77.0	80.3	78.7
	P3	96.4	100.2	98.3	72.2	75.3	73.8
Mean		96.4	100.2	98.3	74.8	77.9	76.4
Control maize		85.3	86.4	85.9	58.8	60.4	59.6
control cowpea		54.7	55.5	55.1	37.7	38.9	38.3

Effect of Cowpea Sowing Date and Intercropping Pattern on Maize Yield and Some Yield Components

Data presented in Tables (4,5,6) and figure (1) show that no significant differences were obtained with sowing date for cowpea treatments and interaction between sowing date for cowpea and intercropping patterns in plant height, stem diameter, ear length, ear diameter, ear weight, grain yield/plant, grain yield kg/ha, N content and oil % of maize, except protein %. Therefore, the highly significant differences were obtained with the intercropping system for all last traits, the highest values were achieved by the third sowing date for cowpea under the second intercropping system in both growing seasons. **These results are in great harmony with those reported by El-Shamy et al (2014) and (2015).**

Table 4. Effect of sowing date for cowpea and intercropping system with maize on plant height, cm, stem diameter, cm, Ear length, cm and Ear diameter, cm of maize in the two growing seasons

Sowing date	Intercropping	Plant height, Cm		Stem diameter, Cm		Ear length, Cm		Ear diameter, cm	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
D_1	P_1	250.4	251.3	1.99	2.00	19.99	20.17	4.57	4.62
	P_2	257.9	258.6	2.02	2.03	20.60	20.76	4.91	4.94
	P3	247.0	247.4	1.97	1.98	19.69	19.78	4.51	4.50
Mean D_1		251.8	252.5	1.99	2.01	20.09	20.23	4.66	4.69
D_2	P_1	250.8	251.3	1.99	2.00	20.02	20.17	4.64	4.67
	P_2	255.1	258.6	2.02	2.03	20.71	20.83	4.84	4.87
	P3	247.3	246.7	1.96	1.98	19.57	19.75	4.45	4.46
Mean D_2		251.1	252.2	1.99	2.00	20.10	20.25	4.64	4.67
D_3	P_1	250.9	251.4	1.98	2.00	20.01	20.14	4.57	4.64
	P_2	257.4	258.8	2.04	2.04	20.78	20.88	4.77	4.83
	P3	248.0	247.0	1.96	1.97	19.94	17.74	4.43	4.45
Mean D_3		252.1	252.4	1.99	2.00	20.09	20.25	4.59	4.64
Mean D		251.67	252.4	1.99	2.00	20.09	20.24	4.63	4.67
F. Test		Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
F. Test		**	**	**	**	**	**	**	**
L.S.D. 5% at P		3.2105	2.2567	0.0092	0.0100	0.1460	0.144	0.1317	0.134
D * P		Ns	Ns	*	Ns	Ns	Ns	Ns	Ns

D1= first sowing date for cow pea, D2 = second sowing date, D3= third sowing date P1= 1:1, p2 = 1:2, p3 = 2:4 * and ** represent significant differences between means at 0.05 and 0.01 level of probability, respectively; NS, non-significant. Each value is mean ±S.D.

Table 5. Effect of sowing date for cowpea and intercropping system with maize on Ear weight, g. Grain yield/Plant and Grain yield, kg/ ha of maize in the two growing seasons

Sowing date	Intercropping	Ear weight, g.		Grain yield/ Plant		Grain yield, kg/ Ha	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
D_1	P_1	181.7	182.1	172.2	172.3	6440.0	6450.0
	P_2	201.0	201.2	177.6	177.7	7180.0	7200.0
	P3	182.8	182.8	169.8	169.8	6170.0	6180.0
Mean D_1		188.5	188.7	173.2	173.3	6600.0	6610.0
D_2	P_1	180.9	181.7	171.6	171.8	6370.0	6390.0
	P_2	201.4	201.6	177.0	177.5	7180.0	7190.0
	P3	181.5	181.6	170.4	170.4	6100.0	6130.0
Mean D_2		187.9	188.3	173.0	173.2	6550.0	6570.0
D_3	P_1	181.2	181.4	171.6	172.0	6350.0	6360.0
	P_2	200.9	201.3	177.9	178.0	7250.0	7270.0
	P3	181.4	181.5	169.5	169.5	6100.0	6100.0
Mean D_3		187.9	188.1	173.0	173.2	6560.0	6580.0
Mean D		188.1	188.4	173.1	173.2	6570.0	6586.7
F. Test		Ns	Ns	Ns	Ns	Ns	Ns
L.S.D. 5% at P		1.7934	1.7582	2.368	2.4711	0.0993	0.0998
F. Test		**	**	**	**	**	**
D * P		Ns	Ns	Ns	Ns	Ns	Ns

D1= first sowing date for cow pea, D2 = second sowing date, D3= third sowing date P1= 1:1,p2 = 1:2, p3 = 2:4 * and ** represent significant differences between means at 0.05 and 0.01 level of probability, respectively; NS, non-significant. Each value is mean ±S.D.

Table 6. Effect of sowing date for cowpea and intercropping system with maize on N content. Oil %and Protein %of maize in the two growing seasons

Sowing date	Intercropping	N content		Oil %		Protein %	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
D_1	P_1	1.34	1.37	10.31	10.32	8.85	8.87
	P_2	1.38	1.39	10.40	10.42	8.90	8.93
	P3	1.32	1.34	10.23	10.25	8.32	8.34
Mean D_1		1.35	1.37	10.31	10.33	8.69	8.71
D_2	P_1	1.35	1.36	10.28	10.30	8.72	8.77
	P_2	1.39	1.34	10.42	10.43	8.93	8.96
	P3	1.31	1.33	10.20	10.22	8.33	8.35
Mean D_2		1.35	1.36	10.30	10.32	8.66	8.69
D_3	P_1	1.35	1.36	10.29	10.31	8.72	8.76
	P_2	1.39	1.41	10.42	10.44	8.96	8.98
	P3	1.31	1.32	10.21	10.23	8.45	8.47
Mean D_3		1.35	1.36	10.31	10.33	8.71	8.74
Mean D		1.35	1.36	10.31	10.3	8.69	8.71
F. Test		Ns	Ns	Ns	Ns	Ns	Ns
L.S.D. 5% at P		0.0170	0.0153	0.0295	0.0257	0.0687	0.0620
F. Test		***	***	***	***	***	***
D * P		Ns	Ns	Ns	Ns	*	*

D1= first sowing date for cow pea, D2 = second sowing date, D3= third sowing date. P1= 1:1,p2 = 1:2, p3 = 2:4

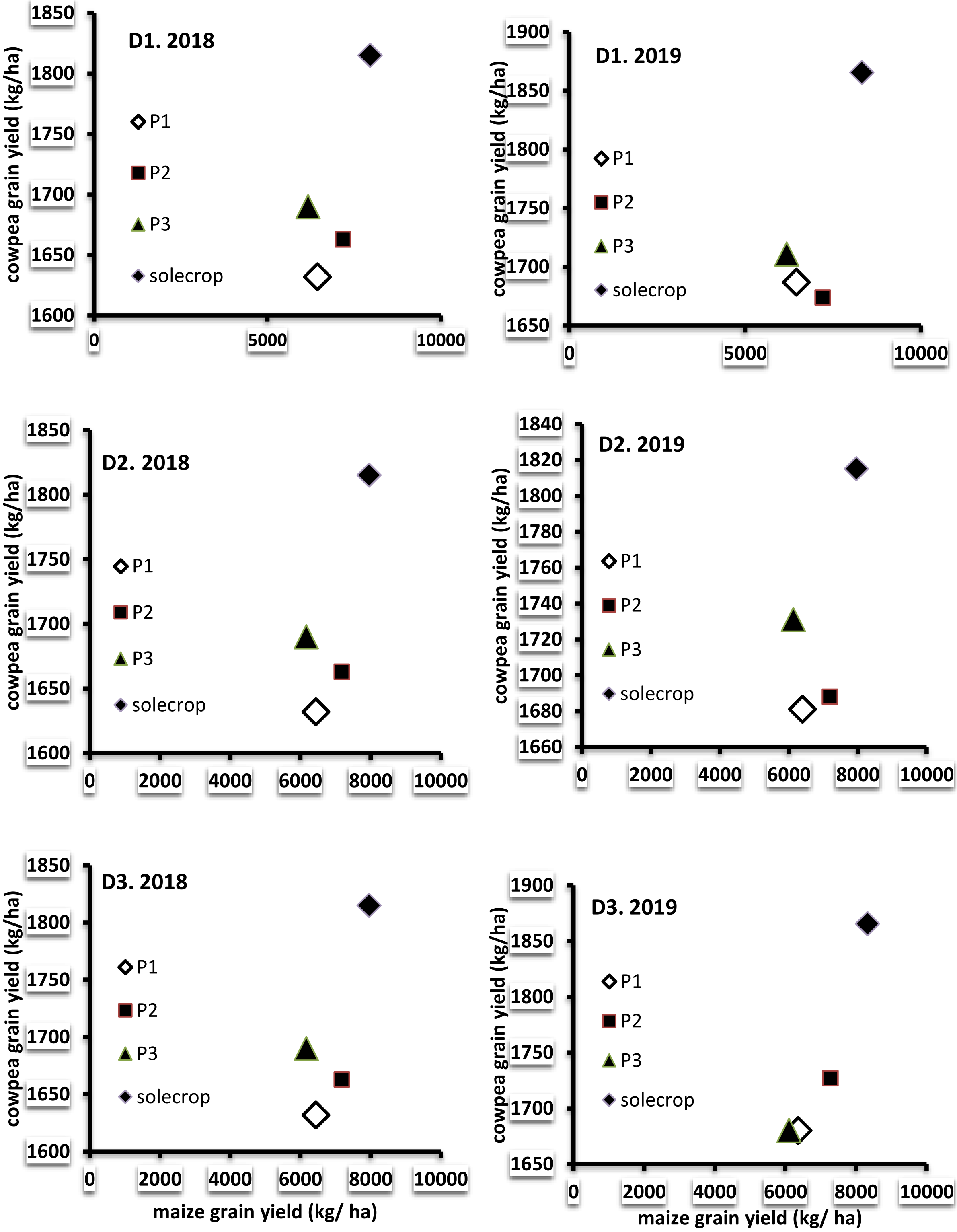


Fig. 1. The relation between Cowpea and Maize yield in the 2018 and 2019 seasons

Effect of Cowpea Sowing Date and Intercropping Pattern on Cowpea Yield and Some Yield Components

Tabulated data in Table (7) indicated that no significant differences were obtained with the sowing date for cowpea treatments and interaction between with sowing date for cowpea and intercropping system in plant height, stem diameter, and no. leaves/plant of Cowpea in the two growing seasons. except for dry matter in the second season with interaction. Therefore, the highly significant differences were obtained with the intercropping system for all last traits, except the second season for no. leaves/plant and dry matter, the highest values were achieved by the third sowing date for cowpea under the second intercropping system in both growing seasons. These results are in great harmony with those reported by **El-Shamy et al (2014) and (2015). and Darwesh et al. (2016).**

Table 7. Effect of sowing date for cowpea and intercropping system with maize on plant height, cm, stem diameter, cm, no. leaves/plant and dry matter of Cowpea in the two growing seasons.

Sowing date	Intercropping	Plant height, cm		Stem diameter, cm		No. leaves/plant		Dry mater,	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
D_1	P_1	144.3	145.5	1.70	1.72	58	58	3.13	3.15
	P_2	151.6	154.0	1.71	1.77	59	59	3.30	3.36
	P3	148.6	149.8	1.68	1.73	58	58	3.26	3.37
Mean D_1		148.2	149.8	1.69	1.74	58.1	58.33	58.33	3.29
D_2	P_1	142.6	149.8	1.63	1.67	58	58.3	3.25	3.27
	P_2	150.4	145.5	1.69	1.79	59	59	3.33	3.37
	P3	149.4	153.2	1.68	1.70	57	57	3.14	3.23
Mean D_2		147.5	150.0	1.67	1.72	57.90	58.33	3.24	3.29
D_3	P_1	142.1	144.8	1.64	1.68	58	58	3.28	3.32
	P_2	150.0	153.4	1.73	1.79	59	59	3.38	2.74
	P3	149.4	150.9	1.70	1.72	57	54	3.20	3.23
Mean D_3		147.1	149.7	1.69	1.73	58.0	58.07	57.27	3.09
Mean D		147.6	149.83	1.68	1.73	58.0	58.0	3.25	3.22
F. Test		Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
L.S.D. 5% at P		3.4638	3.549	0.0214	0.0283	0.0220	-	0.071	-
F. Test		**	**	**	**	**	Ns	**	Ns
D * P		Ns	Ns	Ns	Ns	Ns	Ns	Ns	*

* and ** represent significant differences between means at 0.05 and 0.01 level of probability, respectively; NS, non-significant. Each value is mean ±S.D.

Tabulated data in Table (8) and figure (2) clearly illustrated that no significant differences were obtained with sowing date for cowpea treatments and interaction between with sowing date for cowpea and intercropping Pattern in dry seed yield, kg/ha, dry mater%, fiber% and protein% of Cowpea in the two growing seasons. Except for dry seed yield at the first season with Sowing date for cowpea, and fiber % with interaction was significant. Therefore, the highly significant differences were obtained with the intercropping system for all last traits, except protein % was significant, the highest values were achieved by the third sowing date for cowpea under the second intercropping system in both growing seasons. These **results are in great agreement with those obtained by Darwesh et al. (2016).**

Table 8. Effect of sowing date for cowpea and intercropping system with maize on Dry seed yield, kg/ha, Dry mater%, Fiber%, and Protein% of Cowpea in the two growing seasons

Sowing date	Intercropping	Dry seed yield, kg/ha		Dry matter %		Fiber %		Protein %	
		1st Season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
D_1	P_1	1632	1687	17.17	17.20	32.62	32.82	14.51	14.55
	P_2	1663	1674	17.78	17.81	32.86	33.12	14.62	14.63
	P3	1690	1711	16.98	17.02	31.60	32.28	14.20	14.21
Mean D_1		1661.67	1690.67	17.31	17.35	32.36	32.74	14.44	14.46
D_2	P_1	1678	1681	17.03	17.07	32.08	32.44	14.53	14.55
	P_2	1676	1688	17.78	17.80	32.85	33.00	14.45	14.48
	P3	1727	1731	17.26	17.29	32.13	32.73	14.41	14.43
Mean D_2		1693.67	1700	17.36	17.38	32.36	32.72	14.46	14.48
D_3	P_1	1677	1680	17.05	17.06	31.61	32.04	14.57	14.60
	P_2	1718	1727	17.95	17.98	33.23	33.38	14.60	14.63
	P3	1670	1680	17.14	17.17	31.62	32.35	14.31	14.33
Mean D_3		1688.33	1695.67	17.38	17.40	32.15	32.59	14.49	14.52
Mean D		1681.22	1695.45	17.35	17.38	32.29	32.63	14.46	14.49
L.S.D. 5% at D		9.2239	-	-	-	-	-		
F. Test		*	Ns	Ns	Ns	Ns	Ns	Ns	Ns
L.S.D. 5% at P		17.898	16.393	0.1310	0.1263	0.639	0.421	0.2124	0.2103
F. Test		**	**	**	**	**	**	*	*
D * P		Ns	Ns	Ns	Ns	*	Ns	Ns	Ns

* and ** represent significant differences between means at 0.05 and 0.01 level of probability, respectively; NS, non-significant. Each value is mean ±S.D.

Irrigation Water Use Efficiency and Crop Water Use Efficiency

Presented data which tabulated in Table (9) showed that for irrigation Water Use Efficiency (IWUE), the overall mean values of IWUE, for maize and cowpea yield underplanting date treatments were 0.93, 0.89, and 0.83 kg m^{-3}, for D_1, D_2, and D_3 respectively, and this indicates that IWUE for the first date is better than other dates. Going to the point of intercropping patterns, the highest value for

IWUE is 1.00 kg m^{-3} which was recorded with P_2 (1:2), and the lowest 0.79 kg m^{-3} was observed with P_3 (2:4).

For the Crop Water Use Efficiency (CWUE), data shows that CWUE took the same trend that was achieved from the IWUE for planting dates treatments, and so for intercropping patterns. We found that, according to the dates of cowpea planting, the highest mean value of CWUE was achieved with the first date (1.21 kg m^{-3}) and the lowest (1.08 kg m^{-3}) was under the third date. Coming to intercropping patterns, it was found that the (1:2) intercropping pattern, P_2 was the highest as its average value was 1.21 kg m^{-3}, The lowest value for average Crop Water Use Efficiency was 1.12 kg m^{-3} with P_3 (1:1) comparing with sole maize which was 1.38 kg m^{-3} and sole cowpea 0.48 kg m^{-3}.

In general, it can be concluded that Intercropping maize with cowpea showed significantly higher Irrigation Water Use Efficiency and Crop Water Use Efficiency relative to sole maize (Table 9). This may result in that sole cropping yielded higher than all the maize-cowpea intercrops. These results were in line with those obtained by (**Takim, 2012**) but weren't in agreement with (**Mao et al., 2012**) who stated that Maize-cowpea intercropping results in greater vegetative cover compared with the sole crop stands and therefore a reduction in soil evaporation and increased water use efficiency.

Table 9. Effect of sowing date and intercropping systems on Irrigation Water Use Efficiency (IWUE), and Crop Water Use Efficiency (CWUE), for cowpea intercropped on maize in the two growing seasons

Sowing date	Intercropping systems	IWUE (kg/m^3)			CWUE (kg/m^3)		
		1st season	2nd season	Mean	1st season	2nd season	Mean
D_1	P_1	0.93	0.91	0.92	1.20	1.21	1.21
	P_2	1.02	0.99	1.00	1.27	1.24	1.26
	P_3	0.90	0.88	0.89	1.20	1.17	1.19
Mean		0.95	0.95	0.93	0.94	1.23	1.19
D_2	P_1	0.90	0.87	0.89	1.15	1.12	1.14
	P_2	0.99	0.96	0.97	1.26	1.20	1.23
	P_3	0.87	0.85	0.86	1.17	1.13	1.15
Mean		0.92	0.92	0.89	0.91	1.19	1.15
D_3	P_1	0.83	0.80	0.82	1.07	1.03	1.05
	P_2	0.93	0.90	0.91	1.16	1.12	1.14
	P_3	0.81	0.78	0.79	1.08	1.03	1.05
Mean		0.85	0.86	0.83	0.84	1.10	1.06
Control maize		0.93	0.93	0.96	0.95	1.35	1.38
control cowpea		0.33	0.33	0.34	0.33	0.48	0.48

Where: IWUE = Irrigation Water Use Efficiency r, CWUE = Crop Water Use Efficiency, D_1 = 1st May for Cowpea crop, D_2= 20th May for Cowpea crop, D_3 = 9th June for Cowpea crop, $\mathbf{P_1}$= Growing (1:1) ridge of maize and cowpea respectively, $\mathbf{P_2}$ = Growing (1:2) ridge of maize and cowpea respectively, and $\mathbf{P_3}$= Growing (2:4) ridge of maize and cowpea respectively.

Water Equivalent Ratio (WER)

Water equivalent ratio is a measure used to quantify the amount of water that would be needed in a single crop to achieve the same yield as produced with one unit of water in intercrops **(Mao et al, 2012).** The WER values varied from 1.33 to 1.49 and from 1.28 to 1.44 in the first and second seasons, respectively (Table 10). The highest WER values of (1.49 &1.44) were observed with the D_1P_2 (first sowing date of cowpea under 1:2 intercropping pattern) and the lowest (1.33 &1.28) were obtained with the D_3P_1 (third sowing date of cowpea under 1:1 intercropping pattern) in both seasons, respectively. Since the WER values are higher than 1, then there is indicating the water use advantage of maize-cowpea intercropping. Feng et al, (2016) showed that the water equivalent ratio of two peanut – millet intercropping patterns ranged from 1.17 to 1.22, which implied an increase in water use efficiency of the two patterns by 17 and 22%. **El Mehy et al (2018)** indicated that intercropping sunflowers with peanut systems can utilize water more efficiently than a monoculture of either crop by about 25 and 26 %, respectively.

Table 10. Effect of sowing date and intercropping systems on water equivalent ratio for cowpea intercropped on maize in the two growing seasons

Sowing date	Intercropping pattern	WER		
		S_1	S_2	Mean
D_1	P_1	1.43	1.42	1.43
	P_2	1.49	1.44	1.46
	P_3	1.44	1.40	1.42
D_2	P_1	1.40	1.35	1.37
	P_2	1.48	1.41	1.44
	P_3	1.41	1.37	1.39
D_3	P_1	1.33	1.28	1.31
	P_2	1.40	1.35	1.38
	P_3	1.34	1.29	1.31

Land Equivalent Ratio (LER) and Gross Return (US. $., ha^{-1})

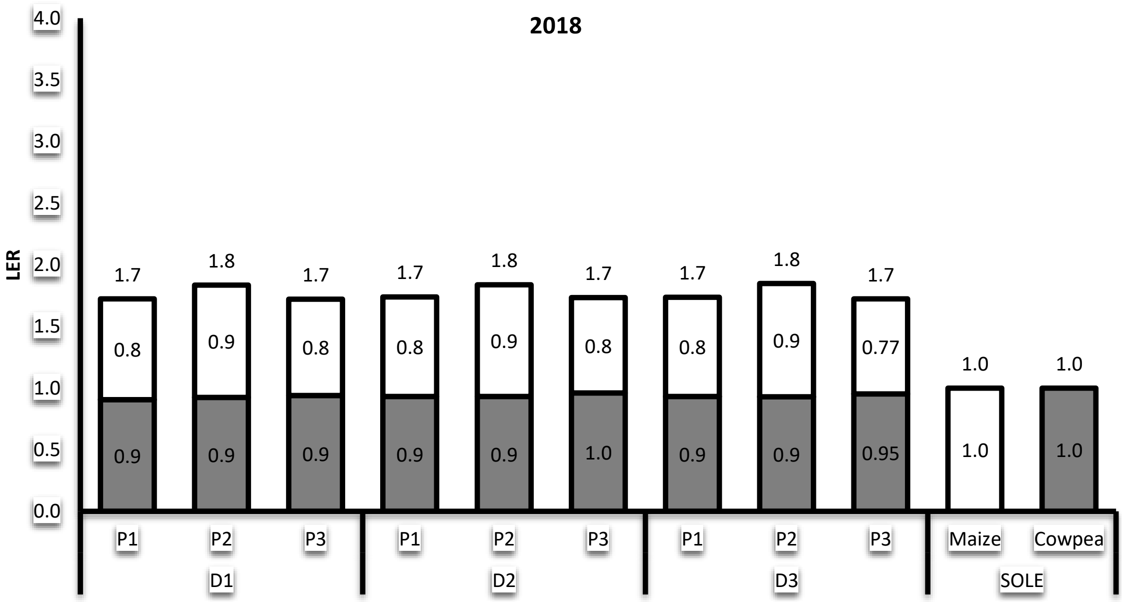
The land equivalent ratio is a method used to calculate the effectiveness of intercropping systems. It is the most widely used index for measuring the advantages of intercropping systems on the combined yield of both crops. It is defined as the relative land area under sole crops required producing yields achieved in intercropping..Data in Table (11) and figure (2) indicated that, the land equivalent ratio values increased above 1.0 due to intercropping cowpea with maize. Parallel results were achieved by **Zohry et al., (2017).** concerning the effect of sowing date on land equivalent ratio, the highest values in the two growing seasons were shown under the third sowing date treatment (D_3) under the second intercropping system (P_2). meanwhile, the lowest values were recorded under the first sowing date treatment(D_1), under the third intercropping system (P_3). These results are in harmony with those obtained by **Abou Khadra et al. (2013)** they concluded that LER values were high at any intercropping systems.

Sowing date and planting pattern affected gross return, for sowing date the highest values were recorded under sowing date treatment D_3 and the values are 3335.21and 4876.63 (U.S.$. ha^{-1}) at the same time, the lowest values were showed under sowing date treatment D_1 and the values are 3258.47 and 4675.88 in the first and second growing seasons, respectively. On the other hand, planting patterns showed an effect on gross return under the overall sowing date for cowpea in the two growing seasons. These results were in line with were reported by **Rahman et al. (2017)** who formulated a land-use advantage from maize-soybean intercropping.

Table 11. Effect of sowing date and intercropping pattern Maize with cowpea on the land equivalent ratio (LER) and gross return (L.E., $ha.^{-1}$) in the two growing seasons.

Sowing date (D)	Intercropping systems (P)	Land equivalent ratio		Gross return (L.E. fed^{-1})	
		1st season	2nd season	1st season	2nd season
D_1	P_1	1.75	1.69	3272.97	4695
	P_2	1.83	1.78	3317.27	4848.75
	P_3	1.72	1.67	3258.47	4675.88
Mean		***1.77***	***1.72***	***3282.903***	***4739.88***
D_2	P_1	1.74	1.68	3259.71	4669.5
	P_2	1.84	1.78	3337.59	4872.63
	P_3	1.73	1.68	3309.30	4701.5
Mean		***1.77***	***1.72***	***3302.2***	***4747.88***
D_3	P_1	1.74	1.68	3256.15	4660.5
	P_2	1.85	1.79	3335.21	4876.63
	P_3	1.72	1.67	3292.234	4686.88
Mean		***1.77***	***1.69***	***3294.531***	***4741.34***

D_1= first sowing date for cowpea, D_2 = second sowing date, D_3= third sowing date, P_1= 1:1,p_2 = 1:2, p_3 = 2:4 Sole maize 789 US,$., 1959.38 US.$ Sole cowpea 2813.4, 3468.75 US. $



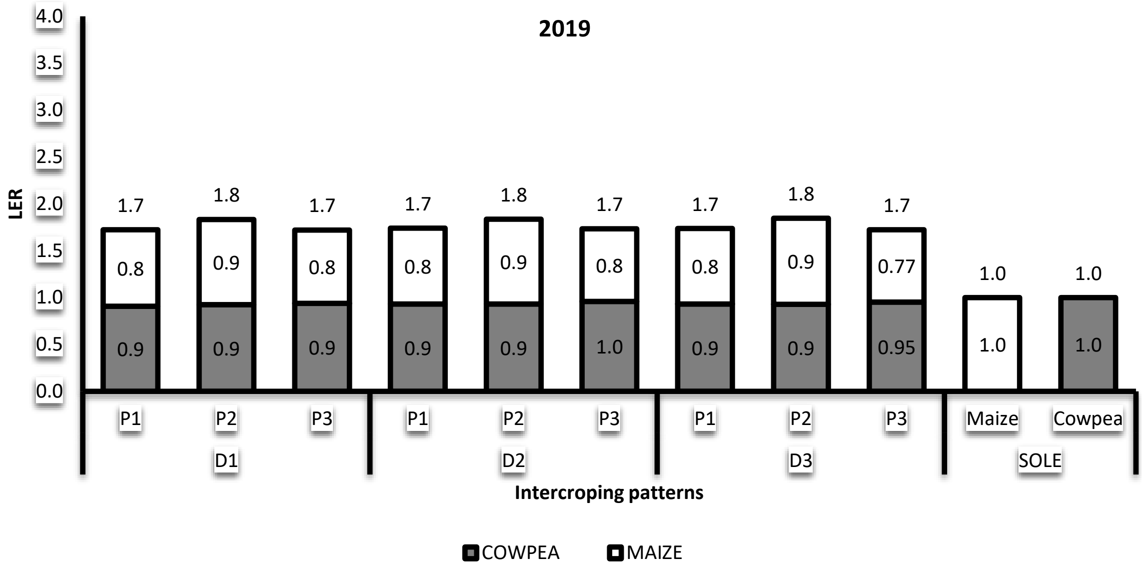


Figure 2. The Land Equivalent Ratio of intercropping cowpea with maize in the two seasons

Discussion

The results showed that the water applied to cowpea intercropped with maize was less than the amount applied to each of the two crops in monoculture. This could be be resulted from lower planting density of cowpea in different intercropping systems and different rooting patterns among cowpea and maize (deep vs. shallow roots), which can allow plants to exploit large volume of soil and enhance access to soil water, which make best use of water. Kamel et al., (2010) reported that, no additional irrigation water is needed to apply to associated crop since it shares the water used for the main crop. Also, Ghanbari et al., (2010) revealed that cowpea intercropped with maize lessen water evaporation and improves soil moisture preservation.

Results also showed that, the intercropping patternss of maize with cowpea have lots of benefits. Tolera (2003) said that cultivate more than one crop at a same time in the same field preserve soil fertility as a result of high root density. Gebru, (2015) reported that intercropping of crops with diverse rooting patterns allow to exploit large volume of soil and gain access to relatively immobile nutrients. Consequently, intercropped plants have a tendency to absorb extra nutrients than those in monocultures and achieve higher yield. These findings could support the truth of better resource use, as articled by Szumigalski and Van-Acker (2008).

Our results indicated that the monoculture yield of maize was lower under different intercropping systems, by comparing to sole planting. This may be due to competition between maize and cowpea on natural resources. From the economic viewpoint, the final obtained yield was cowpea yield in addition to maize yield, that will balance the loss in profit resulted from maize yield reduction.

Conclusions

The study confirms that intercropping maize and cowpea in different sowing dates and different patterns did not affect yield and some components of maize compared to the sole. LER was higher than one in all intercropping systems showed an advantage of intercropping systems. A high additional increase in profits over each cost for all intercropping patterns especially the third sowing date for cowpea under the intercropping system (1:2). It is recommended to the region to use this pattern to improve farmer's income and LER under the North Middle Nile Delta conditions.

References

Abou Khadra, S.H., Shaimaa, A.E.B., Salah, E.A.T., and Dina, E.E.E. (2013). Effect of intercropping wheat with sugar beet on their productivity and land use. *Journal of Agricultural Research es. Kafr El-Sheikh Univ*, 39: 37-53.

Darwesh, R., EL-Mansoury, M., and El-Shamy, M. (2016). Effect of Irrigation Scheduling on Sunflower/Forage Cowpea Intercropping Pattern, Growth, Yield and its Components. *Journal of Soil Sciences and Agricultural Engineering*, 7(2): 135-146.

El-Mehy, A.A., Taha, A.M., and Abd-Allah, A.M. (2018). Maximizing land and water productivity by intercropping sunflower with peanut under sprinkler irrigation. *Alexandria Science Exchange Journal*, 39: 144-160. https://doi.org/10.21608/asejaiqjsae.2018.5820

El-Shamy, M.A., Abdel-Wahab, T.I., Abdel-Wahab, S.I., and Ragheb, S.B. (2014). Efficiency Of Intercropping Soybean With Corn Under Two Corn Plant Distributions and three Mineral Nitrogen Fertilizer Rates. *The 8th International Conference on Technology and Sustainable Development in the Third Millennium*, 22-24.

El-Shamy, M.A., Abdel-Wahab, T.I., Abdel-Wahab, S.I., and Ragheb, S.B. (2015). Advantages of intercropping soybean with maize under two maize plant distributions and three mineral nitrogen fertilizer rates. *Advances in Bioscience and Bioengineering*, 3(4): 30-48.

Fereres, E., and Soriano, M.A. (2007). Deficit irrigation for reducing agricultural water use. *Journal of experimental botany*, 58(2): 147-159.

https://doi.org/10.1093/jxb/erl165 PMID: 17088360.

Gebru, H. (2015). A review on the comparative advantages of intercropping to mono-cropping system. *Journal of Biology, Agriculture and Healthcare*, 5(9): 1-13.

Ghanbari, A., Dahmardeh, M., Siahsar, B.A., and Ramroudi, M. (2010). Effect of maize (Zea mays L.)-cowpea (Vigna unguiculata L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. *Journal of Food, Agriculture and Environment*, 8(1): 102-108.

Hansen, V.W., Israelsen, O.W., and Stringharm, Q.E. (1979). *Irrigation principles and practices, 4th ed.* John Willey and Sons, New York.

Jackson, M.l. (1973). *Soil Chemical Analysis.* Prentice-Hall of India private, LTD New Delhi.

James, L.G. (1988). *Principles of farm irrigation system design.* John Willey and Sons Inc., New York, 543.

Kamel, A.S., El-Masry, M.A., and Khalil, H.E. (2010). Productive sustainable rice based rotations in saline-sodic soils in Egypt. *Egyptian Journal of Agronomy*, 32(1): 73-88.

Klute, A.C. (1986). *Water retention: Laboratory Methods.* In: A. koute (ed), Methods of Soil Analysis, part12nd(ed.) Agron Monogr, 9, ASA, Madison, W1 U.S.A: 635-660.

Mao, L., Zhang, L., Li, W., Van Der Werf, W., Sun, J., Spiertz, H., and Li, L., (2012). Yield advantage and water saving in maize/pea intercrop. *Field Crops Research,* 138: 11–20.

Masvaya, E.N., Nyamangara, J., Descheemaeker, K., and Giller, K.E. (2017). Is maize-cowpea intercropping a viable option for smallholder farms in the risky environments of semi-arid southern Africa?. *Field Crops Research*, 209: 73-87.

Michael, A.M. (1978). Irrigation – Theory, and practices. Vikas Publishing House, New Delhi.

MLAR. (2013). Annual Economical Statistics of the agriculture sector report.

Nofal, F.A.E., and Attalla, R.A. (2006). Intercropping efficiency of some Maize hybrids on peanut in sandy soils. *The Journal of Agricultural Science, Mansoura University*, 31(1): 1-16.

Nyawade, S.O., Gachene, C.K., Karanja, N.N., Gitari, H.I., Schulte-Geldermann, E., and Parker, M.L. (2019). Controlling soil erosion in smallholder potato farming systems using legume intercrops. *Geoderma Regional*, 17: e00225.

Nyawade, S.O., Karanja, N.N., Gachene, C.K., Gitari, H.I., Schulte-Geldermann, E., and Parker, M.L. (2019). Short-term dynamics of soil organic matter fractions and microbial activity in smallholder potato-legume intercropping systems. *Applied Soil Ecology*, 142: 123-135.

Ouda, S.A., El Mesiry, T., Abdallah, E.F., and Gaballah, M.S. (2007). Effect of water stress on the yield of soybean and Maize grown under different intercropping patterns. *Australian Journal of Basic and Applied Sciences,* 1(4): 578-585.

Rahman, T., Liu, X., Hussain, S., Ahmed, S., Chen, G., Yang, F., and Yang, W. (2017). Water use efficiency and evapotranspiration in maize-soybean relay strip intercrop systems as affected by planting geometries. *PloS one*, 12(6): e0178332.

https://doi.org/10.1371/journal.pone.0178332

Szumigalski, A.R., and Van Acker, R.C. (2008). Land equivalent ratios, light interception, and water use in annual intercrops in the presence or absence of in-crop herbicides. *Agronomy Journal*, 100(4): 1145-1154.

Takim, F.O. (2012). Advantages of Maize-Cowpea Intercropping over Sole Cropping through Competition Indices. *Journal of Agriculture and Biodiversity Research,* 1(4): 53-59.

Tolera A. (2003). *Effects nitrogen, phosphorus farmyard manure and population of climbing bean on the performance of maize (Zea mays L.)/climbing bean (Phaseolus vulgaris L.) intercropping system in Alfisols of Bako.* M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University.

Wang, Z., Wu, P., Zhao, X., Gao, Y., and Chen, X. (2015). Water use and crop coefficient of the wheat–maize strip intercropping system for an arid region in northwestern China. *Agricultural Water Management*, 161: 77-85.

Willey, R. (1979). Intercropping-its importance and research needs: Part 1. Competition and yield advantages. *In Field crop abstracts,* 32: 1-10.

Yang, C., Huang, G., Chai, Q., and Luo, Z. (2011). Water use and yield of wheat/maize intercropping under alternate irrigation in the oasis field of northwest China. *Field Crops Research*, 124(3): 426-432.

Zhang, H., Oweis, T.Y., Garabet, S., and Pala, M. (1998). Water-use efficiency and transpiration efficiency of wheat under rain-fed conditions and supplemental irrigation in a Mediterranean-type environment. *Plant and Soil*, 201(2): 295-305.

Zohry, A.E.H.A., Abbady, K.A., and Ahmed, H.M. (2017). Maximizing land productivity by diversified cropping systems with different nitrogen fertilizer types. *Acta Agriculturae Slovenica*, 109(3): 481-492.