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QUIXOTIC COUPLING BETWEEN IRRIGATION SYSTEM AND MAIZE-COWPEA INTERCROPPING FOR WEED SUPPRESSION AND WATER PRESERVATION

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ABSTRACT

Producing more food from less applied water is vital, particularly in arid and semi-arid regions which suffer from water scarcity. A study was conducted at the Research and Experimental Station, Faculty of Agriculture, Ain Shams University at Shalakan, Kalubia Governorate, Egypt, to evaluate the effect of two irrigation systems (trickle and modified furrow irrigation) and five maize (M)-cowpea (C) intercropping patterns (sole M-30, sole M-15, ridge side M: ridge side C, ridge M: ridge C and sole C) on weeds and maize (*Zea mays* L.) attributes, and water use efficiency (WUE). Trickle irrigation surpassed the modified furrow by 6.0 and 36.0% in kernels number row^{-1} and maize grain yield, respectively. The ridge M: ridge C intercrop was the most effective action for diminishing weed biomass. Intercropping patterns were substantially leveled with sole M-30 in maize grain yield. Ridge M: ridge C under two irrigation systems, along with Ridge side M: Ridge side C, and sole M-30 under trickle irrigation were the effective combinations for lowering weed biomass. Each intercropping pattern under trickle irrigation, surpassed its counterpart under modified furrow for promoting kernels number row^{-1}, 100 kernels weight and grain yield of maize. The applied water with trickle irrigation was lower than that of modified furrow irrigation, saving about 8.2% of irrigation water. Also, trickle irrigation achieved higher WUE (45.5%) over the modified furrow. Land equivalent ratio illustrated that ridge M: ridge C and ridge side M: ridge side C patterns saved 25 and 9% of land, respectively. Aggressivity showed that maize was the dominant crop, while cowpea was the dominated one.

Key Words: Furrow irrigation, water use efficiency, *Zea mays*

RÉSUMÉ

Produire plus de nourriture par moins d'eau appliquée est une interrogation vitale, particulièrement dans les régions arides et semi-arides qui souffrent de pénurie d'eau. Une étude a été menée à la station de recherche et expérimentale, Faculté d'agriculture, Université d'Ain Shams au Shalakan, Kalubia gouvernorat, Egypte, pour évaluer l'effet de deux systèmes d'irrigation (irrigation de filet et sillon modifié) et cinq systèmes de cultures intercalaires maïs (M)-haricot (C) (M-30 seul, M-15 seul, côté de la ligne de M: côté de la ligne de C, ligne de M: ligne de C et C seul) sur les mauvaises herbes, le productivité et des attributs de maïs, l'utilisation efficace de l'eau et les indications de la compétition. Irrigation goutte à goutte dépassé sillon modifié un de 6.0 et 36.0% pour les amandes de grains rangée^{-1} et rendement en grains de maïs, respectivement. Le système de cultures intercalaires qui ligne de M: ligne de C était le modèle le plus efficace pour diminuer la biomasse des adventices. Des cultures intercalaires ont été sensiblement nivelées avec M-30 semelle en termes de rendement de grains du maïs. Le système de cultures intercalaires qui ligne de M: ligne de C avec deux systèmes d'irrigation en compagnie de côté de la ligne de M: côté de la ligne de C et M-30 seul avec le système irrigation goutte à goutte sont les combinaisons efficaces pour abaisser la biomasse des adventices. Chaque système de cultures intercalaires en compagnie le système d'irrigation goutte à goutte a dépassé son homologue avec le système d'irrigation sillon modifié un pour la promotion des amandes de grains rangée^{-1}, poids de 100 grains et le rendement en grains de maïs. L'eau appliquée avec irrigation goutte à goutte est inférieur à celui de l'irrigation de sillon modifié, une économie d'environ 8.2% de l'eau d'irrigation. Également, l'irrigation goutte à goutte atteint l'utilisation efficace de l'eau élevée (45.5%) au cours sillon modifié un. Rapport équivalent des terres illustré cette ligne de M: ligne d' C et côté de la ligne de M: côté de la ligne de C enregistrés 25% et 9% des terres, respectivement. En outre, l'agressivité a exposé que le maïs était la culture dominante, tandis que l'haricot est le dominé.

Mots Clés: irrigation de filet, l'utilisation efficace de l'eau, *Zea mays*

INTRODUCTION

Weeds cause appreciable losses in crop production and deplete nutrients in arable land. Weeds interfere with crops, causing serious impacts through competition and allelopathy. A previous study showed that weeds associated with maize plants removed 74.7-306.1, 90-322.2 and 100.8-317.7% of N, P and K, respectively, in weedy check plots more than in weeded treatments (El-Metwally *et al.*, 2009). The presence of weeds in crops causes yield losses due to competition and allelopathic effects. In Egypt, the reduction in maize yield due to weed competition is between 34 and 90% (Abouziena *et al.*, 2007; Abd EL-Samad *et al.* 2012; Saudy, 2013). As a result, development of effective and economical weed management methods is the major objective for maximising crop productivity.

While irrigation systems are usually designed and managed with a crop in mind, the impact of irrigation on weed growth is an important component of any modern production system. However, recent irrigation systems have not been used extensively for field crop production, especially in small-scale farms, because of high initial costs and the uncertainty about these systems' longevity as well. Whereas with increasing concerns about water conservation and water quality protection, particularly, with shrinking available water resources (Kang *et al.*, 1996), irrigators are looking for more efficient irrigation systems. Also, increasing water use efficiency (WUE) associated with crop production is a substantial target for arid and semi-arid areas. Water use efficiency by a crop can be improved by applying appropriate water management practices and integrated land use, such as selection of novel irrigation technologies and intercropping patterns. Efficient use of water by modern irrigation systems is increasingly important in arid and semi-arid regions, with limited water resources (El-Hendawy *et al.*, 2008). In this respect, trickle irrigation is often used in tandem with herbicides. Therefore, the weed control benefits of trickle irrigation are due to the ability to precisely manage and locate water where it will benefit crops most, while reducing availability to weeds. In furrow irrigation systems, instead of flooding entire fields, only furrows between beds are wetted, allowing water to seep into growing beds through capillary action. As would be expected, weed pressure in the irrigated furrows between rows is generally higher than within the rows themselves (Grattan *et al.*, 1988).

Intercropping is a common system for small-scale farmers to improve income and food production per unit area, especially in the developing world. The main reasons for mixing crops are to maximise land use and reduce risk of crop failure (Zimdahl, 2007). In organically managed farms, growing crops in mixtures has become an important element (Lithourgidis *et al.*, 2011). Herein, cereal-legume intercropping for both green fodder and seeds is valued in sustainable agriculture (Uzun *et al.*, 2005; Andersen *et al.*, 2007). One of the explanations for this improvement is that the cereal crop (such as maize) canopy is not able to intercept all the solar radiation during the growth period. Hence, the remaining radiation is captured by the crop growing under the maize, resulting in better use of this resource (Prasad and Brook, 2005) and blocking the light to reach the undesirable plants. Chen *et al.* (2004) found that intercropping maize with legumes was beneficial in yield increment due to improved soil fertility, less competition for water and nutrients between maize and weeds as the latter are suppressed by the leguminous crop. Intercropping maize and legumes considerably reduces weed density compared with the monocropping maize by decreasing in available light for weeds (Dimitrios *et al.*, 2010). Intercropping as a cultural weed management practice has been associated with greater yields and weed control compared with sole crops (Szumigalski and Van Acker, 2005; Zimdahl, 2007). Moreover, the cultural weed control methods, such as intercropping, are considered the best, particularly under sustainable agricultures, where chemical weed control methods are not allowed. The objective of this study was to assess the effect of different intercropping patterns of maize-cowpea on weed suppression and crop productivity under trickle and modified furrow irrigation systems.

MATERIALS AND METHODS

Experimental site. A field experiment was conducted during 2011 and 2012 growing seasons at the Research and Experimental Station (30°192 N, 31°162 E), Faculty of Agriculture, Ain Shams University at Shalakan, Kalubia Governorate, Egypt. The soil represents the old alluvial soil of the Nile Delta clay loam, with approximately 1.15% organic matter, 0.14% total nitrogen and pH of 7.52 (Saudy, 2013). The preceding crop was wheat (*Triticum aestivum* L.) in both seasons.

Experimental procedures. The experiment was established within split plots in a randomised complete block design, using three replicates, where irrigation systems were arranged in the main plots and intercropping patterns were allocated in the sub-plots.

Each of trickle irrigation and modified furrow irrigation (using gated pipes) plots occupied 35.7 m by 42 m. Either of the tested irrigation system was installed in individual five strips, each representing one of the intercropping patterns. The strip was divided by plastic strips into three sub-plots (experimental units). The experimental unit was 88.2 m^2, involving 9 ridges (14 m length and 0.7 m apart with 15 cm depth). In trickle irrigation, a drip line (GR) from polyethylene was used with 16 mm diameter, and dripper discharge was 4 L h^{-1} at 1.0 bar operating pressure. Standard drippers were spaced 50 cm apart along 42 m lateral. The pipes were connected with the main line through 2" Ball valve to joint submarine line 50 mm diameter.

Modified furrow irrigation was designed using gated pipes equipped with 6" aluminum pipes, 6 meter long with holes at 70 cm spacing. The pipes were connected with the main line, through 3" Ball valve (flow regulator) to joint flange 6" to the end for connecting the gated pipe line. Every furrow was irrigated by a single lateral line in the trickle irrigation plots, and by one gate in the modified furrow.

The sowing dates were 3 June 2011 and 1 June 2012. Maize grains (cv. Single cross 10) and cowpea seeds (cv. Balady) were drilled simultaneously, each at a rate of 24 kg ha^{-1}. At 17 days after sowing (DAS), plants were hoed once and thinned to secure one plant hill^{-1} for maize and two plants hill^{-1} for cowpea.

Maize (M)-cowpea (C) intercropping patterns are illustrated in Figure 1 as follow:

(i) sole M-30 (planting maize on one side of the ridge with 30 cm-hill distance and one plant hill^{-1}, recommended practice);

(ii) sole M-15 (planting maize on one side of the ridge with 15 cm-hill distance and one plant hill^{-1} with escaping a ridge between each two-sown ridges, ridge maize: ridge non-sown);

(iii) ridge side M: ridge side C (intercrop maize with cowpea on same ridge, where maize was planted on one side of the ridge with 30 cm-hill distance and one plant hill^{-1}, while cowpea was planted on the other side of the ridge);

(iv) ridge M: ridge C (intercrop maize with cowpea in alternate ridges, where maize was planted on one side of a ridge with 15 cm-hill distance and one plant hill^{-1}, while cowpea was planted on the two sides of the alternated ridge); and

(v) sole C (planting cowpea on the two sides of the ridge).

Under sole or intercropping patterns, the same plant density of maize was maintained (about 47,620 plants ha^{-1}). Also, in all cases when cowpea

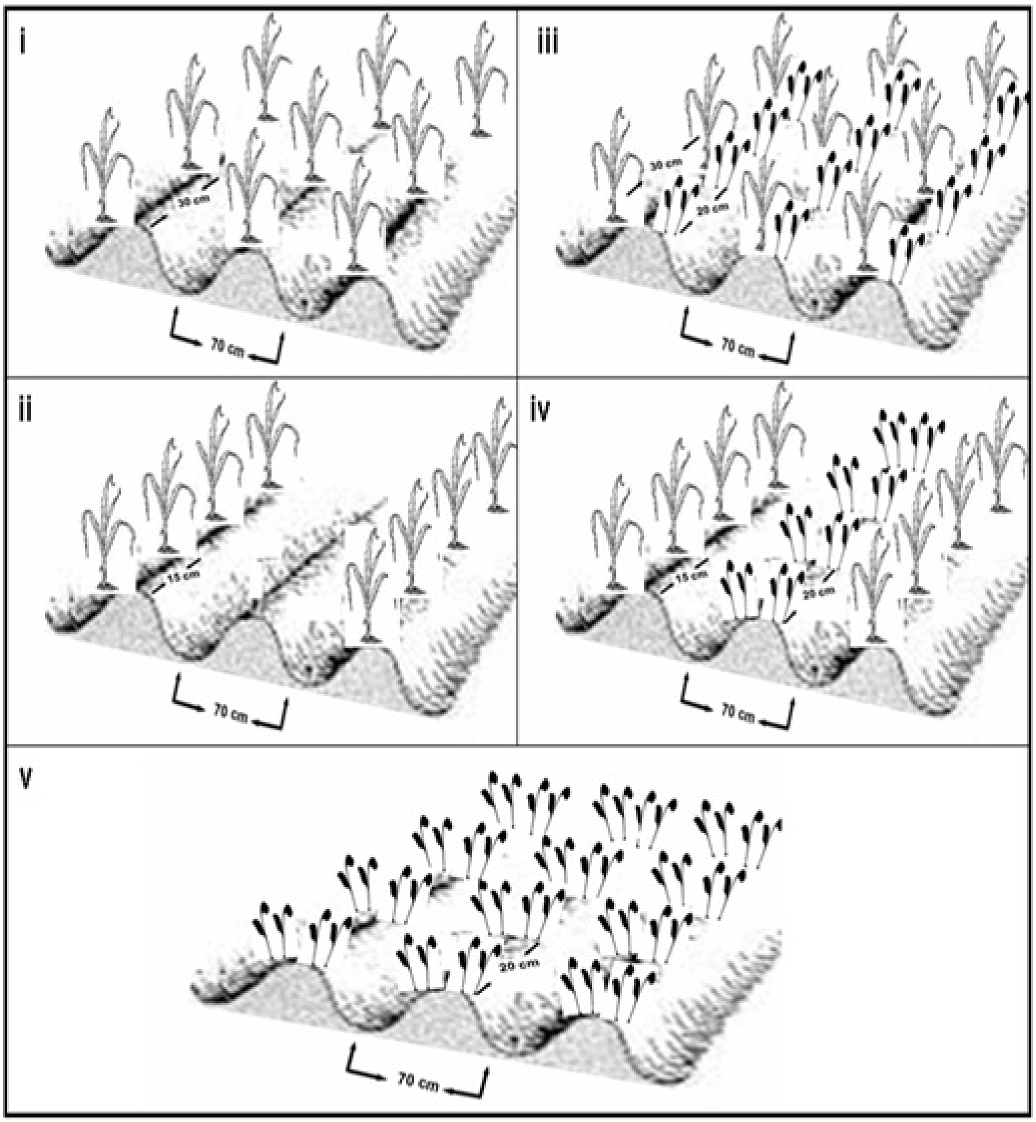

Figure 1. Illustration of different patterns of maize (M)-cowpea (C) intercrops (i, sole M-30; ii, sole M-15; iii, ridge side M: ridge side C; iv, ridge M: ridge C and v, sole C).

was involved, its seeds were sown with 20 cm-hill distance and two plants hill^{-1}.

Nitrogen fertiliser at a rate of 285 kg N ha^{-1} was applied to maize plants in the form of urea (46.5% N), in two half portions, at 20 and 35 DAS. Cowpea plants were not supplied with N fertiliser. Irrigation of maize was ended at three weeks before harvest. All other recommended cultural practices, such as phosphorus fertiliser and insect control were adopted throughout the two seasons.

Sampling and assessments

Weeds. From two fixed quadrats (0.5 m^2) in each plot, weeds were pulled out manually at 80 DAS. Weed samples were bulked and oven-dried for 24 hours at 80 °C to a constant mass to estimate total weed biomass expressed in dry weight.

Cowpea. At 70 DAS, cowpea plants were harvested and a sample of ten plants was chosen from each plot to measure forage yield ha^{-1}.

Maize. Total chlorophyll content (SPAD value) in the fourth leaf of maize was determined at 80 DAS using chlorophyll meter (SPAD–502) according to Soil Plant Analysis Department Section, Minolta Camera Co., Osaka, Japan as reported by Minolta (1989). At harvest (115 DAS), ten plants were randomly chosen from each plot to estimate ear length, kernels number ear^{-1} and weight of 100 kernels. Finally, whole plants of each plot were harvested to estimate maize grain yield ha^{-1}.

Irrigation requirement. Irrigation water requirement for maize was calculated using the meteorological data at Shalakan Station as follows:

(i) Crop evapotranspiration was determined according to Doorenbos *et al.* (1977):

$$ET_c = ET_o \times K_c$$

Where:

ET_c = Crop evapotranspiration (mm day^{-1});
ET_o = Reference evapotranspiration (mm day^{-1}) and
K_c = Crop coefficient.

(ii) Applied irrigation water for maize crop was calculated according to (Keller and Bliesner, 1990):

$$IR = ET_c \times LR \times 4.2 / E_a$$

Where:

IR = Irrigation requirement (m^3 ha^{-1});
LR = Leaching requirement (%),(15%) and
E_a = Water application efficiency, (90% for trickle irrigation and 80% for modified furrow).

Water use efficiency (WUE). Water use efficiency was computed to evaluate treatments for maximum yield per unit of water applied in the field. Maize grains moisture content was about 15.5% and the WUE was expressed as maize grain yield (kg) per applied water (m^3) throughout the growing season, according to Pene and Edi (1996).

Competition indices. Two competition indices i.e. land equivalent ratio (LER) and Aggressivity (A) of maize (A_{maize}) relative to cowpea (A_{cowpea}) were calculated according to Willey and Osiru (1972) and McGilchrist and Trenbath (1971), respectively, using the following equations:

$$LER = (Y_{1\,(IC)} / Y_{1\,(SC)}) + (Y_{2\,(IC)} / Y_{2\,(SC)})$$

$$A = ½\,((Y_{1\,(IC)} / Y_{1\,(SC)}) - (Y_{2\,(IC)} / Y_{2\,(SC)})$$

Where:

Y_1 and Y_2 refer to the yields of two component crops grown either as sole $_{(SC)}$ or as intercropped $_{(IC)}$.

Statistical analysis. Data were subjected to analysis of variance (ANOVA) according to Gomez and Gomez (1984), using MSTATC software. The combined analysis of variance for the data of the two seasons was performed after testing the error homogeneity. The differences among means were tested using the least significant difference (LSD) method at 0.05% probability level.

RESULTS AND DISCUSSION

During the study, the dominant annual broad leaf weeds were common purslane (*Portulaca oleracea*, L.) and malta jute (*Chorchorus olitorius* L.); while the major grasses were jungle rice (*Echinochloa colonum* (L.) Link.) and crowfoot grass (*Dactyloctenium aegyptium* (L.) P. Beauv.).

Weeds, maize yield and its attributes

Effect of irrigation system. Statistical analysis revealed that kernels number row^{-1} and grain yield of maize were markedly affected by irrigation system; while weed biomass, total chlorophyll content (SPAD value) of maize leaf, ear length and weight of 100 kernels were not significantly (P>0.05) different (Table 1). Trickle irrigation surpassed modified furrow irrigation by 6.0 and 36.0% in kernels number row^{-1} and grain yield, respectively. Better maize grain yield with trickle

TABLE 1. Weed biomass, SPAD value and maize yield and yield attributes as influenced by irrigation system and maize-cowpea intercropping pattern in Egypt

Variable	Weed biomass (g m^{-2})	SPAD value	Ear length (cm)	Kernels number row^{-1}	Weight of 100 kernels (g)	Grain yield (t ha^{-1})
Irrigation system						
Trickle	32.27	51.21	19.43	44.55	26.29	11.34
Modified furrow	68.81	47.55	18.87	42.01	22.98	8.34
$LSD_{(0.05)}$	NS	NS	NS	2.25	NS	2.13
Intercropping pattern						
Sole M-30	52.30	51.10	19.51	43.83	25.63	10.20
Sole M-15	82.88	48.50	19.10	43.01	24.65	9.84
Ridge side M: ridge side C	43.32	49.41	18.93	43.08	23.59	9.02
Ridge M: ridge C	23.67	48.72	19.05	43.21	24.67	10.30
$LSD_{(0.05)}$	56.82	NS	NS	NS	1.71	NS

M: maize, C: cowpea, NS: not significant

irrigation may be due to the fact that such system can supply limited quantities of water to an immediate area surrounding the crop root zone with balanced soil moisture in the active root zone, in addition to lowering water leaching. Decreasing the amount of water that leaches beneath the root zone in trickle irrigated maize caused improvement in yield (Payero *et al.*, 2008; El- Hendawy and Schmidhalter, 2010).

Effect of intercropping pattern. As shown in Table 1, only weed biomass and weight of 100 kernels were significantly influenced by the intercropping patterns of maize-cowpea. Ridge M: ridge C intercrop was the most effective one for diminishing weed biomass, but statistically leveled with ridge side M: ridge side C and sole M-30. Sole M-30, along with sole M-15 and ridge M: ridge C, recorded the maximum values of weight of 100 kernels. It is interesting to observe that intercropping patterns were similar to sole M-30 in grain yield.

The efficiency of maize-cowpea in intercropping pattern of ridge M: ridge C for reducing weed biomass may be ascribed to more solar radiation intercepted by the intercropping system canopy, depriving weeds from receiving sufficient light. Intercropping maize and legumes considerably reduces the weed density compared with the monocropping maize by decreasing available light for weeds (Dimitrios *et al.*, 2010). Altier and Liebman (1986) pointed out that intercropping has a potential to suppress weeds and it offers the possibility of capturing a greater share of available resources than sole crop. Intercropping increases light interception by the weakly competitive component and can, therefore, shorten the critical period for weed control and reduces growth and fecundity of late-emerging weeds (Baumann *et al.*, 2000). Moreover, growing mixtures of peas with cereals helps to reduce the level of weed-infestation (Corre-Hellou *et al.*, 2011). This indicates high twining between maize and cowpea for making use of land. Hauggaard-Nielsen *et al.* (2001) found that there was increased efficiency of intercropping for utilisation of environmental resources for plant growth; and better competitive ability towards weeds as compared to sole crops. The apparent increased competitiveness of intercropping systems makes them potentially useful for adoption into low in-put farming systems in which options for chemical weed control are reduced or non-existent (Szumigalski and Van Acker, 2005).

The increment in weight of 100 grains of maize recorded when maize was grown alone or intercropped with cowpea in ridge M: ridge C pattern (Table 1) might be due to the less competition imposed by either maize plants itself or by cowpea, i.e., intra- and inter-specific competition. This explanation was confirmed when maize yields were markedly similar either in sole or in intercropping. Moreover, such results display that maize and cowpea are compatible crops in intercropping of ridge M: ridge C in which cowpea had no adverse effect on maize yield. There was probably better use of nutrients and water by intercropping components (Willey, 1990). Silwana and Lucas (2002) reported that different crop species in mixtures increased the capture of growth limiting resources. Moreover, less weed infestation was obtained with ridge M: ridge C resulting in low inter-specific competition of the associated weeds against maize plants.

Effect of irrigation system x intercropping pattern. All studied traits significantly responded to the interaction between irrigation system x intercropping pattern, except ear length (Table 2). Ridge M: ridge C under the two applied irrigation systems along with ridge side M: ridge side C and sole M-30 each under trickle irrigation, were the effective combinations for lowering weed biomass. Sole M-30 x trickle irrigation produced the highest SPAD value which was equal to sole M-30 x modified furrow irrigation as well as other intercropping patterns under trickle irrigation, The lowest significant values of kernels number row^{-1} and 100-kernel weight were recorded with sole-M 15 or ridge side M: ridge side C under modified furrow irrigation. In addition, all intercropping patterns under trickle irrigation statistically leveled in maize grain yield and exceeded their correspondences under modified furrow irrigation (Table 2).

Applied water and WUE. The calculated amount of water (Table 3) for sole M-30 based on crop coefficient (K_c) and reference evapotranspiration (ET_o) illustrates that trickle irrigation saved about 8.2% of applied irrigation water compared to the modified furrow. Within growth stages of maize, plants consumed the maximum water in mid-season stage which represented more than 60% of total applied irrigation water.

Mean values of applied water and WUE are presented in Table 4. Applied water with trickle irrigation was lower than modified furrow irrigation. Also, trickle irrigation achieved higher WUE, reaching 45.5% over modified furrow. Such results show that highly efficient application of water in trickle irrigation system accompanied with less leaching and evaporation because of the limited surface area wetted. In addition, trickle irrigation achieves uniform distribution of moisture in the effective root zone. Trickle irrigation, if properly managed, is highly efficient with up to 95% application efficiencies (Rogers *et al.*, 1997). Hassanli *et al.* (2009) compared

TABLE 2. Weed biomass, SPAD value and maize yield and yield attributes as influenced by the interaction between irrigation system and maize-cowpea intercropping pattern in Egypt

Variable		Weed biomass (g m^{-2})	SPAD value	Ear length (cm)	Kernels number row^{-1}	Weight of 100 kernels (g)	Grain yield (t ha^{-1})
Trickle	Sole M-30	22.47	53.22	19.98	45.23	26.56	12.19
	Sole M-15	72.35	50.57	19.43	44.93	26.46	11.32
	Ridge side M: ridge side C	17.55	50.45	19.33	44.63	26.46	10.55
	Ridge M: ridge C	16.72	51.00	18.98	43.43	25.66	11.30
Modified furrow	Sole M-30	82.12	48.97	19.05	42.43	24.70	8.22
	Sole M-15	93.42	46.42	18.76	41.10	22.83	8.36
	Ridge side M: ridge side C	69.10	48.37	18.53	41.53	20.71	7.50
	Ridge M: ridge C	30.62	46.45	19.13	43.00	26.68	9.29
$LSD_{(0.05)}$		50.22	4.41	NS	3.89	2.42	1.83

M: maize, C: cowpea, NS: not significant

TABLE 3. Calculated irrigation water amount of trickle and modified furrow irrigation systems for sole maize crop at different stages of growth based on crop coefficient (K_c) and reference evapotranspiration (ET_o) as a combined data of 2011 and 2012 seasons in Egypt

Growth stage	Month	K_c	ET_o (mm day^{-1})	Length (days)	Calculated water amount of irrigation system (m^3 ha^{-1})			
					Day		Stage	
					Trickle	Modified furrow	Trickle	Modified furrow
Initial	June	0.4	8.3	10			950	950
Development	June	0.8	8.3	20			595	595
Mid-season	July	1.2	8.0	31	51.2	57.6	3777	4250
Late	August	0.6	7.3	10	23.6	26.5	560	630
		0.4	7.3	11	13.7	15.4	358	361
Sum							6240	6796

TABLE 4. Water amount and WUE of trickle and modified furrow irrigation under maize-cowpea intercrop patterns in Egypt

Variable		Water amount (m^3 ha^{-1})		Mean	WUE(kg m^{-3})		Mean
		Trickle	Modified furrow		Trickle	Modified furrow	
Sole M-30		6240	6796	6518	1.95	1.20	1.58
Sole M-15		3120	3398	3259	3.63	2.46	3.05
Ridge side M: ridge side C		6240	6796	6518	1.69	1.10	1.40
Ridge M: ridge C		3120	3398	3259	3.62	2.73	3.18
Mean		4680	5097		2.72	1.87	
$LSD_{(0.05)}$	Irrigation	-	-		0.63		
	Intercropping	-	-		0.41		
	Interaction	-	-		0.58		

M: maize, C: cowpea, WUE: water use efficiency

surface trickle and furrow irrigations for maize and reported significant differences in water use efficiency, which was higher for surface trickle than furrow irrigation.

Although, sole M-15 or ridge M: ridge C received the lowest amount of irrigation water (Table 4), it recorded the highest value of WUE. Moreover, under trickle irrigation, sole M-15 or ridge M: ridge C gained minimal amount of irrigation water, but produced the maximum WUE. Average WUE was 4.55 kg m^{-3} from alfalfa and maize mixture fields, 60% higher than that from the fields where only corn or alfalfa was grown (Lei *et al.*, 2003).

Cowpea forage yield. Forage yield of cowpea markedly varied with irrigation system, intercropping patterns and their interaction (Table 5). Trickle irrigation showed 52.9% increment in cowpea forage yield more than modified furrow irrigation. Also, sole cowpea achieved the highest forage yield, surpassing maize-cowpea intercropping in ridge side M: ridge side C and ridge M: ridge C by 4.3 and 2.6 times, respectively. Low plant population per unit area leads to low productivity. A similar result was obtained by Takim (2012), who worked on maize-cowpea intercropping in Nigeria. Moreover, cowpea forage yield produced from ridge M: ridge C was similar to its counterpart from ridge side M: ridge side C under both irrigation systems, implying that maize plants have no adverse effect on cowpea growth when they intercropped together in different patterns. This suggests compatibility of maize and cowpea in intercropping systems.

Competition indices. The effect of intercropping patterns on competitive relationships, i.e. land equivalent ratio (LER) and aggressivity (A) of maize (A_{maize}) and cowpea (A_{cowpea}), are showed in Figure 2. All intercropping patterns exhibited LER greater than unity. When maize and cowpea were intercropped in ridge M: ridge C or ridge side M: ridge side C patterns, LER values reached 1.25 and 1.09, respectively. This result refers to saving, 25 and 9% of land by applying such two intercropping patterns, respectively. Gaining LER

TABLE 5. Cowpea forage yield (t ha^{-1}) of trickle and modified furrow irrigation systems under maize-cowpea intercrops in Egypt

Variable		Trickle irrigation		Modified furrow irrigation	Mean
Sole C		9.47		5.50	7.49
Ridge side M: ridge side C		2.72		2.36	2.54
Ridge M: ridge C		2.92		2.06	2.53
Mean		5.06		3.31	
$LSD_{(0.05)}$	Irrigation		1.36		
	Intercropping		1.02		
	Interaction		1.44		

M: maize, C: cowpea

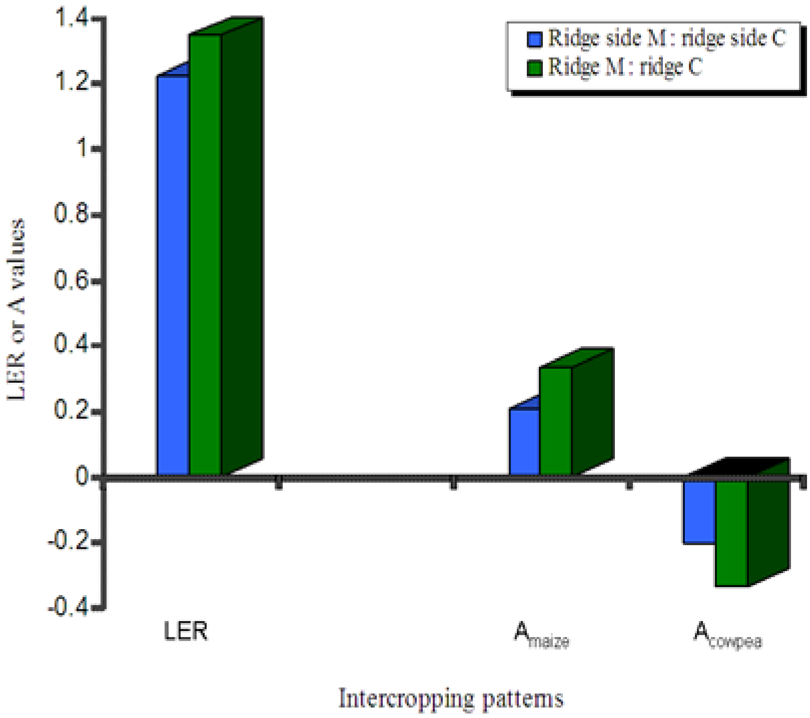

Figure 2. Land equivalent ratio (LER) and Aggressivity (A) of maize (M), A_{maize}, and cowpea (C), A_{cowpea}, in ridge side M: ridge side C and ridge M: ridge C intercrops in Egypt.

greater than unity by either intercropping pattern indicates greater biological efficiency of maize/ cowpea intercropping. This suggests a higher degree of efficiency and compatibility of the maize/cowpea intercrop system, particularly with these systems which provided the maximum advantage. Increasing LER values when maize and cowpea were intercropped is in accordance with that obtained by Dahmardeh *et al.* (2009) who worked on maize and cowpea intercrops in Iran. Because of the spatial and temporal differences in the demand of the growth factors and different crop species, intercropped plants could better utilise nutrients from soils compared with sole cropped plants (Zheng *et al.*, 2003). Hauggaard-Nielsen *et al.* (2006) and Lupwayi and Kennedy (2007) concluded that yield advantage from intercropping is attributed to mutual complementary effect of component crops, such as better use of available resources like soil N, moisture and biological nitrogen fixation. The mixture of nitrogen fixing and non-fixing crops give greater productivity than monocropping (Seran and Brintha, 2009).

Figure 2 shows that A_{maize} was positive and A_{cowpea} was negative, indicating that maize was the dominant crop, while cowpea was the dominated one. The same trend was noticed by Dhima *et al.* (2007) and Takim (2012) and inferred that maize was the dominant species.

CONCLUSION

It could be concluded that rigorous weed management through irrigation and intercropping system can be an eco-friendly approach for reducing weed problems without chemical usage. Intercropping maize-cowpea in ridge M: ridge C is the promising pattern for weed depression, high maize grain yield, maximum water and land use utilisation and obtaining additional cowpea forage yield. This is of importance for animal feeding during early-summer, especially in semi-arid areas, although it required some water amount. If there is a crucial need for cowpea yield, ridge M: ridge C is recommended. Otherwise, the importance of sole M-15 is more appreciable, particularly in regions suffering severe water deficit, where maize was planted on alternative ridges saving 50% of applied water with no yield losses.

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