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Evaluation of different crop sequences for wheat and maize in sandy soil

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ABSTRACT

The objective of this paper was to assess four crop sequence system including wheat and maize grown in sandy soil of Upper Egypt with respect to the applied irrigation amount for each crop sequence, total production and water productivity. Two field experiments were conducted in Egypt during 2013/14 and 2014/15 growing seasons. Each experiment included four crop sequences: maize then wheat (CS1); maize, short season clover (SSC) then wheat (CS2); cowpea, SSC then wheat (CS3); cowpea intercropped with maize, SSC then wheat (CS4). The lowest amount of applied water was added to CS1 which resulted with low value of wheat and maize yield and the lowest water productivity. The highest amount of applied water was applied to CS2 and CS4 (similar values). The highest wheat yield and water productivity were obtained in CS3. The highest maize yield and water productivity was obtained from CS4. The highest total production (170.88 and 213.43 CU ha^{-1} in the 1st and 2nd season, respectively) and water productivity (0.093 and 0.114 CU m^{-3} in the 1st and 2nd season, respectively) for the studied crop sequences was obtained from CS3. In conclusion, higher water productivity for wheat in sandy soil can be attain by cultivating two legume crops before it (CS3); and for maize, it should be intercropped with a legume crop (CS4).

Key words: maize; wheat; short season clover; cowpea; cowpea intercropped with maize; cereal units; Assiut Governorate

IZVLEČEK

OVREDNOTENJE RAZLIČNIH KOLOBARJEV ZA KORUZO IN PŠENICO NA PEŠČENIH TLEH

Predmet te raziskave je bilo ovrednotenje kolobarja za pšenico in koruzo na peščenih tleh v Zgornjem Egiptu glede na obseg namakanja v posameznem kolobarju, celokupno produkcijo in učinkovitost izrabe vode. Izvedena sta bila dva poljska poskusa v rastnih sezonah 2013/14 in 2014/15. Vsak poskus je obsegal štiri sosledja poljščin v kolobarju in sicer : 1 - koruza nato pšenica (CS1); 2 - koruza, kratkosezonska detelja (SSC), potem pšenica (CS2); 3 - čičerka, SSC, potem pšenica (CS3); 4 - čičerka v medsetvi s koruzo, SSC, potem pšenica (CS4). Najmanjša količina dodane vode je bila v sistemu CS1, kar je rezultiralo v majhnem pridelku pšenice in koruze in najmanjši učinkovitosti izrabe vode. Največ vode je bilo dodano v kolobarjih CS2 in CS4 (enake količine). Največji pridelek in največja učinkovitost izrabe vode sta bila dosežena v kolobarju CS3. Največji pridelek koruze in največja učinkovitost izrabe vode sta bila dosežena v kolobarju CS4. Največja celokupna produktivnost (170.88 in 213.43 CU ha^{-1} v prvi in drugi rastni sezoni) in največja učinkovitost izrabe vode (0.093 in 0.114 CU m^{-3} v prvi in drugi rastni sezoni) sta bili za preučevane kolobarje deseženi v kolobarju CS3. Zaključimo lahko, da je večja učinkovitost izrabe vode za pšenico na peščenih tleh dosežena v kolobarju z dvema metuljnicama pred njo (CS3) in za koruzo z medsetvijo metuljnice (CS4).

Ključne besede: koruza; pšenica; kratkosezonska detelja; čičerka; medsetev čičerke v koruzo; žitne enote; Assiut upravna enota

1 INTRODUCTION

Maize and wheat are very important cereal crops all over the world (Valipour 2012a). The cultivated area of these important crops is under competition with other crops with higher economic values (Valipour 2016). In Egypt, there is a large gap between the production of these two crops and its consumption. Therefore, it is important to increase its cultivated area by cultivating low fertile soil on the edges of the Nile Delta and

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Valley. These soils are characterized by low fertility level and high water infiltration rate. Increasing productivity of unit land and water of these soils is a challenge under the prevailing situation of water deficiency and food insecurity in Egypt. For that reason, proper water management for the cultivated crops in such areas is essential. Accurate estimation of reference evapotranspiration is the main factor to attain that. Earlier studies compared different ETo equations for their accuracy revealed that Penman-Monteith equation is the most accurate because of its detailed theoretical base and its accommodation of small time periods (Valipour, 2014). It was found that air temperature and solar radiation contributed most to the temporal variation of ETo in the upper reaches, as well as solar radiation and wind speed were the determining factors for the temporal variation of ETo in the middle-lower reaches (Zhao et al., 2015). Furthermore, comparison between FAO Penman-Monteith with other methods that calculating reference evapotranspiration was done by several authors (Valipour, 2012b and 2014).

The prevailing crop sequence in these areas is two crops per year (a winter then a summer crop). One of the management that could be done to increase productivity of unit land and water in these soils is changing crop sequence from two crops per year to three crops per year, with inclusion of legume crop (early winter, winter then summer crops). The major benefit resulted from this practice is improvement in soil fertility and increased farmers' income (Sheha et al., 2014). In addition, implementing intercropping in one season can play a similar role in increasing productivity of unit land and water (Kamel et al., 2010). A very common crop sequence in Egypt, either on fertile or low fertile soils, is the cultivation of wheat then maize, where both are cereals and its cultivation in a year on the same piece of land leads to imbalance in soil nutrients and decline in the yield of both crops (Hamd-Alla et al., 2015). Previous research on the effect of crop sequence on wheat yield indicated that it was significantly improved when cowpea preceded it. The opposite occurred when maize preceded wheat, where wheat yield was reduced (Hamd-Alla et al., 2015). Under these circumstances, wheat benefited from the residual effect of legume, which positively affected wheat yield (Kumpawat and Rathore, 2003). Furthermore, cultivating short season clover in September before wheat cultivation in November proved to increase wheat yield (Sheha et al., 2014).

Another avenue to increase the productivity of unit land and water is intercropping, where one crop share its life cycle or part of it with another crop (Eskandari et al., 2010). This practice can be used as a way to improve soil fertility, increase land productivity and save on the applied irrigation water (Kamel et al., 2010). Furthermore, it increases water productivity as a result of using less water to irrigate two crops (Andersen, 2005). One example of intercropping systems is cowpea intercropped with maize, which has many advantages, such as increasing maize yield by 10% and reducing associated weeds (Hamd-Alla et al., 2014). Furthermore, no additional water will be applied to cowpea under this system (Kamel et al., 2016). In low fertile soil, such as in Egypt, legume/cereal intercropping system can increase soil fertility via raising its organic content and available nitrogen fixed by legume (Singh et al, 1986), which reduces fertilizer requirements for cereal crops, reduces costly inputs and ensure agricultural sustainability (Megawer et al., 2010). Furthermore, Banik et al. (2006) reported that intercropping can offer opportunity for stable agricultural production in low fertile soil, whereas mono cropping cannot ensure its stability.

Although many studies were done to determine the effect of crop sequence and intercropping systems on maize and wheat productivity in old fertile soil in Egypt (Sheha et al., 2014; Nofal 2012; Zohry 2005a; Zohry, 2005b), there were no previous studies on different crop sequences including wheat and maize in low fertile soil existed on the edges of the Nile value. Such a study can enhance our knowledge about the impact of different crop sequences on the applied irrigation water for these two crops in the whole crop sequence and its consequent total production. Application of such a study in Egypt is important for policy makers and can allow reduction of food gap of these two crops. Thus, the objective of this paper was to assess four crop sequences systems including wheat and maize grown in sandy soil of Upper Egypt with respect to the applied irrigation amount for each crop sequence, total production and water productivity. These crop sequences were: maize then spring wheat; maize, short season clover then spring wheat; cowpea, short season clover then spring wheat; and cowpea intercropped with maize, short season clover then spring wheat.

2 MATERIALS AND METHODS

Two field experiments were carried out at Arab El-Awammer Research Station; Agricultural Research Center; Assiut Governorate; Upper Egypt during two growing seasons of 2013/14 and 2014/15. Each experiment included four crop sequences as follows:

1. Maize then spring wheat (CS1);

2. Maize, short season clover then spring wheat (CS2);
3. Cowpea, short season clover then spring wheat (CS3);
4. Cowpea intercropped with maize, short season clover then spring wheat (CS4).

The soil of the experiment was sandy (sand, 89.9 %, silt, 7.1 % and clay, 3.0 %), with soil pH equal to 8.4, EC was 0.33 dS m^{-1} and $CaCO_3$ was 30.9 %. Furthermore, total N % was 0.008 and available P and K values were 8.31 and 64.00 mg kg^{-1}, respectively. The soil was cultivated for the first time with this experiment. Soil chemical analysis was determined according to Jackson (1958).

Irrigation water was applied each fourth day by using a solid-set sprinkler system. The rotary sprinkler (type Rc160) has 0.87 to 1.23 m^3h^{-1} discharge at 2.10 to 2.5 bars nozzle pressure, with spacing of 9 meters between laterals and 7 meters between sprinklers. A differential pressure tank was connected to the sprinkler irrigation system to inject fertilizer via irrigation water. The soil moisture constants (% per mass) in the depth of 0 - 60 cm were measured. Field capacity was 12.5 - 11.8 %, wilting point was 4.9 - 4.9 % and bulk density was 1.57 -1.55 g cm^{-3}. Reference evapotranspiration (ETo), crop evapotranspiration and irrigation schedule were determined using BISm model (Snyder et al., 2004) for weather data of 2013/14 and 2014/15 growing seasons. The model uses Penman-Monteith equation, as presented in Allen et al., (1989) to calculate ETo.

Table 1 presents weather data and ETo values in both growing seasons in the studied site. There is no rain occurrence in Assuit governorate because it is located in Upper Egypt region.

Table 1. Monthly weather data and ETo in 2013/14 and 2014/15 growing seasons in Assuit Agricultural Research Station

	2013/14 growing season						2014/15 growing season				
	SR	TX	TN	WS	ETo		SR	TX	TN	WS	ETo
Nov13	16.3	27.5	14.0	2.6	4.1	Nov14	16.5	25.6	12.2	2.9	4.1
Dec13	14.1	20.3	7.8	3.1	3.3	Dec14	14.3	22.5	9.1	2.5	3.3
Jan14	15.4	21.7	7.6	2.5	3.3	Jan15	15.2	19.0	5.7	2.7	2.9
Feb14	18.8	23.4	8.0	3.0	4.2	Feb15	17.5	21.8	7.8	2.9	3.8
Mar14	21.8	26.8	11.6	3.0	5.1	Mar15	18.1	26.9	11.9	3.2	5.0
Apr14	25.0	32.2	16.2	3.2	6.7	Apr15	25.9	29.2	12.8	3.6	6.6
May14	26.7	34.9	19.7	3.6	7.7	May15	27.8	34.7	18.9	3.5	7.8
Jun14	29.9	37.2	21.7	3.8	8.8	Jun15	26.8	35.7	21.0	4.0	8.7
Jul14	29.4	37.9	22.7	3.9	8.9	Jul15	29.4	37.7	22.6	3.5	8.6
Aug14	27.6	38.0	23.0	3.5	8.4	Aug15	25.5	40.2	25.4	3.9	9.3
Sep14	24.4	35.7	20.8	3.8	7.6	Sep15	24.2	35.5	20.6	3.6	7.8
Oct14	20.2	30.7	16.9	3.0	5.5	Oct15	20.0	30.5	16.7	2.8	5.8
Average	22.5	30.5	15.8	3.2	6.1	Average	20.9	29.9	15.4	3.3	6.0

SR = solar radiation ($MJ/m^2/day$), TX and TN = maximum and minimum temperature, respectively (°C), WS = wind speed (m s^{-1}), ETo = reference evapotranspiration (mm day^{-1}).

Land preparation was done by ploughing the land twice and then the land was leveled. The experimental design was spilt plot design, where the year was considered to be in the main plot and crop sequences were in the subplots. The size of single experimental plot was 21 m^2.

Regarding to maize, 'SC130' hybrid was sown on 12/5/2013 and 5/5/2014 in the first and second season, respectively using 27 kg of maize grains. Sole maize or intercropped with cowpea, *Vigna sinensis* 'Cream'), was planted with 100 % of its recommended planting density on one side of narrow furrows (70 cm width), 25 cm apart between plants. Nitrogen fertilizer was added at the rate of 360 kg N ha^{-1} of ammonium nitrate (33.5 % N). It was applied in five equal doses, after 15, 25, 35, 45 and 55 days from planting. Maize was also fertilized with 74.4 kg P_2O_5 ha^{-1} of calcium super phosphate, (15.5 % P_2O_5) and potassium sulphate (48.8 % K_2O) at the rate of 58.6 kg K_2O ha^{-1}, both were applied during land preparation, as recommended by Ministry of Agriculture and Land Reclamation in Egypt. Maize plants were harvested on 2/9/2013 and 25/8/2014 in the first and second season, respectively and maize grain yield was measured.

Cowpea seeds (‘Cream’) were planted in 12/5/2013 and 5/5/2014 in the first and second season, respectively using 15 kg of cowpea seeds. Sole cowpea was sown on one side of the narrow furrow (70 cm width), 36 cm apart between plants. Nitrogen fertilizer was added at the rate of 96 kg N/ha of ammonium nitrate (33.5 % N) with the second irrigation. The high applied rate of N fertilizer for cowpea is recommended by the Ministry of Agriculture and Land Reclamation in Egypt because it is known that, in these areas, the activity of soil bacteria could be limited. In addition, 74.4 kg P_2O_5 ha^{-1} of calcium super phosphate (15.5 % P_2O_5) was added during land preparation as recommended by Ministry of Agriculture and Land Reclamation in Egypt. First cut of cowpea was done on 12/7/2013 and 2/7/2014 in the first and second season, respectively. Second cut of cowpea was done on 22/8/2013 and 15/8/2014 in the first and second season, respectively.

Regarding to cowpea intercropped with maize, cowpea was sown on one side of the narrow furrow (70 cm width) and maize was planted on the other side of the narrow furrow with (50 % and 100 % of the recommended rate for cowpea and maize, respectively). No fertilizes was applied to cowpea under this intercropping system.

Short season clover seeds (*Trifolium alexandrinum*‘Fahl’) were planted with its recommended planting density in 15/9/2013 and 10/9/2014 in the first and second season, respectively using 60 kg of seeds. Nitrogen fertilizer was added at the rate of 72 kg N ha^{-1} of ammonium nitrate (33.5 % N), 20 days after planting as a result of low activity of the symbiosis bacteria in the soil. It was also fertilized with calcium super phosphate (15.5 % P_2O_5) as 37.2 kg P_2O_5 ha^{-1} during land preparation as recommended by Ministry of Agriculture and Land Reclamation in Egypt. Harvest was done in 20/11/2013 and 15/11/2014 in the first and second season, respectively.

With respect to wheat, *Triticum aestivum* ‘Sids1’, which is a common wheat cultivar was sown in 1/12/2013 and 25/11/2014 in the first and second season, respectively using 100 % of its recommended planting density (144 kg of grain yield). As recommended by Ministry of Agriculture and Land Reclamation in Egypt, nitrogen fertilizer was added as 288 kg N ha^{-1} in the form of ammonium nitrate (33.5 % N) in five equal doses, after 20, 40, 55, 70 and 85 days after planting. Phosphorus fertilizer was applied in the form of single super phosphate (15.5 % P_2O_5) as 74.4 kg P_2O_5 ha^{-1} and was incorporated into the soil during land preparation. Potassium in the form of potassium sulphate (48.8 % K_2O) as 58.6 kg K_2O ha^{-1} was applied during land preparation. Wheat was harvested on 20/4/2014 and 15/4/2015 in the first and second season, respectively, where wheat grain yields were measured.

For all the studied crops, seeds yield was recorded on the basis of experimental plot area by harvesting all plants, weighted, and then all the plots were combined together . The biomass of all studied crops was removed from the field after harvest. Dry mass of cowpea and short season clover were measured. In the second year experiment, the experiment was implemented on the same area used for the first year experiment.pART27 2mgfp5-ER 103 explants.

All the obtained data from the experiment of each season were subjected to the statistical analysis of complete randomized blocks design with four replications according to Gomez and Gomez (1984). Revised Least Significant Differences (LSD') at 5 % levels of probability was used for comparing means according to Waller and Duncan (1969).

Crop water productivity

Water productivity was calculated for each crop in the sequence, as well as for each crop sequence as a whole. Crop water productivity was calculated by dividing the obtained yield by applied water for each crop. To calculate water productivity for the whole crop sequence, calculation of Cereal Units (CU) (Brockhaus, 1962) for each crop in the sequence was done, then it was added together to obtain one value to represent the total yield from each crop sequence.

The CU has been used as a common denominator in German agricultural statistics for decades and is mainly based on the nutritional value for livestock. It is also an appropriate unit for the description of agricultural products (Brankatschk and Finkbeiner, 2014). Furthermore, Macak et al., (2015) used CU to evaluate productivity of different crop rotations. This methodology is widely used in Egypt to evaluate the production of different intercropping systems. Abou-Keriasha et al., (2013) reported that according to Brockhaus (1962) 100 kg of either wheat or maize is equal to 1.0 CU. Furthermore, 100 kg of short season clover or cowpea equal to 1.14 and 1.12 CU, respectively. Thus, water productivity (CU mm^{-1}) was calculated using the accumulated values of cereal units as numerator and the applied water in millimeters as dominator.

3 RESULTS

3.1 Applied water for crops and crop sequences

Table 2 indicates that water requirements for all the studied crops were higher in the second year compared to the first growing season, except for wheat. With respect to the four crop sequences, the lowest amount of applied water was added to CS1, where only two crops were cultivated. The value of the applied water to CS2 and CS4 were similar in each growing season and different in both growing season. Furthermore, this amount was the highest, compared to what was applied to the other crop sequences.

Table 2: Water requirements (WR, m^3 ha^{-1}) for the studied crops and crop sequences in both growing seasons

	WR 2013/14	WR 2014/15
Wheat	6267	6200
Maize	8440	8947
Short season clover	5400	5507
Cowpea	6853	6933
Cowpea intercropped with maize	8440	8947
Maize then wheat (CS1)	14707	15147
Maize, short season clover then wheat (CS2)	20107	20653
Cowpea, short season clover then wheat (CS3)	18520	18640
Cowpea intercropped with maize, short season clover then wheat (CS4)	20107	20653

3.2 Effect of crop sequence on wheat productivity

Table 3 shows that in all the studied crop sequences, there were significant differences between wheat yields ($P < 0.05$) in both growing seasons, where the lowest wheat yield was obtained when maize/wheat system was cultivated (CS1). In the second growing season, wheat yield was insignificantly higher. Furthermore, wheat cultivation after short season clover in CS2 increased wheat yield by 16 and 47 % in the first and second season, respectively, compared to maize cultivation before wheat system (CS1). The highest wheat yield was obtained when cowpea and short season clover were cultivated before it in both growing seasons (CS3), which increased its yield by 23 and 87 % in the first and second growing seasons, respectively. It can be also noticed, in all crop sequences, that wheat yield value was higher in the second growing season, compared to the first growing season.

Table 3 also reveales that the highest water productivity for wheat was obtained when cowpea and short season clover were cultivated before it in CS3. This result was true in both growing seasons. Furthermore, the lowest water productivity was found when maize preceded wheat in CS1.

Table 3: Spring wheat yield as affected by different crop sequences, percentage of yield increase (PI%) and water productivity (WP) in both growing seasons

Crop sequence	2013/14 growing season			2014/15 growing season		
	Wheat yield (ton ha^{-1})*	PI (%)	WP (kg m^{-3})	Wheat yield (ton ha^{-1})*	PI (%)	WP (kg m^{-3})
CS1	3.70^d	---	0.59	3.73^d	---	0.60
CS2	4.29^c	16	0.68	5.49^c	47	0.89
CS3	4.55^a	23	0.73	6.98^a	87	1.13
CS4	4.48^b	21	0.72	6.05^b	62	0.98

*Means with different letters indicated that it was significantly different

3.3 Effect of crop sequences on maize productivity

Maize yield was insignificantly lower in the CS2 compared to the CS1 in the first growing season. In CS2, maize yield increased by 7 % in the second growing season as a result of the residual effect of the legume crops from the first growing season (Table 4). The highest yield was obtained when cowpea was intercropped with maize in both growing seasons (CS4).

Intercropping cowpea with maize resulted in 3 and 13 % increase in maize yield in the first and second growing season, respectively. The results in Table 4 also revealed that in both growing seasons, there were insignificant differences between maize yield values in the studied crop sequences (*P <0.05*).

The highest water productivity for maize in both growing seasons were obtained when cowpea intercropped with maize (CS4), as a result of higher yield without any increase in the applied irrigation water for the intercropped system (Table 4).

Table 4: Maize yield as affected by different crop sequences in both growing seasons, percentage of yield increase (PI%) and water productivity (WP)

Crop sequence	2013/14 growing season			2014/15 growing season		
	Maize yield ($t\ ha^{-1}$)*	PI (%)	WP ($kg\ m^{-3}$)	Maize yield ($t\ ha^{-1}$)*	PI (%)	WP ($kg\ m^{-3}$)
CS1	5.43^{a}	--	0.64	5.40^{b}	--	0.60
CS2	5.39^{a}	-1	0.64	5.79^{ab}	+7	0.65
CS4	5.62^{a}	+3	0.67	6.12^{a}	+13	0.68

*Means with different letters indicated that it was significantly different

3.4 Effect of crop sequence on productivity of short season clover

Table 5 indicates that there were significant differences between short season clover productivity in the studied crop sequences (*P < 0.05*) in both growing seasons. The highest yield of short season clover was obtained when cowpea preceded it in both growing seasons (CS3), namely 35 and 37 % in the first and second season, respectively. However, when intercropping cowpea with maize preceded by short season clover (CS4), its yield was increased by 12 and 10 % only in the first and second growing season, respectively.

Furthermore, water productivity for short season clover increased when cowpea preceded it in CS3, compared to the other two crop sequences (Table 5).

Table 5: Short season clover dry yield as affected by different crop sequences in both growing seasons, percentage of yield increase (PI %) and water productivity (WP)

Crop sequence	2013/14 growing season			2014/15 growing season		
	Clover yield ($t\ ha^{-1}$)*	PI (%)	WP ($kg\ m^{-3}$)	Clover yield ($t\ ha^{-1}$)*	PI (%)	WP ($kg\ m^{-3}$)
CS2	4.30^{b}	--	0.78	5.10^{b}	--	0.93
CS3	5.82^{b}	35	1.06	6.97^{a}	37	1.27
CS4	4.79^{a}	12	0.87	5.62^{b}	10	1.02

*Means with different letters indicated that it was significantly different

3.5 Effect of crop sequence on cowpea productivity

Table 6 revealed that cowpea yield was significantly different in the studied crop sequences in both growing seasons (*P < 0.05*). Thus, cowpea yield was reduced by 45 and 35 % in the first and second season, respectively. Accordingly, water productivity followed the same trend as cowpea yield did in both crop sequences, where it was lower under intercropping with maize in both growing seasons (Table 6).

Table 6: Cowpea dry yield as affected by different crop sequences in both growing seasons, percentage of yield increase in its (PI %) and water productivity (WP) in both growing seasons

Crop sequence	2013/14 growing season			2014/15 growing season		
	Clover yield ($t\ ha^{-1}$)*	PI (%)	WP ($kg\ m^{-3}$)	Clover yield (tha^{-1})*	PI (%)	WP ($kg\ m^{-3}$)
CS3	5.27^{a}	--	0.76	5.72^{a}	--	0.83
CS4	2.92^{b}	45	0.42	3.70^{b}	35	0.53

*Means with different letters indicated that it was significantly different

3.6 Total production of each crop sequence and its water productivity

The accumulated cereal units for each crop sequence are presented in Table 7. The results showed that the lowest value of accumulated cereal units were found for wheat followed by maize and it was higher in the second growing season. On the contrary, the highest values were obtained when cowpea preceded wheat and followed by short season clover in CS3 in both growing seasons. Furthermore, the highest percentage of increase in total yield of cereal units was found in CS3, namely 88 and 124 %, in the first and second season, respectively.

Table 7: Yield of crop sequences in cereal units (CU) in both growing seasons and percentage of increase (PI%)

Crop sequence	Total yield in 2013/14 (CU ha^{-1})	PI (%)	Total yield in 2014/15 (CU ha^{-1})	PI (%)
CS1	90.91	--	95.17	--
CS2	145.72	60	170.90	80
CS3	170.88	88	213.43	124
CS4	132.12	45	166.12	75

Table 8 reveals that CS3 attained the highest water productivity, compared to rest of crop sequences in both growing seasons.

Table 8: Water productivity (CU mm^{-1}) for each crop sequence in both growing seasons

	2013/14 season	2014/15 season
Maize/wheat (CS1)	0.062	0.063
Maize/clover/wheat (CS2)	0.073	0.082
Cowpea/ clover/wheat (CS3)	0.093	0.114
Cowpea with maize/clover then wheat (CS4)	0.066	0.080

4 DISCUSSION AND CONCLUSION

In this paper, four crop sequences included two major and important crops in Egypt were evaluated. The evaluation was done on the basis of its applied amount of irrigation water, on its total production calculated using cereal units method and on its water productivity.

Our results indicated that the applied amount of irrigation water for each crop in the four sequences was higher in the second year compared to the first year, except for wheat. Table 1 indicated that monthly ETo values in the first growing season of wheat (November-April) were lower than its counterpart in second season from January to April, which resulted in lower water requirements for wheat in the second growing season. Although the value of monthly ETo was lower in June and July in the second growing season of maize (May-September), it has a negligible effect of the applied water to maize and the amount was higher in the second season. In CS4, cowpea was intercropped maize, thus it obtained its water requirements from the applied amount to maize, which resulted in similar applied water to what was applied for CS4 (Table 2). Kamel et al., (2016) indicated that intercropping cowpea with maize did not require applying extra water to cowpea because it shared the applied water to maize.

Wheat cultivated in CS1 achieved the lowest productivity (Table 3), where it was planted after maize and both crops are exhausted to the soil, especially when its fertility is low. Hamd-Allah et al. (2015) indicated that low productivity of wheat was obtained when maize preceded it. Consequently, the lowest total production as expressed by cereal units was obtained for CS1. The increase in wheat yield in the second growing season can be explain by lower temperature in January and February in the second growing season, which could increase wheat tillering and positively affected grain yield. Porter and Gawith (1999) indicted that the optimum temperature for wheat shoot growth is 20.3 °C. Whereas, Hakim et al., (2012) stated that 20-25 °C is consider optimum for growth and development of spring wheat. Furthermore, wheat water productivity was the lowest in CS1in both growing seasons.

Furthermore, wheat yield was increased by inclusion of short season clover in CS2, or cultivation of cowpea and short season clover before it in CS3 in the first growing season. The second highest wheat yield value resulted from CS4 in the first growing season. In the second growing season, wheat yield was increased by higher values in CS2, CS3 and CS4 (Table 3). Accordingly, the highest value of wheat water productivity was obtained in CS3. This result attributed to the residual effect of the two legume crops (cowpea and short season clover) cultivated before wheat on increasing available nitrogen, which benefited wheat yield in the second growing season. This result is supported by the findings of Espinoza et al., (2015). The inclusion of legumes in a cropping sequence can also improve soil quality, porosity, and structure (McCallum et al., 2004) and influence specific microorganism populations in the rhizosphere (Osborne et al., 2010) for the benefit of following crops.

Regarding to maize in CS1, its yield was decreased in the second growing season, as a result of wheat cultivation before it in the first growing season (Table 4). Consequently, the lowest water productivity for maize existed in CS1 (Table 4), as well as the lowest total production (Table 7) and the lowest water productivity (Table 8) existed in the studied four crop sequences. The existence of legume crop (s) in the crop sequences CS2 and CS4 resulted in increasing maize yield and its water productivity (Table 4). This result can be attributed to the ability of legume crops to facilitate the absorption of P and K in the soil by cereal crops, in addition to its role in providing N through N-fixing rhizobium. Bado et al., (2006) stated that N2 -fixing legumes supply N to the subsequent crops through fallen senescent leaves and below ground parts, leading to an increase in succeeding crop yield. Hassan et al., (2010) indicated that legumes mobilize P in the soil during its growth, which increase P uptake of the following cereals. 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.

Regarding to maize, intercropping cowpea with it in CS4 increased its yield in the first growing season. Moreover, higher increase in maize yield was noticed in the second growing season, as a result of the residual effect of short season clover in CS4 (Table 4). Furthermore, the highest maize water productivity was attained in CS4 (Table 4).

Previous research on intercropping cowpea with maize in clay soil under surface irrigation indicated that maize yield was increased by 10 %, as a result of increased nitrogen content in the soil, reduction in the associated weeds competing with maize plants (Zohry, 2005a) and reduction in biological enemies that attack maize plants (Hamd-Alla, 2015) and it was also observed in our experiment. Inclusion of pure stand of cowpea in the crop sequence resulted in more positive effect on soil fertility, compared to its effect when it is intercropped with a soil exhausted crop like maize (Zohry, 2005a). The pure stand of cowpea produced higher yield compared to cowpea intercropped with maize as a result of lower plant density for cowpea, as well as inter-specific competition between cowpea and maize, where maize is the main crop in this system and cowpea is the secondary crop (Dahr et al., 2013). Gharnbari et al., (2010) indicated that cowpea intercropped with maize increased absorbed photosynthetically active radiation. This effect is shown in our experiment, where maize yield was increased, compared to sole maize planting. Furthermore, this intercropping system reduces water evaporation and improves conservation of soil moisture (Gharnbari et al., 2010). For that reason, in our experiment, the applied amount to sole maize was similar to what was applied to cowpea intercropped with maize. Kariaga (2004) concluded that this intercropping system reduced runoff through maintaining ground cover and also it reduced soil erosion.

Our results showed that there was superiority in water productivity for CS3 (only wheat was included), compared to CS1 (both maize and wheat were included) due to the high used amounts of water, which resulted in the highest yield values in both growing seasons. The two legume crops preceded wheat in this crop sequence resulted in higher wheat yield value. CS2 recorded the second with respect to the value of water productivity, where both maize and wheat were included, in addition to short season clover preceded wheat. However, the applied amount of water was the highest, with lower total yield in CU than what was obtained by CS3. In general, Najibnia et al., (2014) indicated that intercropping system was superior in water productivity, compared to sole planting. Thus, the best crop sequence for maize with respect to water productivity was CS4. Thus, it can be concluded that to attain higher yield and water productivity for wheat in new reclaimed soil in Upper Egypt, two legume crops should be cultivated before it. Similarly, to achieve higher yield and water productivity for maize in these types of soils, maize should be intercropped with legume crop, and another legume crop should follow it to benefit from its residual effect in the following growing season. The results of this experiment can be with great benefits to other countries with similar weather and soil conditions in the arid and semiarid regions.

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