Sustainable intensive cropping to reduce irrigation-induced erosion: Intercropping systems under surface irrigation practice

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Abstract

The objective of this study was to compare between the effects of two production packages on the applied irrigation amount, crop yield and soil organic matter contents as indicators of the existence soil loss under surface irrigation. These packages were: farmer practices (FP, resulted in application of large amount of irrigation water), which applied to wheat and sunflower and improved management practices (IMP, reduced the applied irrigation water), where pea and cowpea intercropped with wheat and sunflower, respectively. The results indicated that using the IMP resulted in irrigation water saving by 23 and 22% and yield increase by 13 and 14% for wheat monoculture and intercropped, respectively compared to the FP. Similarly, the water saving for sole and intercropped sunflower was 21 and 20% and yield increase was 11 and 17%, respectively when IMP was implemented. Soil organic content was increased after the fourth growing season by 11%, when intercropping systems were implemented. Land equivalent ratio values were 1.37 and 1.53 for wheat and sunflower intercropping systems averaged over the two seasons. In conclusion, using raised beds and intercropping systems in IMP package with reduced applied water can be useful in reducing soil loss under surface irrigation practice.

Keywords: Raised beds cultivation, intercropping pea with wheat, intercropping cowpea with sunflower, soil organic matter content

INTRODUCTION

Sustainable crop intensification entails increasing the number of crops grown per year on the same land, thereby raising yield per unit of area and time (Krupnik *et al.*, 2015). Sustainable intensification aims to augment land productivity by increasing resource use efficiency while minimizing environmental destructions (Pretty and Bharucha, 2014). Soil erosion has been identified by the European Commission as one of the most important factors of environmental degradation (Jones *et al.*, 2012). Moreover, one of the greatest global threats to sustainable high agricultural productivity is irrigation-induced erosion (Sojka *et al.*, 2007).The most productive irrigated soils are typically fragile arid soils with thin, easily eroded "A" horizons, where erosion of these horizons can reduce crop yield potential as much as 50% (Carter *et al.*, 1993).Water management practices, such as monitoring crop water use, increasing application efficiency, in addition to timing considerations based on crop needs, soil water storage capacity, as well as water application method and intensity can play a major role in reducing soil erosion under furrow irrigation (Sojka *et al.,* 2007). Improvements in these practices can reduce water application and runoff amounts, thereby reducing erosion (Trout et *al.,* 1994).

Intercropping systems can add another dimension to sustainable crop intensification. Intercropping is a planting system with cultivation of two crops (main and secondary crops) resulting in increased light interception, root contact with more soil, microbial activity and deterrent to pests and weeds (Altieri, 1999). Furthermore, the most common reason for the adoption of intercropping systems is yield advantage, which is due to greater resource depletion by intercrops than monocultures (Hauggaard-Nielsen *et al.*, 2006). The efficiency of intercropping depends directly on proper management of production factors such as spatial arrangement of crops and planting density to reduce the competition for resources and increase the efficiency of the system (Porto *et al.*, 2011). These factors, when properly managed, can bring ecological and economic benefits as a result of increasing production when compared to monoculture or chemical, physical and biological soil enrichment (Batista *et al.*, 2016).

Furthermore, intercropping with legumes can be an excellent practice for controlling soil erosion and sustaining crop production (Dwivedi *et al.,* 2015). Deep roots of legume crops penetrate far into the soil and use moisture and nutrients from deeper soil layers, whereas shallow roots of cereal crops fix the soil at the surface and thereby help to reduce erosion (Machado, 2009). Growing legumes with cereals resulted in N_2 fixation in the soil and consequently organic content increase (Hauggaard-Nielsen *et al.*, 2006). Examples include faba bean intercropped with wheat (Abdel-Wahab and El Manzlawy, 2016), soybean intercropped with sorghum (Arshad and Ranamukhaarachchi, 2012), and cowpea intercropped with maize (Hamd-Alla *et al.*, 2014). Reduced runoff and soil loss were observed in intercrops.

Sorghum intercropped with cowpea system reduced runoff by 20-30% compared to sorghum sole planting and by 45-55% compared to cowpea monoculture. Additionally, soil loss was reduced with intercropping by more than 50%, compared with sorghum and cowpea monocultures (Lithourgidis, 2011). Some legume crops are better in maintaining crop cover than the others. Kariaga (2004) compared between cowpea intercropped with maize system and bean intercropped with maize system regarding soil erosion and found that cowpea performed as best cover crop as bean in reducing soil erosion.

Furrow irrigation is a common practice in Egypt, where there is no specific pattern for the furrow length or width, depth of tillage, choice of direction of flow of water, frequency of water application and cropping pattern. The farms are irregularly subdivided into basins with different sizes with short farrows that can be filled up quickly during irrigation to shorten the duration of watering. Consequently, a lot of soil might have been lost during furrow irrigation in Egypt, which has a great negative impact on the productivity of cultivated crops. It was reported that changing cultivation method from furrows to raised beds can reduce the amount of applied water to irrigate a crop (Abouelenein *et al.*, 2010), thus it can reduce soil erosion. Moreover, it was reported that implementing intercropping systems containing legumes and cereals crops can reduce soil erodibility (Lithourgidis, 2011).

The objective of this study is to compare between the effects of two production packages on the applied irrigation amount, crop yield and soil organic matter contents as indicators of the existence of soil loss under surface irrigation.

MATERIALS AND METHODS

Two field experiments were conducted in El-Minia governorate (latitude= 28.05°, longitude= 30.44° and elevation above sea level= 40.0 m), Middle Egypt in 2015/16 and 2016/17 winter and summer growing seasons to compare the effect of farmer practices in monoculture cultivation of wheat and sunflower and improved management practices including intercropping systems for wheat and sunflower. The comparison was done on the basis of applied irrigation water, final yield of both crops and the soil organic matter after the harvest of the fourth growing season. These measurements are indicators of the existence of soil loss. The treatments can be defined as two production packages as followed:

Farmer practices

The common farmer practices were mimicked, which include low land leveling, furrow cultivation, application of large amount of irrigation water as a result of using fixed time interval, regardless of crop needs. These practices by the farmer usually result in soil loss. This production package was applied to wheat in the winter season and to sunflower in the summer season.

Wheat (Sakha94 cultivar) was sown on the 17th of November in both seasons with 100% of its planting density. The cultivation was done on furrows in three rows. Irrigation was applied every 21 days. In the summer season, sunflower (Sakha53 cultivar) was sown on the 15th of June in one row on 60 cm furrow width. Irrigation was applied every 15 days.

Improved management practices

The improved management practices were adopted to correct practices by the farmer and to reduce soil loss. The package included implementing precise land leveling to save 5% on the applied irrigation water (Bahnas and Bondok, 2010), cultivation on raised beds to reduce the amount of applied water by 15-20% (Abouelenein *et al.*, 2009) and irrigation scheduling to apply water according to crop needs (Taha, 2012). This package was applied to winter and summer intercropping systems, where pea was intercropped with wheat and cowpea was intercropped with sunflower. The entire practice were done to reduces soil loss and improve soil fertility.

Sole or intercropped wheat was planted on the same day as in farmer practices. Sole pea seeds (Master B cultivar) were sown in the 1st of October in both seasons in two rows on raised beds 120 cm apart. Sole wheat was sown in the middle of raised beds in six rows (100% of its planting density). In pea intercropping with wheat system, pea seeds were drilled on both sides of the raised beds in 50% of its planting density. Wheat was sown in the middle of raised beds in six rows (100% of its planting density). This spatial arrangement proved to reduce competition between wheat and pea plants and increase land equivalent ratio (Zohry *et al.*, 2017).

Regarding summer season, sole cowpea seeds (Karim1 cultivar) were sown on the 22nd of May in both seasons on two rows on the raised beds. Sole sunflower seeds were sown on the 15th of June on one row on the raised beds.

In intercropping cowpea and sunflower system, cowpea was drilled on the middle of the raised beds in two rows (50 % of its planting density) and sunflower was sown on both sides of the raised beds with 100% of its planting density in the above planting dates.

Soil physical and chemical analysis as described by Chapman and Pratt (1961) were done and recorded in Table 1.

Applied fertilizer amounts

Wheat, either sole (farmer or improved packages) or intercropped and pea either sole or intercropped was fertilized with calcium super phosphate (15.5% P_2O_5) with an amount of 240 kg/ha added before sowing. Potassium sulphate (48% K_2O) was added at the rate 120 kg/ha in two equal rates with first and second irrigation events. Nitrogen was added for wheat (sole or intercropped) as urea (46% N) at the rate of 166.6 kg/ha for sole wheat and 261.8 kg/ha for pea intercropped with wheat system in three doses after first, second and third irrigation events. Sole pea received 95.2 kg/ha of urea in three doses after first, second and third irrigation events.

Sunflower sole (farmer or improved packages) or intercropped and cowpea either sole or intercropped was fertilized with calcium super phosphate (15.5 % P_2O_5) with an amount of 240 kg/ha added before sowing. Furthermore, potassium sulphate (48 % K_2O) was added in the rate of 120 kg/ha in two equal doses with the first and second irrigation events. Nitrogen was added to sunflower (farmer or improved packages) as urea (46% N) in the rate of 71.4 kg/ha for sole sunflower and 142.8 kg/ha for cowpea intercropped with sunflower system in three doses after first, second and third irrigation events. Sole cowpea received 71.4 kg/ha of urea in three doses after first, second and third irrigation events.

The experiment was laid out in a randomized complete block design for each system with four replications. Weather data values were collected for the studied two growing season and reference evapotranspiration was calculated using Penman-Monteith equation presented in BISm model (Snyder *et al.*, 2004) (Table 2). The rain was negligible in the winter and there was no rain recorded in the summer season.

Field capacity, wilting point, available soil moisture and bulk density of the experimental soil are presented in Table 3.

Table 1: Some physical and chemical characteristics of the studied soil

Depth (cm)	**Particle size distribution**			
	Sand (%)	**Silt (%)**	**Clay (%)**	**Texture**
0 – 10	7.50	37.00	55.50	Loamy clay
10 – 30	6.75	35.75	58.50	Loamy clay
30 – 60	5.50	36.50	59.00	Loamy clay
Depth (cm)	Chemical characteristics			
	N (mg/kg)	O.M. (%)	EC (dS/m)	pH
0 – 10	55.50	1.88	1.11	7.11
10 – 30	53.50	1.75	1.25	7.30
30 – 60	53.60	1.69	1.21	7.11
Depth (cm)	Cations (Me/L)			
	K^+	Na^+	Mg^{++}	Ca^{++}
0 – 10	0.32	4.75	3.50	2.50
10 – 30	0.36	5.60	3.50	3.00
30 – 60	0.32	5.25	3.50	3.00
Depth (cm)	Anions (Me/L)			
	SO_4^{--}	Cl^-		HCO_3^-
0 – 10	4.07	6.50		0.50
10 – 30	4.46	7.50		0.50
30 – 60	4.07	7.50		0.50

Table 2: Weather data and ETo values in the experimental site

Month year	**SR**	**TX**	**TM**	**TD**	**WS**	**ETo**
Nov 2015	15.3	25.8	13.5	9.8	3.0	4.2
Dec. 2015	13.3	20.3	8.1	6.3	3.0	3.0
Jan 2016	13.7	18.3	5.0	2.3	2.6	2.8
Feb 2016	17.5	23.5	8.3	2.3	2.4	4.0
Mar 2016	19.7	26.6	11.6	1.7	2.8	5.5
Apr 2016	24.7	33.4	15.4	2.0	3.1	8.0
May 2016	26.8	35.4	18.6	4.6	3.4	9.1
Nov 2016	15.5	25.8	13.1	8.5	2.9	4.3
Dec 2016	13.1	18.5	6.5	5.1	2.8	2.7
Jan 2017	13.6	17.5	4.9	2.6	2.3	2.5
Feb 2017	17.3	19.9	5.4	2.3	2.5	3.4
Mar 2017	21.2	25.1	9.7	2.2	3	5.4
Apr 2017	24.0	30.8	13.5	2.8	3.2	7.3

SR=*solar radiation (MJ/m²/day),* **TX, TN** *and* **TD**=*maximum, minimum and dew point temperature, respectively (°C),* **WS**=*wind speed (m/s),* **ETo**=*reference evapotranspiration (mm/day).*

Table 3: Soil moisture contents in the experimental site for the two growing seasons

Soil depth (cm)	Field capacity (%)	Welting point (%)	Available soil moisture (%)	Bulk density(g/cm^3)
0 – 15	35	18.50	16.50	1.18
15 – 30	34	17.20	16.80	1.23
30 – 45	32	16.50	15.50	1.28
45 – 60	30	15.45	14.55	1.33

The applied irrigation amounts were calculated using 4-inch diameter tube according to Michael (1978) using the following equation:

$$Q = \frac{0.61 \times A \times \sqrt{2x981xh}}{1000 \times 1000} x60 \quad [1]$$

Q = water discharged (m^3/t)
A = tube sectional area (cm^3)
h = water head over the center of the tube (cm)

Irrigation scheduling was done using BISm model (Snyder *et al.*, 2004), where the measured water consumptive use values in the field was compared with the estimated values by the model to improve the accuracy of the irrigation scheduling process.

For all the studied crops, final yield was recorded on the basis of experimental plot area by harvesting all plants, then all plots were combined together. Wheat grains and sunflower seeds were measured as ton per hectare. Pea yield was measure as fresh pods per hectare and cowpea was measured as fresh weight per hectare. In the second year, the experiment was implemented on the same area used for the first year experiment.

Soil organic matter content

Soil organic matter content was measured before cultivation and after the harvest of all the cultivated crops at the end of second season under farmer practices and improved management practices packages by collecting soil samples of three soil layers (0-20, 20-40 and 40-60 cm). The carbon content was measured using wet oxidation (Walkley and Black, 1934). The organic matter content was calculated by multiplying organic carbon with 1.724.

Land equivalent ratio (LER)

LER is an evaluation of the land utilization efficiency of the intercropping (Willey and Rao, 1980). The value of LER is calculated according to the following formula:

$$\mathbf{LER = LER_A + LER_B = (Y_{int,A}/Y_{mono,A}) + (Y_{int,B}/Y_{mono,B})} \quad [2]$$

Where: LER_A and LER_B are the partial land equivalent ratio of crop A (wheat or sunflower) and crop B (pea or cowpea), respectively. $Y_{int,A}$ and $Y_{int,B}$ are the intercropping yield of crop A and crop B. $Y_{mono,A}$ and $Y_{mono,B}$ are the monoculture yield of crop A and crop B, respectively. If LER is more than 1, it indicates that the land utilization efficiency of the intercropping is higher than that of monoculture. The values of LER were estimated using the data of monocultures of wheat and sunflower.

Statistical analysis

All the obtained data from the experiment of each season were subjected to the statistical analysis of randomized complete blocks design with four replications according to Gomez and Gomez (1984). Least Significant Differences (LSD) at 5% levels of probability was used to compare means.

RESULTS

Applied irrigation water to the cultivated crops

The results in table 4 indicated that there were significant differences between the amounts of applied water to either wheat or sunflower between farmers and improved management practices. With respect to the applied irrigation amounts for wheat cultivated in the farmer practices, its value was higher by 23% than its counterpart value under sole planting and by 21% under intercropped with pea system using improved management practices (averaged over the two growing seasons). A similar trend was observed for sunflower, where the farmer practices increased the applied water by 21% than its counterpart value under sole planting and by 20% under intercropped with cowpea (averaged over the two growing seasons). Table 4 also indicated that the total applied water to both wheat and sunflower intercropping systems under the improved management practices was lower than its counterpart value applied in the farmer practice. Furthermore, the total applied irrigation water in the winter and summer seasons was the highest in farmer practices by 21%, compared to intercropping systems under improved management practices, averaged over the two growing seasons (Table 4).

Table 4: Applied irrigation water (m^3/ha) to crops cultivated under farmer practices and improved management practices in both growing seasons

	First growing season			Second growing season		
	Farmer Practices	Improved practices		Farmer Practices	Improved practices	
		Sole	Intercropped		Sole	Intercropped
Winter crops						
Wheat	7 216 a	5 500 b	5 605 b	7 467 a	5 848 b	5 889 b
Pea	--	4 266	--	--	4 429	--
LSD $_{Wheat}$	773			441		
Summer crops						
Sunflower	10 233 a	7 984 b	8 136 b	10 525 a	8 315 b	8 439 b
Cowpea	--	6 840	--	--	6 985	--
LSD $_{Sunflower}$	1 039			795		
Total	17 517	24 590	13 741	17 992	25 577	14 328

**Means with different letters indicates significant differences*

Productivity of the cultivated crops

The results in table 5 indicated that either wheat or sunflower yields (sole or intercropped) was significantly affected by the improved managements practices, compared to farmer practices. This result was true in both growing seasons. Furthermore, the significant difference between either pea or cowpea under sole and intercropping systems can be attributed to the reduced planting density (50% of its recommended density for either crops) under intercropping systems, compared to sole planting (100% of its recommended density).

Table 5 also indicated that the value of wheat yield in farmer practices was lower than its counterpart value of sole planting by 13%. Moreover, 14% increase in wheat yield was observed when pea was intercropped with it, compared to the value of farmer practices averaged over the two growing seasons. A similar trend was observed for sunflower, where its yield value in farmer practices was lower than its counterpart value of sole planting by 11% under improved management practices. An increase by 17% in sunflower yield was obtained when cowpea was intercropped with it, as averaged over the two growing seasons. However, the situation was different for wheat under intercropping system, where lower yield was observed, compare to sole planting.

Soil organic matter content

Table 6 presented soil organic matter content before planting and after harvest in farmer practices and in improved management practices. The results indicated that the percentage of soil organic matter increased after harvest of the cultivated crops in the fourth growing season under intercropping systems for either wheat and sunflower by 11 and 9%, respectively compared to zero-time (averaged over 60 cm soil depth). This result implied depletion of organic matter content in the soil after wheat and sunflower cultivation.

Land equivalent ratio (LER)

The obtained results were strongly coincided with the definition of LER. The results in Figure 1 indicated that intercropping pea with wheat in the winter season increased LER value, compared to wheat monoculture. The LER values were 1.33 and 1.40 in the first and second seasons, respectively.

Similarly, in the summer season (Figure 2), intercropping cowpea with sunflower resulted in an increase in the LER above 1.00. Higher value of LER was obtained in the second growing season, namely 1.55 versus 1.51 in the first growing season. Similar results were obtained by Zohry *et al.*, (2017).

Table 5: Productivity of the cultivated crops (t/ha) in farmer practices and improved management practices in both growing seasons

	First growing season			Second growing season		
	Farmer Practices	Improved practices		Farmer Practices	Improved practices	
		Sole	Intercropped		Sole	Intercropped
Winter crops						
Wheat	6.51 b	7.19 a	6.99 a	6.41 c	7.39 b	7.73 a
Pea	---	3.25 a	1.19 b	---	3.37 a	1.22 b
LSD $_{Wheat}$	0.38			0.22		
LSD $_{Pea}$	0.28			0.23		
Summer crops						
Sunflower	3.23 b	3.48 a	3.63 a	3.13 c	3.53 b	3.82 a
Cowpea	---	46.2 a	21.7 b	---	48.0 a	22.7 b
LSD $_{Sunflower}$	0.21			0.10		
LSD $_{Cowpea}$	3.03			1.35		

**Means with different letters indicates significant differences*

Table 6: Soil organic matter contents before cultivation and after harvest of the cultivated crops under farmer practices and improved management practices

	Zero-time (Start of first season)	First growing season			Second growing season		
		Farmer	Improved management		Farmer	Improved management	
			Sole	Intercropped		Sole	Intercropped
Wheat							
0-10	1.88	1.85	2.02	2.10	1.87	2.05	2.24
20-30	1.75	1.73	1.78	1.98	1.72	1.79	1.88
30-60	1.69	1.69	1.70	1.75	1.65	1.72	1.78
Sunflower							
0-10	1.88	1.87	2.01	2.09	1.88	2.06	2.22
20-30	1.75	1.74	1.78	1.93	1.72	1.80	1.83
30-60	1.69	1.69	1.70	1.72	1.66	1.73	1.74

DISCUSSION

Irrigation-induced erosion is one of the greatest global threats to sustainable agricultural productivity, especially under furrow irrigation, which is common in Egypt. Reduction of soil loss under surface irrigation can be accomplished using improved management practices. Our results showed that implementing precise land leveling, cultivation on raised beds and irrigation scheduling resulted in considerable saving in the applied irrigation amounts, compared to farmer practices (Table 4). The results in table 4 also showed that the amount of applied water to either pea intercropped with wheat system or cowpea intercropped with sunflower system were lower than the applied amount to irrigate each of the two crops in monoculture. This can be attributed to lower planting density of pea and cowpea in both intercropping systems (50% of its recommended density) and different rooting patterns between pea and wheat, as well as cowpea and sunflower (deep versus shallow roots), which can permit greater exploitation of a larger volume of soil and improves access to soil water, which maximize water use efficiency.

Naresh *et al.*, (2014) indicated that precise land leveling increased land uniformity, improved nutrient uptake and weed management resulted in increased yields. Hobbs *et al.*, (2000) and Ahmad *et al.*, (2009) demonstrated that raised beds planting contributed significantly in improving water distribution and efficiency. Sing *et al.*, (2010) found lower water consumption by wheat on raised beds planting than under conventional flatbeds planting due to decrease in irrigation amount with no yield loss. Research trials in India showed that raised beds were most suited for growing crops like maize, wheat and soybean as it significantly decreased water use (Zhang *et al.*, 2007).

Our results showed that the applied irrigation water to wheat or sunflower intercropping systems was slightly higher than the applied amount to wheat or sunflower monoculture. Kamel *et al.*, (2010) indicated that, in intercropping systems, no extra irrigation water is required to be applied to the companion crop because it shares the applied water of the main crop. Furthermore, Ghanbari *et al.*, (2010) indicated that cowpea intercropped with maize reduces water evaporation and improves conservation of soil moisture. Kariaga (2004) concluded that cowpea/maize intercropping system reduced runoff through maintaining ground cover, thus reduced soil erosion.

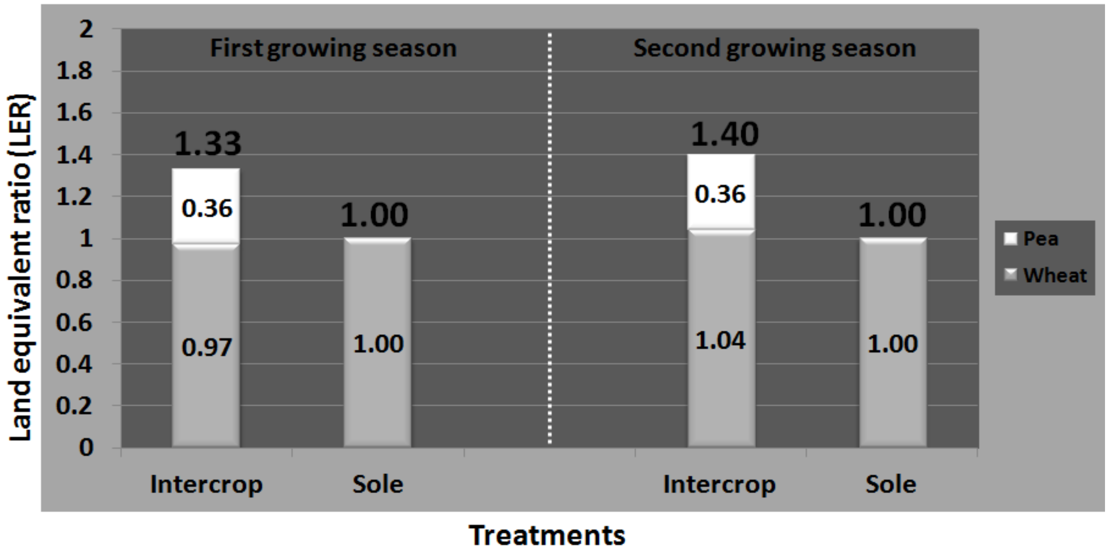

Figure 1. The LER of intercropping pea with wheat in the two seasons

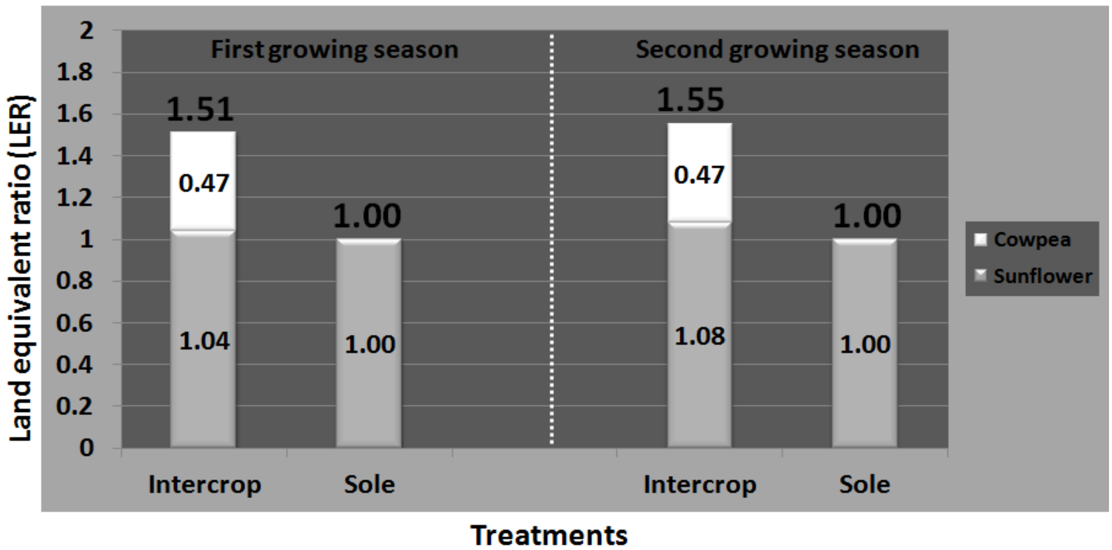

Figure 2. The LER of intercropping cowpea with sunflower in the two seasons

The results in table 5 showed that the rise in yield of both wheat and sunflower monoculture under improved management practices package can be partially attributed to cultivation on raised beds. Abouelenin *et al.*, (2010) and Majeed *et al.*, (2015) indicated that cultivation on raised beds increased wheat productivity by 10-20% and increased fertilizer use efficiency by 15%, compared to flat planting. Raised beds planting also created better soil physical environment throughout the crop growth period, which led to higher crop productivity (Aggarwal and Goswami, 2003).

Furthermore, the intercropping systems of wheat and sunflower with legume crops have many benefits. Tolera (2003) indicated that growing more than one crop at a time in the same field maintain soil fertility due to greater root concentrations of the soil profile. Intercropping of plants with different rooting patterns permits greater exploitation of a larger volume of soil and improves access to relatively immobile nutrients (Gebru, 2015). As a result, intercropped plants tend to absorb more nutrients than those in monocultures and attain higher yield. These findings can explain the observed increased in the yield of sunflower under improved management practices in the intercropping systems, compared to sole crops and farmer practices, which can be attributed to enhanced resources use as stated by Szumigalski and Van-Acker (2008).

Our results showed that the yield of monoculture wheat was lower under intercropping system, compare to sole planting when the improved management practices was implemented. This can be attributed to high competition on natural resources between wheat and pea, where pea plants are considered more aggressive than wheat (Zohry *et al.*, 2017). From the economic point of view, the farmer obtained pea yield in addition to wheat yield, which will compensate the loss in his profit resulted from wheat yield reduction. In this context, Ghanbari *et al.*, (2010) indicated that cowpea intercropped with maize increased absorbed photosynthetically active radiation, which reflected on maize final yield.

The increase in soil organic matter content can be attributed to cultivation on raised beds and implementing intercropping systems. Limon-Ortega *et al.*, (2002) indicated that raised beds cultivation improves soil quality, which led to enhanced root growth. In addition, Dey *et al.*, (2015) indicated that root length density in upper 45 cm in the raised beds was increased due to porous soil environment. Raised beds cultivation significantly and substantially increased microbial functional groups and enzyme activities compare to flat planting, thus it increases the availability of essential crop nutrients by stimulating microbial activity (Zhang *et al.*, 2012). Bado *et al.*, (2006) stated that legumes supply N to the subsequent crops through fallen senescent leaves and below ground parts, leading to an increase in succeeding crop yield. These findings implied that the roots residuals of the crops cultivated on raised beds cultivation will be higher than furrow cultivation and that could result in increasing organic content in the soil.

Furthermore, Tolera (2003) indicated that implementing intercropping systems maintains soil fertility, where greater root concentrations of the soil profile occur. In addition, legume crops have the ability to facilitate the absorption of P and K in the soil by cereal crops and providing N through N-fixing rhizobium. Hassan *et al.*, (2010) indicated that legumes mobilize P in the soil during its growth, which increases P uptake of the following cereal. Ferguson *et al.,* (2013) indicated that legumes have the ability to remove calcium and magnesium in the soil more than cereals and replace it with hydrogen, which results in removing OH^- ions and increases H^+ thus lowering the soil pH. These findings could explain the increase in organic matter content in the soil after the fourth growing season when pea or cowpea were planted solely or intercropped. An increase by 6 and 5% in organic matter content were obtained after harvest of these two sole and intercropped legume crops, respectively.

CONCLUSION

Soils are the basis for agriculture and the medium in which nearly all food-producing plants grow, thus its management is fundamental. The results presented in this research put an emphasis on adopting the use of improved management practices in food production. These practices not only can increase food production, but also play a role on preventing soil degradation. Precise land leveling, cultivation on raised beds, irrigation scheduling and implementing intercropping systems with legume crops resulted in reduce soil loss by irrigation, which was evident by wheat and sunflower yield increase, in addition to the increase in soil organic content percent. In conclusion, our results implied that using the improved agricultural management package can be useful in reducing soil loss under surface irrigation practice.

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