UNDER PEER REVIEW

Productivity and land equivalent ratio of intercropping Egyptian cotton with some winter crops in Egypt

ABSTRACT

Two field experiments were carried out at Research Station, El-Sharkia Governorate, ARC, Egypt during 2009/2010 and 2010/2011 seasons to investigate the effect of relay intercropping cotton with some winter cropsas compared with sequentialsolid planting of these crops on the productivity, land equivalent ratio$_s$and net return of these patterns. The experimental treatments were conducted in split plot design with three replications. Two cotton cultivars were grown in the main plots, while cropping systems were allocated in sub plots as followed: relay intercropping cotton with faba bean and wheat at 20th March, faba bean and wheat were grown with low and high plant densities. These treatments were compared with growingcotton after Egyptian cloverat 20th March, 20th April and 20th May, as well as, after faba bean at 20 Apriland after wheat at 20th May.

Results showed that cotton cultivars and the interactions between cotton cultivars and cropping systems had insignificant effects on yield /ha. of preceding crops (faba bean and wheat) while cropping systems had significant effects on yield /ha of wheat and faba bean. Wheat (solid) planting in two rows/ridge (S10) has the highest grain yield / ha of wheat, also, faba bean (solid) in high density hasthe highest inseed yield / ha.On the other hand,there were significant differences between cultivars, cropping systems and their interaction on seed cotton yield per ha.Cotton cultivar Giza 86 had higher values of seed cotton yield per ha. thanGiza 90. Growing cotton plants as followed of E.c or intercropping with faba bean at 20th March gave higher values, also it had the same effects of cotton traits grown in solid plantings at 20th April after faba bean. Growing cotton plants as followed E.c at 20/4 or intercropping with wheat at 20th March had the same effects of cotton traits. The late date planting cotton (20th May) as followed after Egyptian clover or wheat caused highly significant reductions in the studied cotton traits as compared with those grown in the early date. Growing cotton after/with legumes had positive effect on cotton traits in comparison with those followed or intercropped with wheat.Low plant density of faba bean (one row/ridge) or wheat (two rows/ridge) decreased their effects on cotton traits under relay intercropping, meanwhile, the cotton traits was not affected by plant density of faba bean or wheat when cotton was grown after these crops. All intercropping systems gave advantages in (LERs) as compared with sequential cropping systemwhere it ranged from 1.9 to 2.81 of S_2 and S4 respectively..The results revealed that cotton cultivar Giza 86 had higher total and net returns than the other cultivar (Giza 90). In regard to cropping systems, total and net returns of cotton after faba bean at 20th April gave the highest total and net returns while planting cotton after wheat and E.c at 20thMay had lowest values.

INTRODUCTION

In recent years, trends in agricultural production systems have changed towards achieving high productivity and promote sustainability over time as a result of the rapid increase of the population in Egypt. It is known that Egyptian cotton (*Gossypium barbadense* L.) is an important crop for fiber and vegetable oil not only in Egypt but also in the world. However, one of the main problems associated with the Egyptian farmers is escaping from growing cotton in their farms as a result of low cotton productivity after wheat harvest. A gradual reduction of cultivated area of cotton was occurred from448thousand ha. in 1982 to 136thousand ha. in 2012 as a result of high costs of cotton productivity as compared with

UNDER PEER REVIEW

other summer crops,*i.e.*maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Additionaly, wheat (*Triticum aestivum* L.)and faba bean (*Vicia faba*) are grown in Egypt whereasthey are considered as strategic cereal crops and the main.On the other hand, Egyptian clover (*Trifolium alexandrinum*L.) is very important for successful animal production.The cultivated area of wheat, Egyptian clover and faba bean were1,336,788 million,746,787 thousand and 45,362thousandha, respectively **(Bulletin of Statistical Cost Production and Net Return, 2014)**.

To solve the problem efficiently, intercropping cotton is a promising strategy through increasing cropping index and maximizing land use.Intercropping should technically help the agricultural policy to be in the challenge against food crises in Egypt **(Sayed Galal and Metwally 1986 and Metwally, 1999)**.Relay intercropping is a kind ofintercroppingsystems in which two or more crops grew simultaneously during part of the life cycle.

So, it may be possible thatrelay intercropping cotton with wheat or faba bean without tillage. So, it may be possible thatrelay intercropping cotton with wheat or faba bean with no tillage through modified cotton sowing dates could be increased land use and decreased fixed costs.Also, modifying in growing cotton after wheat, Egyptian clover or faba bean could be more remunerative to cotton growers.All intercropping systems with cotton have an advantage in land productivity compared to mono cultures (**Zhang*et al*., 2007**). The present study aimed to investigate the effect of cotton cultivars and cropping systems on the productivityand land equivalent ratio, as well as, net return.

MATERIALS AND METHODS

The present investigation was carried out at Kafr EL-Hamam El-Sharkia governorate, ARC, Egypt, during the two successive seasons 2009/2010 and 2010/2011 to investigate the effect of cotton cultivars and some new cropping systems on the productivity, land equivalent ratio and net return of cotton and somewinter crops.The experiment included twenty two treatments which were the combinations between two cotton cultivars and eleven cropping systems (Table 2). The Egyptian cotton cultivars Giza 86 and Giza 90 were used.The preceding winter crops were wheat (Sakha 93),faba bean (Giza 3) and Egyptianclover(Helaly) were used in the two growing seasons. Some varietal differences of the two tested Egyptian cotton cultivars are presented in Table(1). Cropping systems of growing cotton in relay intercropping or after harvesting winter crops are illustrated in Table (2) and Figure (1). The experiments were carried out in clay loamy soil and the preceding crop was rice in the two seasons before winter crops.

UNDER PEER REVIEW

Table (1).Some varietal differences of the two Egyptian cotton cultivars.

Cotton cultivars	**Giza 86**	**Giza 90**
Pedigree	Cross (Giza 75 x Giza 81)	Cross (Dandra x Giza 83)
Country of origin	Egypt	Egypt
Class –growing areas	North Delta	Middle and Upper Egypt (South)
The 1st node of sympodial branch	7 or 8	6 or 7
Plant height	Tall	Medium (110-140 cm)
Size of boll casings	Medium	Large ($^3/_4$ of boll size)

- **These data were obtained by Cotton Research Institute, F.C.R.I., A.R.C., Giza, Egypt.**

Table (2). Cropping systems of growing cotton in relay intercropping or after harvesting winter crops.

No.	**Cropping system**
S_1	Cotton was planted on one side of the ridge(70 cm) after two cuts of Egyptian clover at 20th March (control).
S_2	Faba bean was planted on one side of the ridge (70 cm) atmid- October and cotton was intercropped with faba bean on the other side of the ridge at 20th March on the next year. This system is called 'relay intercropping cotton with faba bean'.
S_3	Faba bean was planted on two sides of the ridge (70 cm) at mid-October and cotton was intercropped with faba bean on one side of the ridge at 20th March on the next year. Plant density of faba bean was doubled than that of cropping system S_2
S_4	Relay intercropping cotton with wheat, which was planted by two rows on the ridge (70 cm) at mid-November(low density) and cotton was intercropped on one side of the ridge at 20th March on the next year .
S_5	Relay intercropping cotton with wheat as that of system 4, but wheat was grown by three rows on the ridge (high and recommended density)
S_6	Cotton was planted after three cuts of Egyptain clover at 20th April, as that of cropping system S_1
S_7	Planting cotton after harvesting faba bean at 20th April without tillage; wheras,faba bean was grown as that of cropping system S_2.
S_8	Planting cotton after harvesting faba bean at 20th April without tillage; wheras, faba was grown as that of cropping system S_3.
S_9	Cotton was planted after four cuts of Egyptian clover at 20th May.
S_{10}	Planting cotton after harvesting wheat at 20th May without tillage; wheras, wheat was grown as that of cropping system S_4.
S_{11}	Planting cotton after harvesting wheat at 20th May without tillage; wheras, wheat was grown as that of cropping system S_5.

UNDER PEER REVIEW

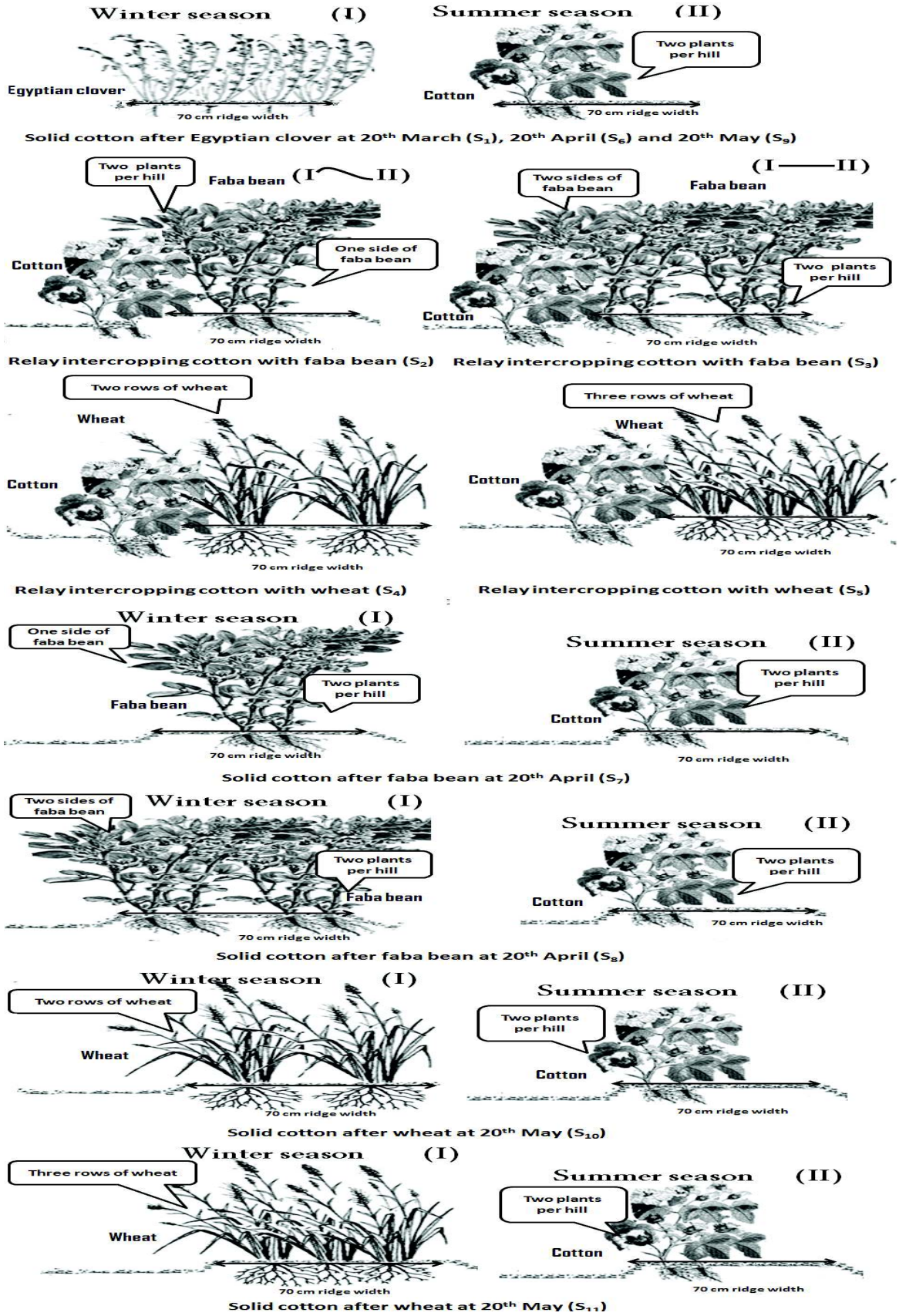


Figure (1). Cropping systems of growing cotton in relay intercropping or after harvesting winter crops.

UNDER PEER REVIEW

Treatments were arranged in a split plot in Randomized complete Block design withthree replications. Cotton cultivars were assigned to the main plots, while cropping systems were allocated in sub plots.Each sub plot consisted of 6 ridges, 5.0 m in length, 0.7 m in width and plot area was 21.0m^2. Other agronomic recommended practices were practiced according to technical recommendations of cotton, wheat, faba bean and Egyptian clover. Cotton cultivars were grown by 142857 plants per ha, while faba bean was planted by 285714 plants per ha in S_3 and S_7 but density at S_2 and S_6reduced to 142857 plants per ha. Egyptian cloverwas drilled by rate of 48.0 kg per ha. Wheat was planted by rate 119kg/ ha(high density) in S_5 and S_9, while S_4 and S_8 was planted by rate 95 kg/ha. (low density). Ten individual guarded plants from cotton, faba bean and wheat were randomly taken from each experimental plot to study yield components. Seed cotton yield per ha was estimated as the weight of seed cotton yield picked from the four middle ridges in plot, then converted to yield per ha. With respect to faba bean seed yield and wheat grains per ha.were estimated from the four middle ridges in sub plots and converted to yield per ha. Forage yield of E. clover per ha. (ton) was estimated as fresh weight of cuttings taken from the sub plot and converted toyield per ha.

The studied traits:

A. Yield

1.Seed cotton yieldper ha (ton).

2.Yieldper ha (ton) of wheat andfaba bean, as well as, forage yield of Egyptian cloverper ha (ton).

B. Competitive relationship

1-Land equivalent ratio (LER)

LER defined as the ratio of area needed under solid cropping to one of intercropping at the same management level to produce an equivalent yield **(Mead and Willey, 1980)**. It is calculated as follows:LER= $(Y_{ab}/Y_{aa})+(Y_{ba}/Y_{bb})$, Where Y_{aa}= pure stand yield of crop a(cotton), Y_{bb} = pure stand yield of crop b(faba bean or wheat),Y_{ab} =intercrop yield of crop a (cotton),

Y_{ba}= intercrop yield of crop b (faba bean or wheat).

UNDER PEER REVIEW

2- Area time equivalent ratio (ATER)

It is calculated according to **Hiebsch and McCollum (1987)** as follows: ATER=(L_aT_a + L_bT_b) / T where, L_a= relative yield of the first crop(wheat or faba bean), T_a= the time of the first crop, L_b = relative yield of the second crop(cotton), T_b= the time of the second crop, T= the time from planting the first crop until harvesting the second crop.

C. Financial return

Farmer's benefit was calculated by determining each of totalreturn, costs and net returns of intercropping cultures, as well as, solid plantings according to **Metwally*et al.* (2009)**

1.Total return/ha (L.E.).

Total return = (yield a x price a + yield b x price b).Theprices were presented by **Bulletin of Statistical Cost Production and Net Return (2013),** as well as, market prices.

2. Net return / ha (L.E.).

Net return / ha = total return – variable costs for both crops in solid and intercropping patterns.

D. Statistical manipulation

The data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split plot design using COSTAT Computer software package. LeastSignificant Difference (L.S.D.) was used to test the differences between treatment means at 5%level of probability as described by **Gomez and Gomez (1984)**.The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimantal seasons was carried out.

RESULTS AND DISCUSSION

1. Seed cotton yield

1.Cotton cultivars

Seed cotton yieldper ha wasaffected significantly by the two cotton cultivars in the combined data across 2010 and 2011 seasons (Table 3). Allover cropping systems,cotton cultivar Giza 86 had higher values for seed cotton yield per ha than Giza 90. These results may be due to some varietal differances of each cultivar which formed its canopy could be interacted with the environmental conditions (Table 1) that reflected finally on seed cotton yield per ha. (Table 3).

So, it is known that differing cotton leaf shapes with varying lobing cause large alterations in the structure of the plant canopy and its ability to intercept light **(Wells and Meredith, 1986)**. Accordingly, cotton cultivr Giza 86could bemore adapted to environmental

UNDER PEER REVIEW

conditions of the experiment such as light intensity and temperature than the other cultivar during boll formation and maturation. These results are in agreement with those of **Hosny et al. (1990), Zhang et al. (2007) and Safina et al. (2014)**.

2.Cropping systems

Seed cotton yield per ha. was affected significantly by cropping systems. Table (3).Growingcotton after Egyptian clover or relay intercropping with faba bean at 20th March (S_1, S_2 and S_3) gave higher values of seed cotton as compared with other cropping systems. Also, relay intercroppingcottonwith faba bean or afterEgyptian clover at 20th March gave significant increases of seed cotton yields per ha than relay intercropping cotton with wheat(S_4 and S_5).

Table (3).Seed cotton yield /ha as affected by cotton cultivars, cropping systems and their interaction (combined data across 2010 and 2011 seasons).

Cropping systems	Seed cotton yield/ha (ton)		
	Giza 86	Giza 90	Mean
(S1) Solid cotton after Egyptian clover at 20th March (2 cuts)	3.46	3.11	3.28
(S2)Intercropping cotton with faba been at low density (one side /ridge) at 20th March	3.59	3.10	3.34
(S3) Intercropping cotton with faba been at high density (two sides/ridge) at 20th March	3.35	2.88	3.11
(S4) Intercropping cotton with wheat at low density (two rows/ridge)at 20th March	3.03	2.31	2.67
(S5)Intercropping cotton with wheat at high density (three rows/ridge)at 20th March	2.76	2.26	2.51
Average of 20th March	**3.23**	**2.73**	**2.98**
(S6)Solid cotton after Egyptian clover at 20th April (3 cuts)	2.68	2.42	2.55
(S7)Solid cotton after faba been at low density (one side/ridge) at 20th April	3.15	2.76	2.95
(S8)Solid cotton after faba been at recommended density (two sides/ridge) at 20th April	3.10	2.81	2.95
Average of 20th April	**2.97**	**2.66**	**2.81**
(S9) Solid cotton after Egyptian clover at 20th May (4 cuts)	1.42	1.47	1.44
(S10) Solid cotton after wheat at low density (two rows/ridge) at 20th May	1.61	1.62	1.61
(S11)Solid cotton after wheat at recommended density (three rows/ridge) at 20th May	1.38	1.53	1.45
Average of 20th May	**1.47**	**1.54**	**1.50**
Average of cropping ystems	**2.68**	**2.38**	**2.53**
Sig.cotton cultivars (A)	**		
L.S.D. 0.05 Cropping systems (B)	**0.58**		
L.S.D. 0.05 Interaction (AB)	**0.82**		

UNDER PEER REVIEW

UNDER PEER REVIEW

These results could be due to the reduction of inter and intra-specific competition between the two species for basic growth resources in relay intercropping cotton withfaba beanas compared with those with wheat. Also, it seems thats faba bean and E.c fixe most of their N requirements from the atmosphere and not compete with cotton for N resource. Management of a crop residue can contribute to increase nutrient cycling and greater crop yields **(Delgado et al., 2007).**In addition to short period of growing both crops through the intercropping systems between faba bean and cotton (a month) as compared to wheat and cotton (2 months)

It is evident from the data that one row of faba bean per ridge (two plants distanced at 20 cm between hills) could be formed suitable spaces for light transmission during the seedling stage of cotton in comparison with those grown with faba bean under highplant density (S_3). It is known that the light environment surrounding plants affects seedling growth **(Schopfer and Plachy, 1984)** and resource use efficiency is not likely to be much affected in intercropping systems with component crops that differ in growing period, since competition between component crops is weak **(Fukai and Trenbath, 1993).**

Growing cotton with wheat increased inter and intra-specific competition between the two species for basic growth resources *i.e*. light, water and nutrients from the sowing cotton at 20th March, until harvesting wheat at20thMay. During this period (about 8 weeks), shading of wheat had adverse effects on cotton plants. This effect was increased by incraesing plant density of wheat from two to three rows per ridge**.**Increasing plant density of wheat may be increase soil nutrients defeciency through its allelopathic effects for cotton growth and development compared withlow density(S_4 and S_8).Allelopathic effects of wheat stubble indirectly influenced seed cotton yield by affecting population densities (**Hicks *et al*., 1989**).Also, three rows of wheat per ridge allowed lower light transmission inside cotton canopy than two wheat rows. Relay intercropping with wheat at 20th March increased seed cotton yield significantly as compared with cotton after E.c and wheat at 20th May, these may be due tolonger period of vegetative growth during available normal environmental conditions to produce more dry matter accumulation through photosynthesis process from stem elongation stage to pollination process as compared with the late date. In this case, planting date of cotton was the most affected factoron seed cotton yield/ ha than intercropping systems.

UNDER PEER REVIEW

3. Respone of cotton cultivars to cropping systems

Seed cotton yields per plant and per ha were affected significantly by theinteraction between the two cotton cultivars and cropping systems (Table 3). Relay intercropping cotton cultivar Giza 86 with low density of faba bean gave the highest value of seed cotton yield per ha than other systems. Also,Cotton cultivar Giza 86 recorded higher seed cotton yields per ha than the other cultivar in all cropping systems except growing it at 20th May after wheat or Egyptian clover. These results revealed that cotton cultivar Giza 90 was more tolerant to delaying sowing date than cultivar Giza 86.

B. Yield production of wheat grains and Faba bean seed

1. Cotton cultivars

In general, there were nosignificant effects ofcotton cultivars on productiviy of wheat and faba bean.

2. Cropping systems

Productivity of wheat crop

Grain yield of wheat per ha were affected significantly by cropping systems (Table 4). Grain yield per ha was decreased significantly under intercropping culture (S_4) and (S_5) compared to solid ones (S_{10} and S_{11}). These results may be due to the competition between cotton and wheat plants for nutrients and available water. These results are in agreement with those obtained by **Zohry (2005), Hussein (2006), Toaima *et al*. (2007), Zhang *et al*. (2007)** and **El-Hawary (2009) .**

With regard to wheat plant densities, there were no significant differences between high and low densities under solid or intercropping systems.

Productivity of faba bean crop

Seed yield per ha was decreased significantly under intercropping culture (S_2) and (S_3) as compared to solid ones, (S_7 and S_8). These results may be due to the competition between cotton and faba bean plants for nutrientsand available water (Table 4).

With respect to faba bean plant densities, seed yield per ha was higher by doubling plant density of faba bean (on both sides) under solid and intercropping cultures($S_3$and S_8)than low plant densities(one side). The increasing in seed yield per ha was quite expected as a result of increasing stand of faba bean as compared by low densiy.Results are in

UNDER PEER REVIEW

agreement with those reported by **El-Douby *et al*. (1996), Hassan and Hafiz (1998), Mokhtar (2001) , El-Metwally *et al*. (2003)and Abdel-Galil *et al*. (2014)** .

3. Respone of the interaction between cotton cultivars and cropping systems

The interaction between cotton cultivars and cropping systems had no significant effects on grain yield ofwheat, as well as, faba bean seed yields (Table 4).

Productivity of Egyptian clover

Forage yield of Egyptian clover recorded 26.19, 41.65 and 57.12 ton/ha of cropping systems (S_1, S_6 and S_9), respectively, as a result of increasing number of cuts and growing cycles.

Table (4).Yield of preceding winter crops (faba bean, wheat and Egyptian clover) as affected by cotton cultivars, cropping systems andtheir interaction (combined data across 2010 and 2011 seasons).

Characters / Cropping systems	Seed yield of faba bean (ton/ha)			Grain yield of wheat (ton/ha)			Forage yield of Egyptian clover (ton/ha)
	Giza 86	Giza 90	Mean	Giza 86	Giza 90	Mean	
Intercropping cotton with faba bean(S_2) / wheat (S_4) at 20th March (low densities)	2.55	2.47	**2.51**	5.00	5.03	**5.01**	---
Intercropping cotton with faba bean(S_3) / wheat (S_5) at 20th March (high densities)	2.84	2.78	**2.81**	4.84	4.87	**4.86**	---
Solid faba bean(S_7) / wheat(S_{10}) at20thApril and 20thMay (low densities)	3.12	3.08	**3.10**	5.22	5.29	**5.25**	---
Solid faba bean(S_8)/ wheat (S_{11}) at20thApril and 20thMay (high densities)	3.27	3.20	**3.23**	5.20	5.14	**5.17**	---
Average	**2.94**	**2.88**	**2.91**	**5.06**	**5.08**	**5.07**	---
Egyptian clover – 2 cuts at 20th March(without cotton)*	---	---	---	---	---	---	**26.19**
Egyptian clover – 3 cuts at 20th April (without cotton)*	---	---	---	---	---	---	**41.65**
Egyptian clover – 4 cuts at 20th May (without cotton)*	---	---	---	---	---	---	**57.12**
Average	---	---	---	---	---	---	**41.65**
Sig.cotton cultivars(A)			N.S.			N.S.	
L.S.D.0.05 Cropping systems (B)			0.21			0.39	1.16
L.S.D. 0.05 Interaction (AB)			N.S.			N.S.	

*Cotton was grown after harvesting E. clover as solid plantings.

UNDER PEER REVIEW

UNDER PEER REVIEW

C. Competitive relationships

Land equivalent ratio (LER)

Yield of relay intercropping cotton with faba bean or wheat compared with solid double cropping of these crops*; i.e.* cotton after faba bean or wheat. Relative yield of intercropping cotton with faba bean or wheat was affected significantly by cotton cultivars (Table 5). Cotton cultivar Giza 86 had higher values of relative seed cotton yield than those of other cultivar (Giza 90).

Relative seed cotton yield of relay intercropping cotton with faba bean was increased significantly than that of sequential cropping system (compare systems S_2 and S_3 with system S_8, Table 5). Also, relative seed cotton yield of intercropping cotton with wheat was increased (178%) as compared by sequential doubling cropping system (100%), (compare systems S_4 and S_5 with system S_{11}). These increments were due to long period of vegetative growth during normal environmental conditions to produce more dry matter accumulation.

Relative seed cotton yield of intercropping cotton with low densities of faba bean or wheat in S_2 and S_4 had higher relative yield of cotton compared to high densities of these crops at S_3 and S_5 systems. These results may be due to little competition effects at low densities of faba bean and wheat.

In regard to relative yields of other crops (faba bean and wheat), relative yield of faba bean and wheat did not affect significantly by cotton cultivars. (Table 5). Relative yield of faba bean was decreased significantly by relay intercropping cotton with it than that of sequential double cropping system (S_2 and S_3 with S_8).

On other side, relative yield of wheat did not differ significantly by relay intercropping cotton as compared by solid culture (S_4 and S_5 with S_{11}). Relative seed yield of faba bean was decreased significantly by decreasing in plant density butit is not true with wheat.

Values of LERs were estimated by using data of relay intercropping compared with solid double cropping systems Table (5).

LER was not affected significantly by cotton cultivars in case of faba bean. But the converse was true with wheat (Table 5 and Figure 2). Cotton cultivar Giza 86 had higher values of LER than that of cultivar (Giza 90).

With respect to faba bean, LER was decreased significantly by intercropping cotton with faba bean (S_2 and S_3) as compared to solid double cropping system (S_8).

In regard to intercropping cotton with wheat, LER increased significantly 74% more than solid double cropping system (S_{11}). (Table 5)

UNDER PEER REVIEW

Intercropping cotton with two rows of wheat (S_4) had higher value of LER compared to cropping system (S_5). These results may be due to growing cottonwith two rows of wheat (S_4) had little negative effects on seed cotton yield per unit area with decreasing inter and intra-specific

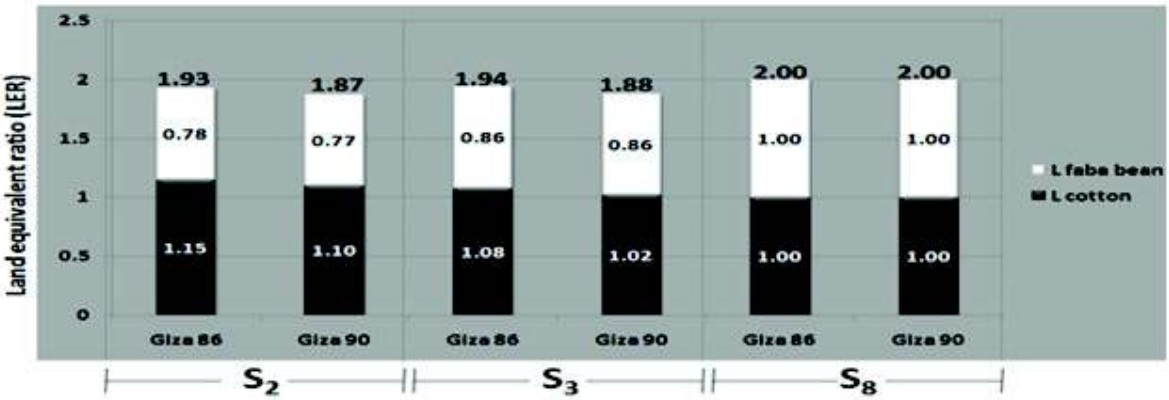
Table 5. Relative yields and LERs of relay intercropped cotton with faba bean and wheat, as compared by double cropping system of winter crops (combined data 2010and 2011 seasons).

Characters	Relative yield						LER		
	L cotton			L other crops					
Cropping systems	Giza 86	Giza 90	Mean	Giza 86	Giza 90	Mean	Giza 86	Giza 90	Mean
Intercropping cotton with faba been (low density)at 20th March (S_2)	1.15	1.10	1.12	0.78	0.77	0.77	1.93	1.87	1. 90
Intercropping cotton with faba been (high density)at 20th March (S_3)	1.08	1.02	1.05	0.86	0.86	0.86	1.94	1.88	1.91
Average	1.11	1.06	1.08	0.82	0.81	0.81	1.93	1.87	1.90
Solid cotton after faba bean (recom. density) at 20th April (S_8)	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Sig.cotton cultivars (A) L.S.D. 0.05 Cropping systems (B) L.S.D. 0.05 Interaction (AB)	* * 0.09			N.S. * N.S.			N.S. * N.S.		
Intercropping cotton with wheat (low density)at 20th March (S_4)	2.19	1.50	1.84	0.96	0.97	0.96	3.15	2.47	2.81
Intercropping cotton with wheat(high density) at 20th March (S_5)	2.00	1.47	1.73	0.93	0.94	0.94	2.93	2.41	2.67
Average	2.09	1.48	1.78	0.94	0.95	0.95	3.04	2.44	2.74
Solid cotton after wheat (recommended density) at 20thMay (S_{11})	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Sig.cotton cultivars (A) L.S.D. 0.05 Cropping systems (B) L.S.D. 0.05 Interaction (AB)	N.S. * N.S.			N.S. N.S. N.S.			* * 0.13		
cotton after Egyptian clover - 2 cuts at 20th March (S_1)	2.43	2.11	2.27	0.45			2.89	2.56	2.72
cotton after Egyptian lover - 3 cuts at 20th April (S_6)	1.88	1.64	1.76	0.72			2.60	2.36	2.48
cotton after Egyptian clover - 4 cuts at 20th May (S_9)	1.00	1.00	1.00	1.00			2.00	2.00	2.00
Sig.cotton cultivars (A) L.S.D. 0.05 Cropping systems (B) L.S.D. 0.05 Interaction (AB)	* * 0.09						* * 0.12		

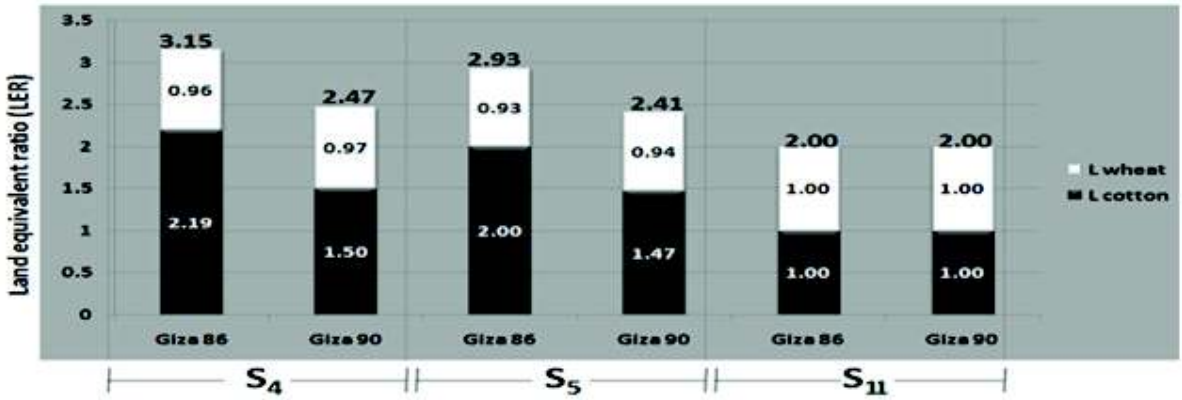
competition between the two species (cotton + wheat).These results are in agreement with those obtained by **(Hosny *et al.,* 1990; Mohamed *et al.*, 1990 and Kamel *et al*., 1991)**.

LER was not affected significantly by the interaction between cotton cultivars and cropping systems in case of faba bean but the converse was true with wheat.LER was decreased more by intercropping cotton cultivar Giza 86 with high density of wheat(S_5) as compared with low densiy.

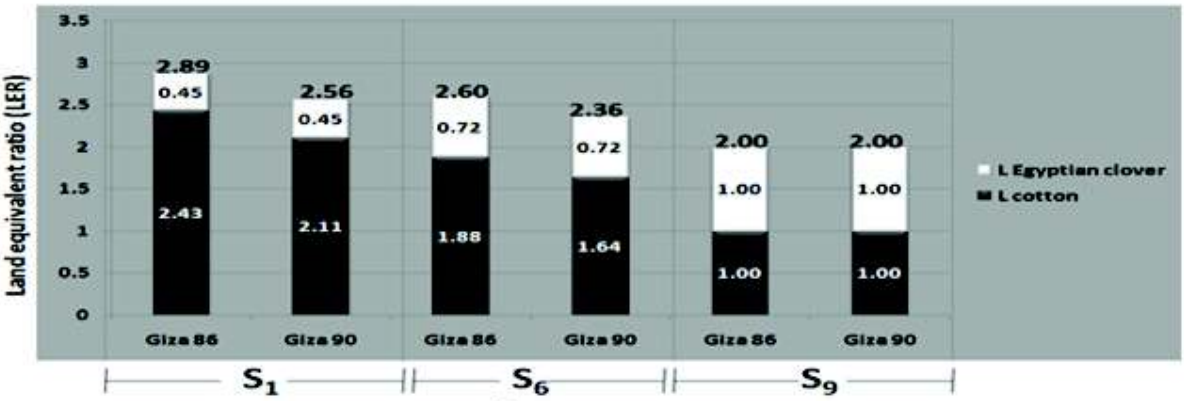
UNDER PEER REVIEW



	Relative yield of cotton	Relative yield of faba bean	LER
L.S.D. 0.05 Cotton cultivars	*	N.S.	N.S.
L.S.D. 0.05 Cropping systems	*	*	*
L.S.D. 0.05 Interaction	0.09	N.S.	N.S.



	Relative yield of cotton	Relative yield of wheat	LER
L.S.D. 0.05 Cotton cultivars	N.S.	N.S.	*
L.S.D. 0.05 Cropping systems	*	N.S.	*
L.S.D. 0.05 Interaction	N.S.	N.S.	0.13



	Relative yield of cotton	LER
L.S.D. 0.05 Cotton cultivars	*	*
L.S.D. 0.05 Cropping systems	*	*
L.S.D. 0.05 Interaction	0.09	0.12

UNDER PEER REVIEW

Figure 2. Relative yields and LERs of relay intercropped cotton with faba bean and wheat, as compared by double cropping system of winter crops (combined data 2010and 2011 seasons).

2- Area time equivalent ratio (ATER)

The ATER is the concept that considers the time factor along with land area. The ATER accurately estimates the biological efficiency which is defined as the rate at which radiant energy is converted to harvestable biological energy the myriad processes that take place in green plants(**Hiebsch and McCollum, 1987**). It is clear that the values of ATER were less than that of LER values.

Table 6. Area time equivalent ratio (ATER) of relay intercropped cotton with faba bean and wheat, as compared by double cropping systems of winter crops (combined data 2010 and 2011 seasons.

Characters	Relative yields						ATER		
	L cotton			L other crops					
Cropping systems	Giza 86	Giza 90	Mean	Giza 86	Giza 90	Mean	Giza 86	Giza 90	Mean
Intercropping cotton with faba bean (low density) at 20th March (S_2)	1.15	1.10	1.12	0.78	0.77	0.77	1.06	1.02	1.04
Intercropping cotton with faba bean (high density) at 20th March (S_3)	1.08	1.02	1.05	0.86	0.86	0.86	1.06	1.02	1.04
Average of intercropping cotton with faba bean	1.11	1.06	1.08	0.82	0.81	0.81	1.06	1.02	1.04
Solid cotton after faba bean (recommended density) at 20th April (S_8)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sig.cotton cultivars (A) L.S.D. 0.05 Cropping systems (B) L.S.D. 0.05 Interaction (AB)		* * 0.09			N.S. * N.S.			N.S. * 0.02	
Intercropping cotton with wheat (low density) at 20th March (S_4)	2.19	1.50	1.84	0.96	0.97	0.96	1.91	1.48	1.69
Intercropping cotton with wheat (high density) at 20th March (S_5)	2.00	1.47	1.73	0.93	0.94	0.94	1.78	1.44	1.61
Average of intercropping cotton with wheat	2.09	1.48	1.78	0.94	0.95	0.95	1.84	1.46	1.65
Solid cotton after wheat (recommended density) at 20th May (S_{11})	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sig.cotton cultivars (A) L.S.D. 0.05 Cropping systems (B) L.S.D. 0.05 Interaction (AB)		* * N.S.			N.S. N.S. N.S.			* * 0.06	

With respect to faba bean crop, ATER was not affected significantly by cotton cultivars (Table 6). But it was affected significantly by cropping systems (Table 6). In general, intercropping cotton with faba bean (S_2 and S_3) had higher ATER compared to (S_8). This mean that yield advantage was produced and land usage efficiency increased by intercropping cotton with faba bean by 4%.ATER was affected significantly by the interaction between cultivars and cropping systems.

With respect to intercropping cotton with wheat crop, ATER was affected significantly by cotton cultivars, cropping systems and the interaction between them. Giza 86 was higher

UNDER PEER REVIEW

than Giza 90(Table 6). Intercropping cotton with two rows of wheat (low density, S_4) had higher ATER values as compared to cropping systems (S_5 and S_{11}) whereas it reached 1.69%. These results may be due to decreasing inter and intra-specific competition between the two species (cotton + wheat) and the same species (wheat), respectively, for basic growth resources (nutrients, water and solar radiation)

D. Farmer's benefit

The results revealed that cotton cultivar Giza86 had higher total and net returns than the cultivar Giza 90. In regard to cropping systems, total and net returns of intercropping cotton or cotton afterfaba bean gave the highest total and net returns*ie*6434.0and 2845.0USD respectively (Tables 7 and 8); while, planting cotton at 20/5 after wheat or E.c were the lowest values in total and net return, *i.e.* (4609.0 and 4423.0) and (1144.0 and 1454.0) USD /ha. in S_{11} and S_9 respectively because production costs of cotton was higher than total return. Intercropping cotton with faba bean at March(S_2 and S_3), as well as, growing cotton as solid planting after faba bean at April(S_7 and S_8) gave higher returns than of cropping systems (S_4 and S_5). Net return of cropping systems depends on the production of crop components as cotton, faba bean, wheat and E.c. Net return of cotton decreased by delaying planting date from March to May. These results were in agreement with those obtained by (**El-Shazly,1992; Seif El-Nasr *et al*., 1996; Hussein, 2006 and Toaima *et al.,* 2007**).

UNDER PEER REVIEW

Treatment	Crops	Total return			Costs		
		Giza 86	Giza 90	mean	Giza 86	Giza 90	mean
Intercroppinng cotton with faba been at low density at 20th March (S_2)	Faba bean	2276.0	2214.0	2245.0	1771.0	1771.0	1771.0
	Cotton	4405.0	3812.0	4108.0	1818.0	1818.0	1818.0
	Total	6682.0	6027.0	6354.0	3589.0	3589.0	3589.0
Intercroppinng cotton with faba been at high density at 20th March (S_3)	Faba bean	2496.0	2454.0	2475.0	1771.0	1771.0	1771.0
	Cotton	4111.0	3531.0	3821.0	1818.0	1818.0	1818.0
	Total	6608.0	5986.0	6297.0	3589.0	3589.0	3589.0
Average	Faba bean	23860	2334.0	2360.0	1771.0	1771.0	1771.0
	Cotton	4258.0	3672.0	3965.0	1818.0	1818.0	1818.0
	Total	6645.0	6006.0	6325.0	3589.0	3589.0	3589.0
Intercroppinng cotton with wheat at low density at 20th March (S_4)	Wheat	2827.0	2878.0	2852.0	1740.0	1740.0	1740.0
	Cotton	3715.0	2832.0	3274.0	1724.0	1724.0	1724.0
	Total	6542.0	5710.0	6126.0	3464.0	3464.0	3464.0
Intercroppinng cotton with wheat at high density at 20th March (S_5)	Wheat	2841.0	2861.0	2851.0	1740.0	1740.0	1740.0
	Cotton	3389.0	2772.0	3081.0	1724.0	1724.0	1724.0
	Total	6230.0	5633.0	5932.0	3464.0	3464.0	3464.0
Average	Wheat	2834.0	2869.0	2851.0	1740.0	1740.0	1740.0
	Cotton	3552.0	2802.0	3177.0	1724.0	1724.0	1724.0
	Total	6386.0	5671.0	6028.0	3464.0	3464.0	3464.0
Solid cotton after faba been at low density at 20th April (S_7)	Faba bean	2711.0	2680.0	2695.0	1771.0	1771.0	1771.0
	Cotton	3872.0	3393.0	3632.0	1818.0	1818.0	1818.0
	Total	6583.0	6073.0	6328.0	3589.0	3589.0	3589.0
Solid cotton after faba been at recommended density at 20th April (S_8)	Faba bean	2826.0	2776.0	2801.0	1771.0	1771.0	1771.0
	Cotton	3812.0	3453.0	3632.0	1818.0	1818.0	1818.0
	Total	6639.0	6229.0	6434.0	3589.0	3589.0	3589.0
Average	Faba bean	2768.0	2728.0	2748.0	1771.0	1771.0	1771.0
	Cotton	3842.0	3423.0	3632.0	1818.0	1818.0	1818.0
	Total	6611.0	6151.0	6381.0	3589.0	3589.0	3589.0
Solid cotton after wheat at low density at 20th May (S_{10})	Wheat	2955.0	2999.0	2977.0	1740.0	1740.0	1740.0
	Cotton	1982.0	1986.0	1984.0	1724.0	1724.0	1724.0
	Total	4937.0	4985.0	4961.0	3464.0	3464.0	3464.0
Solid cotton after wheat at recommended density at 20th May (S_{11})	Wheat	3025.0	3031.0	3029.0	1740.0	1740.0	1740.0
	Cotton	1696.0	1876.0	1786.0	1724.0	1724.0	1724.0
	Total	4721.0	4907.0	4815.0	3464.0	3464.0	3464.0
Average	Wheat	2990.0	3015.0	3003.0	1740.0	1740.0	1740.0
	Cotton	1841.0	1930.0	1885.0	1724.0	1724.0	1724.0
	Total	4831.0	4945.0	4888.0	3464.0	3464.0	3464.0
Solid cotton after Egyptian clover – 2 cuts at 20th March (S_1)	E.C	1321.0	1321.0	1321.0	589.0	589.0	589.0
	Cotton	4253.0	3816.0	4035.0	2159.0	2159.0	2159.0
	Total	5575.0	5138.0	5356.0	2749.0	2749.0	2749.0
Solid cotton after Egyptian clover – 3 cuts at 20th April (S_6)	E.C	1982.0	1982.0	1982.0	809.0	809.0	809.0
	Cotton	3288.0	2975.0	3131.0	2049.0	2049.0	2049.0
	Total	5270.0	4958.0	5114.0	2859.0	2859.0	2859.0
Solid cotton after Egyptian clover – 4 cuts at 20th May (S_9)	E.C	2643.0	2643.0	2643.0	1030.0	1030.0	1030.0
	Cotton	1747.0	1811.0	1779.0	1938.0	1938.0	1938.0

UNDER PEER REVIEW

	Total	**4391.0**	**4455.0**	**4423.0**	**2969.0**	**2969.0**	**2969.0**
Average	**Total**	5834.0	5463.0	5648.0	3344.0	3344.0	3344.0

Table 7.Total return and costs/ha. of cotton and winter crops (faba bean, wheat and Egyptian clover) in Egyptian pounds as affected by cotton cultivars, cropping systems and their interactions.

Prices of main products are that of 2012: ton of cotton=1227.0 USD, ton of wheat=416.0 USD, ton of faba bean =764.0 USD and average forage price per cutting / ha=660.0 USD. ton of Straw crop value wheat = 100.0 USD. Straw crop value faba bean /ha = 324.0 USD.

Table 8. Net returns in Dollar (USD). for two E. cotton cultivars grown under different cropping systems with faba bean, wheat and E.c.

Treatment	Crops	Net return		
		Giza 86	Giza 90	mean
Intercroppinng cotton with faba been at low density at 20th March (S_2)	Faba bean	505.0	443.0	474.0
	Cotton	2587.0	1994.0	2290.0
	Total	3093.0	2437.0	2765.0
Intercroppinng cotton with faba been at high density at 20th March (S_3)	Faba bean	725.0	683.0	704.0
	Cotton	2293.0	1713.0	2003.0
	Total	3018.0	2397.0	2707.0
Average	Faba bean	615.0	563.0	589.0
	Cotton	2440.0	1853.0	2147.0
	Total	3055.0	2417.0	2736.0
Intercroppinng cotton with wheat at low density at 20th March (S_4)	Wheat	1086.0	1137.0	1111.0
	Cotton	1991.0	1108.0	1550.0
	Total	3077.0	2245.0	2661.0
Intercroppinng cotton with wheat at high density at 20th March (S_5)	Wheat	1100.0	1120.0	11100
	Cotton	1665.0	1048.0	1356.0
	Total	2765.0	2168.0	2466.0
Average	Wheat	1093.0	1128.0	1110.0
	Cotton	1828.0	1078.0	1453.0
	Total	2921.0	2206.0	2563.0
Solid cotton after faba been at low density at 20th April (S_7)	Faba bean	940.0	909.0	924.0
	Cotton	2053.0	1575.0	1814.0
	Total	2994.0	2484.0	2739.0
Solid cotton after faba been at recommended density at 20th April (S_8)	Faba bean	1055.0	1005.0	1030.0
	Cotton	1994.0	1635.0	1814.0
	Total	3049.0	2640.0	2845.0
Average	Faba bean	997.0	957.0	977.0
	Cotton	2024.0	1605.0	1814.0
	Total	3021.0	2562.0	2792.0
Solid cotton after wheat at low density at 20th May (S_{10})	Wheat	1214.0	1258.0	1236.0
	Cotton	257.0	262.0	260.0
	Total	1471.0	1520.0	1495.0
Solid cotton after wheat at recommended density at 20th May (S_{11})	Wheat	1284.0	1291.0	1287.0
	Cotton	-27.0	152.0	62.0
	Total	1257.0	1443.0	1350.0
Average	Wheat	1249.0	1274.0	1261.0
	Cotton	117.0	206.0	161.0

UNDER PEER REVIEW

	Total	1366.0	1480.0	1422.0
Solid cotton after Egyptian clover – 2 cuts at 20th March (S_1)	**E.C**	732.0	732.0	732.0
	Cotton	2094.0	1657.0	1875.0
	Total	2826.0	2389.0	2607.0
Solid cotton after Egyptian clover – 3 cuts at 20th April (S_6)	**E.C**	1172.0	1172.0	1172.0
	Cotton	1238.0	926.0	1082.0
	Total	2411.0	2098.0	2255.0
Solid cotton after Egyptian clover – 4 cuts at 20th May (S_9)	**E.C**	1612.0	1612.0	1612.0
	Cotton	-191.0	-126.0	-158.0
	Total	1421.0	1486.0	1454.0
Average	**Total**	2489.0	2118.0	2303.0

CONCLUSION

The finding of this study is useful to increase cotton area in Egypt by intercropping cotton withfaba bean and wheatat 20th March, as well as,planting cotton after faba bean at 20th April, in addition to convential practice of planting coton after E.c at 20th March.

REFERENCES

Abdel-Galil M.A., El-Ghobashy, Y.E. and Lamlom M.M. 2014. Sugar beet productivity and profitability as affected by three cropping systems and mineral nitrogen fertilizer rates. The 8thInt. Conf. Techno. and Sustain. Dev., Third millennium, 22 – 24 November 2014, pp. 161 – 188.

Bulletin of Statistical Cost Production and Net Return, 2013. Summer and Nili Field Crops and Vegetables and Fruit. Agriculture Statistics and Economic Sector, Ministry of Egyptian Agriculture and Land Reclamation", Part (2), August 2013.

Bulletin of Statistical Cost Production and Net Return 2014. Winter Field Crops and Vegetables and Fruit. Agriculture Statistics and Economic Sector, Ministry of Egyptian Agriculture and Land Reclamation", Part (1).

Delgado J.A., Dillon M.A., Sparks R.T. and Essah S.Y.C. 2007. A decade of advances in cover crops: Cover crops with limited irrigation can increase yields, crop quality, and nutrient and water use efficiencies while protecting the environment. J Soil Water Conserv., 62 (5): 110A –117A .

El-Douby K.A., El-Habbak K.E.D., Khalil H.E. and AttiaZahira M. 1996. Effect of some intercropping patterns on growth and yield of corn and soybean. Ann. Agric. Sci., Moshtohor, 34 (3): 919–33.

El-Hawary N.A. 2009. Formulas for relay intercropping andcropsequence systems evaluation. J. Appl. Sci. Res., 15 (2): 2079 – 2082.

El-Metwally, El-M.A; Abdalla, M.M.F;Darwish, D.S and Mohamed, Waffa, K.(2003). Performance of two faba bean cultivars under different plant distribution patterns. Abstract of Proc. 10th National Conf. Agron.,7-10 Oct., El- Arish, Egypt. 24-25.

El-Shazly W.M.O.1992. Studies on cotton growing methods. Ph.D.Thesis, Fac.Agric., Kafr El-Sheihk, Tanta Univ., Egypt, 276 Pp.

Fukai S. and Trenbath B.R. 1993. Processes determining intercrop productivity and yields of component crops. Field Crops Res., 34: 247–271.

UNDER PEER REVIEW

Gomez K.A. and Gomez A.A. 1984. Statistical procedures for agriculture research. 2nd Ed., John Willey and Sons, NewYork, USA.

Hassan, A.A. and Hafiz, Si.I.(1998). Agronomic Characteristics, yield and its components of some field bean cultivars as affected by planting methods and plant spacing. Proc. 8 thConf.Agron., Suez Canal Univ., Ismailia, Egypt, 28-29. Nov.317-325

Hicks S.K., Wendt C.W., Gannaway J.R. and Baker R.B. 1989. Allelopathic effects of wheat straw on cotton germination, emergence and yield. Crop Sci., 29: 1057–1061.

Hosny A.A, Mohamed H.M.A and Aly S.A. 1990. Effect of preceding crops and nitrogen levels on yieldand yieldcomponents of Giza 80 cottonvariety. Ann. Agric. Sci., Moshtohor, 28 (2): 761 – 782.

Hussein Samira M.A. 2006. Performance of cotton and wheat under intercropping planting patterns and nitrogen fertilization. Ann Agric. Sci., Moshtohor, 44 (4): 1385 -1404.

Kamel A.S., El-Habbak K.E., El-Masry M.A., El-Mihi M.M. and Gaber E.A. 1991. Effect of preceding crops and planting methods on growth yield and yield components of cotton. Ann. Agric. ScI.,Moshtohor, 29 (2): 689 – 698.

Mead R. and Willey R.W. 1980. The concept of a "land equivalent ratio" and advantages in yields from intercropping. Exp. Agric., 16: 217 – 28.

Metwally A.A. 1999. Intensive cropping systems in the battle against food crises. Proc. 1stcongress on Recent technologies in Agriculture, Cairo Univ. Fac. Agric. 333-341.

Metwally A.A., Shafik M.M., Sherief M.N. and Abdel-Wahab .2009. Intercropping maize with Egyptian cotton. Egypt. J. Agron., 31 (2): 179 – 197.

Mohamed H.M.H., Hosny A.A. and Aly S.A. 1990. Wheat as preceding crop before cotton. Ann. Agric. Sci., Moshtohor, 28 (2): 783 – 792.

MokhtarSoheir A. 2001.Response yield and yield components of Faba bean (*Viciafaba* L) to increasing levels nitrogen and phosphorus under two levels of plant stand density. Ann Agric. Sci., Ain Shams Univ., Cairo, 46 (1): 143 – 154.

Safina S.A., Noaman A.H. and Metwally A.A. 2014. Performance of Egyptian cotton cultivars under solid and intercropping cultures with Maiza. Int. J. Agric. and Crop Sci., 7 (11): 778 – 785.

SayedGalal Jr. and Metwally A.A. 1986. Science in practice. Proc. 2nd Conf. Agron., Alexandria Univ., 1: 489 – 503.

Schopfer P. and Plachy C. 1984. Control of seed germination by abscisic acid. Plant Physiol., 76: 155 – 160.

Seif El-Nasr F.M, AttiaZahira M., Khalil H.E.; Sharms S.A.A. and Kamel A.S. 1996. Growing long duration wintercrop in cotton rotation. Ann. Agric. Sci., Moshtohor,34 (2): 501 – 512.

Toaima S.E., Gadallah R.A. and Mohamadin E.S.A. 2007. Effect of relay intercropping system on yield and its components of wheat and cotton. Ann. Agric. Sci. AinShams Univ., 52 (2): 317 – 326.

Wells R. and Meredith W.R.J. 1986. Okra leaf normal leaf yield interactions. II. Analysis of vegetative and reproductive growth. Crop Sci., 26: 219 – 228.

Zhang L., Vander Werf W., Zhang L. and Spiertz J.H.J.2007.Growth yield and quality of wheat and cotton in relay strip intercropping system. Field CropRes., 3 (3): 178 – 188.

Zohry A.A. 2005. Effect of relaying cotton on some crops under bio-mineral N fertilization rates on yield and yield components. Ann. Agric. Sci., Moshtohor, 43(1): 89 – 103.