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EFFECT OF ECONOMIC USE OF IRRIGATION WATER ON GROWTH AND YIELD OF INTERCROPPED MAIZE AND SUNFLOWER

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ABSTRACT

Three maize/ sunflower intercropping patterns (S_1, S_2 and S_3) were tested compared to pure maize (Pm) and pure sunflower (Psu) grown in solid planting under three irrigation treatments during 2005 and 2006 seasons. Intercropping unit, that repeated twice, consisted of four ridges, of which 3 were sown with sunflower and the fourth was sown with maize on one side (S_1) or two sides (S_2) of ridge. In S_3, maize was grown as in S_2 with additional side on the third sunflower ridge. Irrigation treatments were frequent irrigation (I_1) every 15 days and skipping either second (I_2) or the third (I_3) irrigation (at 35 or 50 days after sowing, respectively). Frequent irrigation of maize gave significantly greater plant height, percent of fertile plants, 100-grain weight and grain yield/ fed., under (I_1) irrigation regime compared to maize grown under I_2 and I_3 irrigation levels. Maize intercropped with sunflower in S_3 system produced the tallest plants, while pure maize in (Pm) plots, followed by that of S_1 system, produced heavier 100-grain weight and greater grain yield/ fed. than those obtained from S_2 and S_3 systems. Pure maize, followed by maize in S_1, gave higher values for plant height, number of grains/ ear and grain yield/ fed., compared to S_2 and S_3 systems over I_2 and I_3 irrigation regimes.

Frequent irrigation followed by early drought (I_2) significantly surpassed late drought (I_3) for sunflower characters of seed yield/ plant, 100-seed weight and seed yield/ fed. The S_1 system with frequent irrigation produced greater sunflower 100-seed weight and seed yield/ fed. than from S_2 and S3 over I_2 and I_3 irrigation treatments.

The maximum LER (1.59) was obtained from S_1 applied with (I_1) irrigation treatment. It is suggested that as total populations in the intercrop are higher (S_2 and S_3) than that of sole cropping, yields could be less than sole crop yields because of the increased competition for moisture under high stress conditions (I_3).

INTRODUCTION

Water availability is thought to be the most critical limiting factor for photosynthesis and hence for agricultural production. A lack of water has deleterious effects on numerous plant processes which can impinge on photosynthesis with productivity reduction, however, the reverse is true for plants best supplied with water (Opik *et al.*, 2005). Response of plants to water stress is influenced by the degree of stress conditions, growth stage of stressed plants and growth habits of plants during water stress (Lorens *et al.*, 1987).

In Egypt, competition for cultivated area and irrigation water in favor of cotton and rice at the expense of other summer crops, as maize and sunflower, has shifted the agronomists' interest towards increase efficiencies of land use and growth resources utilization through maize-sunflower intercropping (EL-Doubi, 1992 and Khalil, 1994). Sunflower has a tap root system whereas maize has a fibrous one, consequently, there is complementarity in the use of soil water by the two crops during intercropping (Nyakata and Nyati, 1998).

Sunflower plants, when water stressed in early growth stages, give acceptable yield (Connor and Sadras, 1993) because of deeply penetrating roots (d'Andrie *et al*., 1995) to enable the plant to extract soil water, but when stressed in the period from flowering to achene filling, sunflower gives low yields (Hedge and Havanagi, 1991).

Exposure of maize to drought during vegetative phase inhibits shoot growth and endangers the development of reproductive organs. However, there is a negative response of number of grains/ ear, 100-grain weight and yield as drought occurred, during grain filling period (Weerathaworn *et al.*, 1992).

Several studies have reported that maize/ sunflower intercropping can produce higher yields than sole stands (Adetunji, 1993; Khalil, 1994; Nyakata and Nyati, 1998; EL-Doubi (1992), Khalil (1994) and Nyakata and Nyati (1998) concluded that sunflower-maize associations gave LER values of > 1 , < 1 or = 1 to indicate different advantages of these associations.

This investigation was conducted to study maize and sunflower performance when grown either alone or in association and to investigate the water economic advantage of their intercropping through the skipping of one irrigation throughout the growth period of the crops.

MATERIALS AND METHODS

Two field experiments of maize (3-way cross hybrid, Giza 310) and sunflower (Vedok cultivar) were conducted at Agriculture Research Station, Alexandria University, under 3 levels of irrigation during 2005 and 2006 seasons. The present work aimed to study maize and sunflower performance when grown either alone or in association and to investigate the water economic of their intercropping throughout the skipping of one irrigation throughout the growth period of the crops. Soil chemical analysis of the experimental site showed the following properties: pH= 8.3, organic matter= 0.19%, total N= 0.13% and total P= 1.6% (as an average of the two seasons). A split plot design with three replications was used in both seasons, where irrigation levels and cropping patterns occupied the main and sub plots, respectively. Each experimental unit comprised 12 ridges, 3 m long and 0.7 m apart with an area 25.2 m^2. Water irrigation treatments were irrigation as recommended (I_1,every 15 days after irrigation) and irrigation with skipping either the second (I_2 , 35 days after sowing), or the third (I_3, 50 days after sowing). The cropping patterns were:

1-Pure stands of maize (Pm)

2-Sunflower (Psu)

3-Single ridges of maize (one side of ridge) in alternate with 3 ridges of sunflower (S_1).

4-Single ridges of maize (grown on two sides) in alternate with 3 ridges of sunflower (S_2).

5-One ridge of maize (grown on two sides) followed by maize intercropping with sunflower on the second ridge (each of the crops grown on one side of ridge) in alternate with 2 ridges of sunflower (S_3).

Sowing dates for pure or intercropping crops were on May 10 and 15 during the two successive seasons, in hills (one plant/ hill) spaced either at 20 cm for (Vedok cultivar) sunflower or at 30 cm for maize (3 way cross hybrid Giza 310). Other agricultural practices were uniformly applied according to the recommendations in the region.

At harvest, the inner eight ridges were taken to denote the representative samples of each crop characters. Recorded traits for maize were plant height (cm), number of leaves/ plant, fertile plant percent (%), number of grains/ ear, 100-grain weight (g) and grain yield/ fed. (ardab). Measured traits in sunflower were plant height (cm), number of leaves/ plant, head diameter (cm), 100-seed weight (g), seed yield/ plant (g) and seed yield/ fed. (kg). Analysis of variance for each crop was separately applied according to Gomez and Gomez (1984).

Land use efficiency measurement, as land equivalent ratio (LER), was used to express intercropping advantages compared to monocultures as proposed by Willey (1979).

RESULTS AND DISCUSSION

1- Effects of irrigation level and cropping pattern on maize:

The results pointed out that, water supply treatments significantly influenced plant height, fertile plants percent, number of grains/ ear and grain yield/ fed. In addition, cropping pattern caused significant variations in plant height, 100-grain weight and grain yield/ fed. In both seasons.

Frequent irrigation (I_1) produced the tallest plants followed by plants of I_2 (skipping the second irrigation) treatment, whereas skipping the third irrigation (I_3 applied) produced the shortest plants. Increase, in plant height of I_1 were 18.63 and 38.29 cm compared to I_2 and I_3, as an average of the two seasons, respectively. Increasing soil moisture with I_1 applied increased plant water uptake, thus accelerating division and expansion of intercalary cells, in addition to increasing auxin level which affects internodes elongation (Gardner *et al.* 1985). Lack of water during vegetative stage (early drought) exhibited hormones unbalance within plants, resulting in a reduction of stem height (Weerathaworn *et al.,* 1992). On the other hand, drought happening at later period (late drought), accompanied with high temperature and increased tendency towards water loss by evaporation increased the relative severity of drought in term of drastic decrease in plant height (Sinha, 1987).

Application of I_1 irrigation level proved superior to I_3 but similar with I_2 in fertile plants (%) over the two seasons (Table 1). Compared to I_3, increases in I_1 and I_2 irrigation levels for such trait, as an average of the two seasons, were 35.33 and 26.03%, respectively. Several studies reported that increasing the period of water deficit, early in the season, increased the period from anthesis to silking in maize and increases plant sterility (Bolanos and Edmeads, 1993 and Edmeads *et al.*, 1993). Wilhelm *et al.* (1999) showed that the late drought caused pollen grains mortality or/ and sterility at higher temperature during this period.

Data in (Table 1) indicated that the treatments I_1 and I_2 had statistically the same number of grains/ ear and both exceeded significantly that of I_3 over the two seasons, Compared to the number of grains/ ear for plants in I_3 plots, decreases in such trait were 31.50 and 40.17 grains in the first season while respective values for the second season were 10.91 and 57.75 grains in I_2 and I_1 treatments, respectively. Reductions in photosynthesis and translocation of assimilates to ears due to severe drought conditions (in I_3) increased spikelets abortion, and pollen infertility, hence decreased number of grains/ ear (Schussler and Westage, 1991). Weerathaworn *et al.* (1992) pointed out that early drought endangered the development of reproductive organs, while drought during grain filling reduced number of grains/ ear.

Grain yield/ fed (Table 1) varied significantly with the irrigation level in both seasons. Average over the two seasons, yield decreases (in ardab) were 1.175 for I_2 and 3.14 for I_3, compared to that of I_1 regime. Increases in I_1 grain yield may be due to increases in number of fertile plants and number of grains/ ear in addition to 100-grain weight (though insignificant). In conclusion, the magnitude of yield reduction, as affected by drought, depends on the growth stage and environmental conditions under which stress occurs. During vegetative stage, early drought inhibits the growth of leaves and stems, consequently decreases the florets development, while drought during reproductive periods (late drought) adversely affected fertility, formation and number of spikelets followed by decreased in ear grain number and grain yield/ fed.

Data in (Table 1) further indicated that intercropping increased heights of maize plants compared to those of sole cropping (Pm) in both seasons. Differences in plant heights were significant between Pm and S_1 (one ridge of maize: 3 ridges of sunflower) plots, S_2 (maize in one ridge with two sides: 3 ridges of sunflower) and S_3, (one ridge with two sides maize, followed by maize intercropping with sunflower in the second ridge alternated with two ridges of sunflower). Maize in S_3 had the tallest plants, however, the shortest were obtained from pure maize. The shade effect and higher competition due to plant crowding, attributable to the overseeding in S_2 and S_3 intercropping patterns, resulted in internode and plant elongation (Adetunji, 1993 and Edmeads *et al.*, 1993). These results agreed with Khalil (1994) and contradicted with EL-Doubi (1992) who found a tendency for an increase in maize plant height at lower population density.

Differences in 100-grain weight due to studied cropping patterns were significant in both seasons (Table 1). The highest value for such trait was obtained from pure maize, meanwhile the S_2 and S_3 intercropping pattern produced the lowest record for 100-grain weight. Uniform plant distribution and lower intra-competition of pure maize increased capture of growth resources, photosynthesis and dry mater accumulation in grains causing increases in 100-grain weight (Gardner *et al.*, 1985, Vandermeer, 1989 and Loomis and Connor, 1992).

Data in Table (1) also revealed that all intercropping patterns were significantly lower in grain yield/ fed., compared with that grown solid over the two seasons. These results could be expected due to lower maize plant population density and higher intercompetition between mixture components, compared to maize under sole planting. Increases in grain yield of sole maize over S_1, S_2 and S_3 intercropping patterns were 166.3, 279.1 and 278.1% in the first season while corresponding values were 169.7, 281.5 and 275.6% in the second season. Nevertheless, increasing maize plant population in the intercrop combinations of S_2 and S_3, compared to S_1 intercropping pattern, reduced maize grain yield. These results may be attributed to greater competition in S_2 and S_3 (due to higher plant population) in addition to better plant orientation in S_1 that favored better utilization of resources by maize leading to yield increase (Clark and Francis, 1985). In conclusion, modification of growth environment by using appropriate pattern could idealize utilization of growth resources, resulting in higher dry matter production and translocation into grains, that is expressed in higher grain yields.

The two factor interaction *i.e*, irrigation × cropping pattern (Table 2) indicated that intercropping patterns were superior in maize plant height to sole cropping over the three irrigation levels in the two seasons. These results may be due to higher intercompetition in all intercropping patterns compared to the intracompetition in pure maize overall the irrigation levels. Furthermore, increasing maize population density in S_2 and S_3 intercropping patterns increased greatly plant height due to higher competition and shade effects on increasing plant height. In addition, over the different cropping patterns, frequent irrigation compared to the other two irrigation levels, produced taller plants. As concluded, the shortest plants were obtained from pure maize under late drought and the tallest were the results of I_1 application to S_3 cropping pattern.

Interaction of irrigation supply treatment × cropping pattern revealed that maize gave the lowest number of grains/ ear with S_3 cropping pattern at water supply of I_3, but gave the highest record for such character when it was grown solid or in cropping pattern at I_1 application. Increasing plant population density, within the intercropping patterns (S_2 and S_3) or/ and drought shifting into period of high temperature increased drought severity thus decreasing number of grains/ ear as a result spikelets abortion and pollination failure (Sinha, 1987).

In addition, data of irrigation supply and cropping pattern interactions (Table 1) showed that intercropping decreased maize grain yield across the irrigation treatment, due to lower population density of maize compared to maize in solid planting over the two seasons. Furthermore, data indicated that S_1 pattern performed better than the other two intercropping patterns (S_2 and S_3) through all the different irrigation levels in utilization of environmental resources and hence in producing higher grain yield. Meanwhile, yield reduction was greatly affected by timing of drought where the later the water shortage (I_3 treatment) the greater the yield reduction obtained across the

Table (1): Means of maize characters as affected by irrigation supply and cropping patterns in 2005 and 2006 seasons

Treatment	Plant height (cm)		Number of leaves/ plant		Fertile plants percentage (%)		Number of grains/ ear		100-grain weight (g)		Grain yield/ fed (ardab)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Irrigation supply												
I_1	243.50	273.67	16.43	19.77	90.08	85.58	479.92	521.17	30.46	36.78	7.87	9.25
I_2	231.83	248.09	16.46	19.59	76.50	80.55	471.25	474.33	30.28	36.70	8.43	8.34
I_3	216.00	224.59	16.33	19.49	50.50	54.50	439.75	463.42	30.25	36.20	8.92	6.92
$L.S.D._{0.05}$	6.03	8.56	N.S.	N.S.	14.20	8.46	21.05	24.98	N.S.	N.S.	0.30	0.49
Cropping pattern												
Pure (Pm)	220.00	236.89	16.50	19.70	71.00	75.47	462.78	487.78	31.07	39.10	14.86	16.75
S_1	224.55	244.45	16.16	19.60	70.36	75.39	462.11	487.67	30.59	37.67	5.58	6.21
S_2	232.44	251.67	16.52	19.56	70.22	75.11	469.22	484.39	29.60	35.56	3.92	4.39
S_3	244.78	262.11	16.38	19.57	69.81	74.92	460.45	485.44	29.08	34.47	3.93	4.46
$L.S.D._{0.05}$	3.81	3.98	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.27	2.08	7.07	7.94

- I_1= Frequent irrigation, I_2 and I_3= skipping an irrigation 35 or 50 DAS, respectively.
- Three sunflower ridges alternate with maize on one side of ridge. (S_1), two sides of ridge (S_2) or three sides of two adjacent ridges (S_3)

Table (2): Means of plant height, number of grains/ ear and grain yield/ fed. for maize as affected by irrigation level × cropping system interaction during 2005 and 2006 seasons

Treatment	Plant height (cm)				Number of grains/ ear				Grain yield/ fed. (ardab)			
	Pm	S_1	S_2	S_3	Pm	S_1	S_2	S_3	Pm	S_1	S_2	S_3
Irrigation supply	2005											
I_1	233.67	235.67	247.33	243.50	564.67	567.33	450.00	479.92	15.86	6.08	5.12	4.29
I_2	223.33	225.33	233.00	231.83	516.67	512.00	476.67	461.25	14.53	5.50	3.43	3.03
I_3	208.00	213.33	217.00	216.00	457.00	457.00	433.00	419.75	12.67	4.46	3.17	3.37
$L.S.D._{0.05}$	8.57				20.14				0.72			
Irrigation supply	2006											
I_1	256.00	269.67	280.33	273.67	570.33	570.33	545.00	551.17	18.57	7.70	5.79	5.50
I_2	238.67	241.67	249.00	248.09	510.33	510.00	460.67	474.33	16.40	6.43	4.59	4.27
I_3	216.00	222.00	225.67	224.59	512.78	512.67	474.33	445.44	14.75	5.81	4.47	4.20
$L.S.D._{0.05}$	8.95				13.43				0.80			

different cropping patterns. Therefore, the treatment combination of S_2 and S_3 cropping patterns and I_3 irrigation supply produced the lowest grain yield/ fed. These results could be attributed to overseeding in S_3 with greater water loss (in I_3) that increased relative severity of drought leading to reductions in grain number and grain weight which were reflected in decreased grain yield (Natarajan and Willey, 1986 and Nyakata and Nyata, 1998).

II- Effects of irrigation level and cropping pattern on sunflower:

Results in Table (3) showed that differences in seed yield/ plant between the irrigation treatments of I_1 and I_2 were insignificant in both seasons and both were significantly superior to I_3. These findings confirm the ability of sunflower to tolerate early water drought and to bear high seed yield/ plant (d'Andrie *et al.*, 1995). The significant reduction in seed yield/ plant of I_3 compared to I_1 treatment revealed the sensitivity of sunflower to late drought which increased the number of empty achenes leading to a decrease in seed yield/ plant (Connor and Sadras, 1993).

Variations in 100-seed weight between the various irrigation levels were significant and more pronounced than seed yield/ plant during the two seasons (Table 2). Increases in 100-seed weight due to I_1 over I_2 and I_3 were 0.58 and 1.06 g in 2005 season and 0.19 and 1.72 g in 2006 season, respectively. Increases in such trait for I_1 level may be a result of more plant canopy expansion, more light use efficiency and more assimilates production and translocation into seeds. Decrease in 100-seed weight due to I_2 and I_3 irrigation levels were, on average of the two seasons, 0.39 g and 1.39 g, respectively, compared to I_1. Severe reduction in 100-seed weight with late drought (I_3) may be attributed to water greater loss by evapotranspiration as drought shifted into a period of high temperature, in addition to its coincidence with the beginning of seed formation.

Differences in seed yield/ fed. between the irrigation levels were significant, being in the order of $I_1 > I_2 > I_3$ in both seasons (Table 3). Reductions in seed yield/ fed. of I_2 and I_3 compared to I_1 irrigation treatment were 73.72 and 102.32 kg in the first season and 77.52 and 99.28 kg in the second season, respectively. These results were in accordince with Hedge and Havanagi (1991) who reported that sufficient water supply caused better utilization of water in photosynthesis and dry matter production that was translocated into heads increasing the head fertile surface and single seed weight, hence total seed yield/ fed. (Cox and Jollif, 1986 and 1987). d'Andrie *et al.*, (1995) reported that water stress during vegetative phase of sunflower stimulated deeply penetrating root for water extraction, associating with acceptable yields. However, Hedge and Havangi (1991) reported that sunflower was sensitive to water stress in the phases between flowering and achene filling.

Regarding cropping pattern (Table 3), recommended plant orientation and uniform light interception by plant canopy decreased plants competition for light in pure sunflower producing the shortest plants compared to those of all intercropping patterns. Increasing sunflower plant crowding, as a result of increasing maize plant density per intercropping unit within the intercropping pattern, increased both inter and intra-competition for light associated with increase in internodes and plant elongation. Differences in plant height were significant between the three intercropping patterns, where pattern (S_1) was significantly shorter in plant height than S_2 and S_3 patterns in the first season only. These results were in agreement with Kamel *et al.* (1990) and Khalil (1994) who reported that plant height of sunflower was increased by intercropping.

Table (3): Means of sunflower characters as affected by irrigation supply and cropping patterns in 2005 and 2006 seasons

Treatment	Plant Height (cm)		Number of leaves/ plant		Head diameter (cm)		Seed yield/ plant (g)		100-seed weight (g)		Yield/ fed. (kg)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Irrigation supply												
I_1	155.32	170.00	23.33	20.68	15.70	17.47	38.10	39.30	6.21	7.36	953.20	944.05
I_2	155.00	170.00	23.28	20.61	15.60	17.45	37.80	39.10	5.63	7.17	879.48	866.53
I_3	155.34	168.10	23.23	20.62	15.50	17.45	33.63	37.50	5.15	5.64	850.88	844.77
L.S.D.$_{0.05}$	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.76	0.36	0.30	0.16	26.27	33.35
Cropping pattern												
Pure (Psu)	143.30	165.80	23.35	20.70	15.63	17.50	37.00	39.90	5.25	6.89	1071.43	1041.77
S_1	144.90	166.60	23.23	20.63	15.60	17.50	35.10	38.20	5.24	6.74	853.3	852.43
S_2	148.60	171.90	23.22	20.62	15.59	17.48	33.80	36.60	5.15	6.66	773.07	775.43
S_3	146.25	169.40	23.20	20.64	15.62	17.50	34.50	37.18	5.20	6.59	700.90	709.43
L.S.D.$_{0.05}$	1.48	2.36	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.08	0.15	23.50	22.66

Data in Table (3) indicated that intercropping patterns were lower in yield/ fed than sunflower grown solid during the two successive seasons. This could be expected due to increased capture and conversion of growth resources and hence in dry matter accumulation in pure sunflower. Such evidences were results of uniformity in light distribution (*i.e.*, idealism of light uptake and conversion into assimilates) and plant to plant competition, compared to sunflower sown in different intercropping patterns, respectively. Decreases in seed yield/ fed. were 203.74 , 285.35 and 351.44 kg to for S_1, S_2 and S_3 compared to sunflower grown solid, as an average of the two seasons, respectively. These results were in conformity with Shafshak *et al.* (1986), Cox and Jollif (1986 and 1987), Abdel-Gelil (1993) and Khalil (1994) who reported the yield superiority for solid-grown sunflower over the intercropped plants. Concerning intercropping patterns, alleviation in crowding of plants and idealism of plants orientation in S_1 intercropping pattern was associated with lower intra as well as inter-competition compared to those of S_2 and S_3 patterns. That also was associated with greater seed yield/ fed. for S_1 over the other two intercropping patterns.

Irrigation level × cropping pattern interaction affected significantly on 100-seed weight over the two seasons (Table 4). Variations in 100-seed weight between the irrigation levels were significant over all the cropping patterns in both seasons. Compared to I_1 irrigation level, decreases in 100-seed weight were greater at I_3 than at I_2 irrigation treatment in both seasons. Treatment combination I_1 and Psu levels gave the heaviest 100-seed weight, however, the lowest value for such trait was obtained from the combination of I_3 and S_3 level, as compared to the remaining treatment combinations.

In addition, the two factor interaction (Table 4) indicated that seed yield/ fed. was decreased by combined effect of intercropping and water drought, as compared to solid planting under frequent irrigation in both seasons. Consequently, sunflower intercropping with maize in three sides of the two adjacent ridges (S_3) produced the lowest seed yield/ fed., in both seasons as it was subjected to late drought.

In conclusion, data showed the ability of sunflower to tolerate a short period of water deficit and to maintain acceptable behavior of growth aspects, however, greater severity of drought due to skipping an irrigation during reproductive phases caused drastic declines in sunflower growth characters. In addition, intercropping affected growth aspects of sunflower compared to sunflower grown in pure standing. Suitable orientation of sunflower, as maize was inter planted in one ridge (on one side) between sunflower strips (3 ridges per such) produced greater yield compared to the two other intercropping patterns. That gave an indication that the more favorable sunflower response to S_1 cropping pattern resulted in the intercropping advantages. Generally, timing of drought incidence had a negative effect on the yields of both crops especially maize which suffered significant reductions in grain yield when it was subjected to early or late drought periods. On the other hand, sunflower showed considerable tolerance to early drought incidence but seed yield was considerably decreased by late drought periods.

Table (4): Means of 100-seed weight and seed yield/ fed. of sunflower as affected by irrigation supply and cropping pattern interaction during 2005 and 2006 seasons

Treatment	100-seed weight (g)				Seed yield/ fed. (kg)			
	Pm	S_1	S_2	S_3	Pm	S_1	S_2	S_3
Irrigation supply	2005							
I_1	6.30	6.25	6.15	6.21	1176.00	926.70	870.00	840.00
I_2	5.60	5.69	5.59	5.65	1118.30	813.30	798.30	788.00
I_3	5.24	5.24	5.15	5.08	920.00	670.00	653.30	636.70
$L.S.D._{0.05}$	0.28				52.81			
Irrigation supply	2006							
I_1	7.70	7.57	7.13	7.36	1162.30	917.30	863.30	833.30
I_2	7.33	7.30	7.03	7.17	1089.70	806.70	789.70	780.00
I_3	6.71	6.65	6.39	5.04	873.30	683.30	673.30	665.00
$L.S.D._{0.05}$	0.50				90.52			

III- Competition relationships as affected by intercropping pattern and irrigation level

Relative yields of sunflower and maize (Table 5) exhibited similar trends either as $S_1 > S_2 > S_3$ for intercropping patterns at all irrigation levels or as $I_1 > I_2 > I_3$ for irrigation levels under each of the intercropping patterns. As previously reported, relative yields for the two crops were proportionately decreased with increases of plant crowding in S_2 and S_3 patterns and also declined by drought, especially late drought (I_3) occurrence. These results gave an indication that the more competitive relationships of sunflower and maize to water increased with the increase in both population density per intercropping unit and water deficit (especially late drought).

Table (5): The intercropping patterns and irrigation supply effects on land equivalent ratio (LER) obtained from yields of maize and sunflower in 2005 and 2006 seasons

Character	Irrigation system	2005				2006			
		S_1	S_2	S_3	mean	S_1	S_2	S_3	mean
Relative yield of sunflower (RYSu)	I_1	0.782	0.740	0.714	0.745	0.809	0.773	0.747	0.776
	I_2	0.727	0.714	0.705	0.715	0.740	0.725	0.686	0.717
	I_3	0.742	0.730	0.722	0.731	0.762	0.741	0.751	0.751
	mean	0.750	0.728	0.714		0.770	0.746	0.788	
Relative yield of Maize (RYM)	I_1	0.377	0.270	0.254	0.300	0.383	0.323	0.293	0.333
	I_2	0.392	0.280	0.260	0.311	0.379	0.236	0.233	0.283
	I_3	0.394	0.303	0.285	0.327	0.352	0.250	0.266	0.289
	mean	0.388	0.284	0.266		0.371	0.270	0.264	
LER	I_1	1.159	1.010	0.968	1.046	1.192	1.096	1.04	1.109
	I_2	1.119	0.994	0.965	1.026	1.119	0.961	0.929	1.03
	I_3	1.136	1.033	1.007	1.059	1.114	0.991	1.017	1.042
	mean	1.138	1.012	0.980		1.048	1.016	0.992	

However, late drought severely reduced the yield of both crops, since it coincided with the reproductive phase in both crops. Water deficit in that stage affects fertility of pollen grains, in addition to inhibition of fertilization, hence less seeds are formed and that was reflected in lower yields.

The LERs of maize-sunflower mixtures (Table 5) at the intercropping population ratios were greater or lesser than unity when frequent irrigation was applied. However, they were also more than 1 for S1 intercropping pattern (1 ridge with one side maize: 3 ridges of sunflower) over all the irrigation treatments.

Data indicated that the response of sunflower and maize to intercropping pattern depends upon the ratio of each component in the intercropping unit in addition to the type of competitive relationship of the two intercrops. Reduction in the intracompetition for each component in S_1 (in addition to frequent irrigation) increased the resources uptake and utilization for dry mater formation and translocation. However, the mutual inhibition due to increases in the total competition between the two intercrops as a result of increasing plant density and drought severity led to yield reductions (S_3 systems) under I_2 and I_3 irrigation treatments, hence LER value were less than one. That could be explained by the more favourable above ground conditions in S_1 which was reflected in higher equivalent ratios (Willey, 1979 and 1986, Fukai and Trenbath, 1993 and Morris and Garrity, 1993).

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تأثير الاستخدام الاقتصادى للماء على نمو ومحصول عباد الشمس والذرة الشامية المحملين

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أقيمت تجربتات حقليتان بمزرعة كليةالزراعة- جامعة الإسكندرية خلال موسـمى ٢٠٠٥ ، ٢٠٠٦ وذلـك لدراسة استجابة تحميل كلاً من الذرة الشامية وعباد الشمس وكذلك الزراعة النقية لثلاث معاملات رى. وقد تكونت وحدة التحميل من (٤) خطوط (مكررة مرتين) تم زراعة الثلاثة الأولى منها بعباد الشمس بينما زرع الخط الرابع سواء علـى ريشة واحدة (S_1) او ريشتين (S_2) بنباتات الذرة الشامية. بينما كانت معاملة التحميل (S_3) مثل المعاملـة (S_2) مـع إضافة الذرة على الجانب الأخر من الخط الثالث المنزرع بعباد الشمس. وتمثلت معاملات الرى: بالرى المنتظم كل ١٥ يوم من الزراعة (I_1) أو الرى مع تخطى الرية الثانية ٣٥ يوم من الزراعة (I_2) أو الثالثة بعد ٥٠ يوم مـن الزراعـة (I_3).

وكانت أهم النتائج المتحصل عليها:

١- أ. أدى الرى المتكرر كل ١٥ يوم فى حالة الرى المنتظم (I_1) إلى زيادة معنوية فى كلا من طول النبـات، ووزن ١٠٠ حبة ومحصول الفدان بالأردب ونسبة النباتات الخصبة لنباتات الذرة عنه فى حالات الرى الأخرى.

ب. أعطت الذرة الشامية المنزرعة منفردة (يليها الذرة فى معاملة التحميل S_1) أثقل وزن مائة حبة وأعلى إنتاجا للفدان من الحبوب بالأردب.

٢- أ. زادت إنتاجية النبات الفردى وإنتاجية الفدان من البذور وكذلك وزن المائة بذرة لعباد الشمس فى حالـة الـرى المنتظم عنها فى حالة I_2 (تخطى الرية الثانية).

ب. تفوق وزن المائة بذرة وإنتاجية الفدان لعباد الشمس فى معاملة التحميل S_1 عنها فى كلتا المعاملتين S_2 ، S_3 تحت معاملتى الرى I_2 ، I_3

٣- بلغت قيمة مكافئ استغلال الأرض أقصاها (١,١٦٥) عندما تم تحميل الذرة وعباد الشمس فـى المعاملـة S_1 مـع إجراء الرى المنتظم مقارنة بالمعاملتين S_2 ، S_3 تحت معاملات الرى الأخرى.