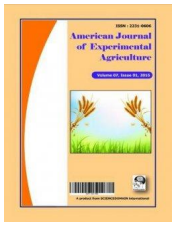

American Journal of Experimental Agriculture
14(1): 1-15, 2016, Article no.AJEA.27523
ISSN: 2231-0606

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Productivity and Land Equivalent Ratio of Intercropping Cotton with Some Winter Crops in Egypt

A. A. Metwally[1*], A. A. Abuldahab[1], M. N. Shereif[2] and M. M. Awad[2]

[1]Department of Agronomy, Faculty of Agriculture, Cairo University, Giza, Egypt.
[2]Department of Crop Intensification Research, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt.

Authors' contributions

This work was carried out in collaboration between all authors. Author AAM designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors AAA and MNS reviewed the experimental design and all drafts of the manuscript and managed the analyses of the study. Author MMA carried out the field experiment and performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2016/27523
Editor(s):
(1) Peter A. Roussos, Lab. Pomology, Agricultural University of Athens, Greece.
Reviewers:
(1) Halil Demir, Akdeniz University, Turkey.
(2) Joyce J Lelei Ndemo, Egerton University Kenya, Kenya.
(3) Addam Kiari Saidou, INRAN, Niamey, Niger.
(4) Mrityunjoy Biswas, Sylhet Agricultural University, Bangladesh.
Complete Peer review History: http://www.sciencedomain.org/review-history/16322

Original Research Article

Received 6th June 2016
Accepted 30th August 2016
Published 24th September 2016

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 crops as compared with sequential solid plantings of these crops on the productivity, land equivalent ratio and net returns from these systems. The split plot design with three replications was used. Two cotton cultivars were grown in the main plots, while cropping systems were allocated in sub-plots as follows: relay intercropping cotton with faba bean and wheat at 20th March, faba bean and wheat were grown with two population densities. These treatments were compared with growing cotton after Egyptian clover each of 20th March, 20th April and 20th May, as well as, faba bean at 20th April and wheat at 20th May in solid plantings. Intercropping cotton with

**Corresponding author: E-mail: drabdmetwally.agric@hotmail.com;*

faba bean and wheat lead to significant reductions in yields of these crops. The results showed that cotton cultivar Giza 86 had higher seed cotton yield than Giza 90. Intercropping cotton with faba bean at 20th March as well gave higher yield, also it had the same effects of cotton characters grown in sequential solid plantings at 20th April after faba bean and after Egyptian clover at 20th March. Intercropping cotton with wheat at 20th March had the same values of cotton characters of traditional culture. Late planting date of cotton (20th May) as followed after Egyptian clover or wheat caused significant reductions in cotton characters as compared with those grown in the early date. Low plant densities of faba bean or wheat decreased their effects on cotton characters under relay intercropping. Also, cotton cultivars and the interactions between cotton cultivars and cropping systems had insignificant effects on yield of preceding crops (faba bean and wheat), while cropping systems had significant effects on yield of wheat and faba bean. Solid planting of wheat in two rows/ridge (S_{10}) has the highest grain yield; also, solid planting of faba bean in high density has the highest seed yield. All intercropping systems gave advantages in LERs as compared with sequential cropping systems where it ranged from 1.9 to 2.81 of S_2 and S_4 respectively. The results revealed that cotton cultivar Giza 86 had higher values of economic returns than cultivar Giza 90.

Keywords: Cropping systems; cotton cultivars; field crops; competitive relationships; economic return.

1. INTRODUCTION

In recent years, trends in agricultural production systems have changed towards achieving high productivity and promote sustainability over time as to meet the need result 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 on their farms in view of low cotton productivity after wheat harvest. A gradual reduction of cultivated area of cotton occurred from 448 thousand ha in 1982 to 136 thousand ha in 2012 as a result of high costs of cotton cultivation as compared with other summer crops, *i.e.* maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Additionaly, wheat (*Triticum aestivum* L.) and faba bean (*Vicia faba* L.) are grown in Egypt whereas they are considered as strategic cereal crops and the main stay as food. 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 were 1,336,788 million, 746,787 thousand and 45,362 thousand ha, respectively [1].

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 [2,3]. Relay intercropping is a kind of intercropping systems in which two or more crops grew simultaneously during part of the life cycle.

So, it may be possible that relay intercropping cotton with wheat or faba bean with no tillage through modified cotton sowing dates could increase land use and decrease 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 [4]. The present study investigated the effect of cotton cultivars and cropping systems on the productivity and land equivalent ratio, as well as, net returns from relay intercropped cotton and some winter crops.

2. MATERIALS AND METHODS

2.1 Treatments of the Study

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 returns of cotton and some winter 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 as planting material. The preceding winter crops were wheat (Sakha 93), faba bean (Giza 3) and Egyptian clover (Helaly) during the two growing seasons. Some varietal differences of the two

tested Egyptian cotton cultivars are as follows: Pedigree (Giza 86, Giza 75 x Giza 81 & Giza 90, Dandra x Giza 83), country of origin (Egypt), class – growing areas (Giza 86, North Delta & Giza 90, Middle and Upper Egypt), the 1st node of sympodial branch (Giza 86, 7 or 8 & Giza 90, 6 or 7), plant height (Giza 86, tall & Giza 90, medium) and size of boll casings (Giza 86, medium & Giza 90, large). Cropping systems of growing cotton in relay intercropping or after harvesting winter crops are illustrated in Table 1 and Fig. 1. The experiments were carried out in clay loamy soil and the preceding crop was rice in the two seasons before winter crops.

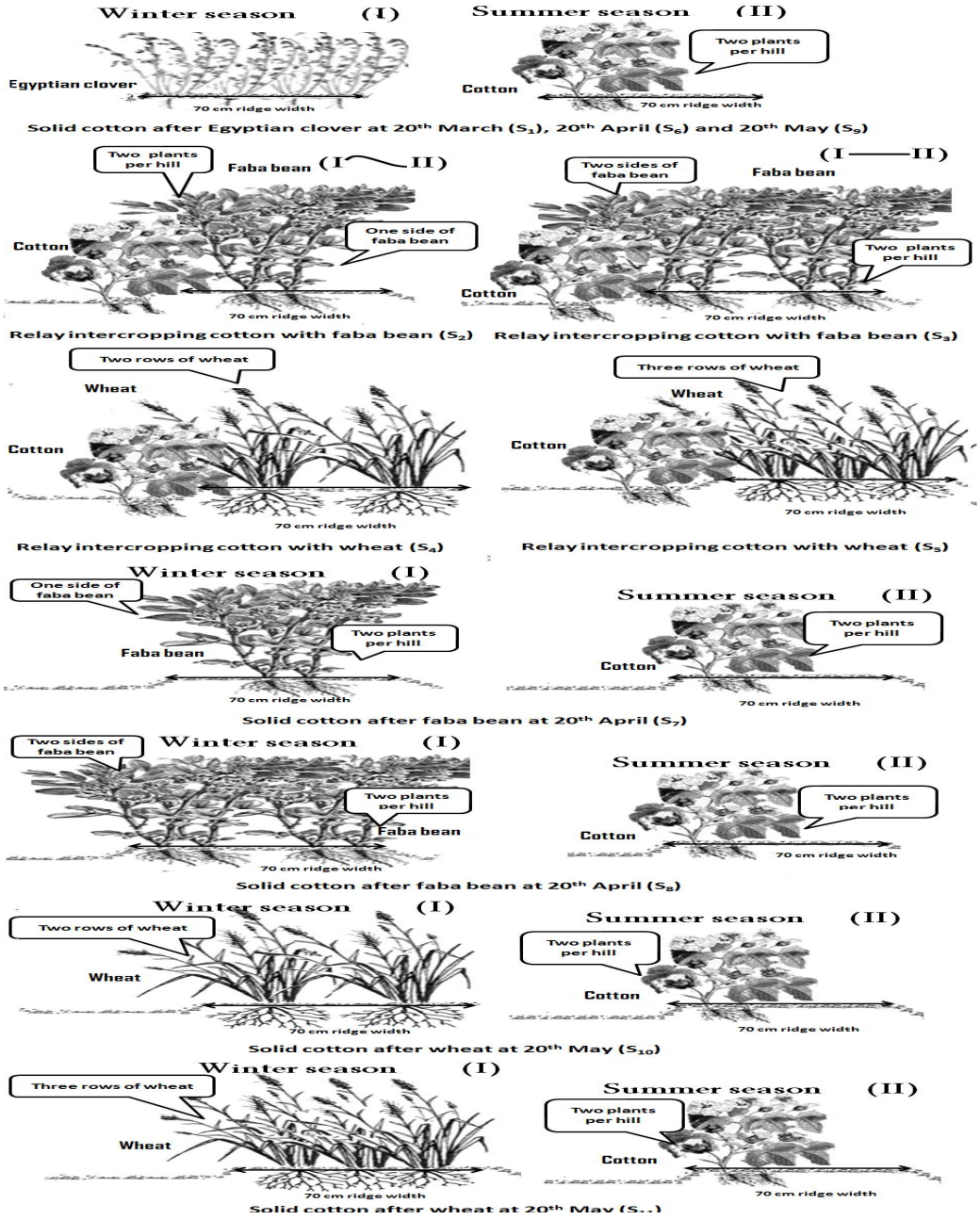

Fig. 1. Cropping systems of growing cotton in relay intercropping or after harvesting winter crops

Table 1. Cropping systems of growing cotton in relay intercropping or after harvesting winter crops

No.	Cropping system
S_1	Cotton planted on one side of the ridge (70 cm) after two cuts of Egyptian clover at 20th March (control)
S_2	Faba bean planted on one side of the ridge (70 cm) at mid- October and cotton intercropped with faba bean on the other side of the ridge at 20th March in the next year. This system is called 'relay intercropping cotton with faba bean'
S_3	Faba bean 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 double than that of cropping system S_2
S_4	Relay intercropping cotton with wheat, which was planted in 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 in the next year
S_5	Relay intercropping cotton with wheat as that of system 4, but wheat was grown in three rows on the ridge (high and recommended density)
S_6	Cotton 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 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

Treatments were arranged in a split plot design with three 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 21.0 m^2. Other agronomic recommended practices were practiced according to technical recommendations of cotton, wheat, faba bean and Egyptian clover. Cotton cultivars were grown by 142,857 plants per ha, while faba bean was planted by 285,714 plants per ha in S_3 and S_7, but density at S_2 and S_6 reduced to 142,857 plants per ha. Egyptian clover was drilled by rate of 48.0 kg/ ha. Wheat was planted by rate 119 kg/ 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 Egyptian clover per ha (t) was estimated as fresh weight of cuttings taken from the sub plot and converted to yield per ha.

2.2 The Studied Characters

2.2.1 Yield

1. Seed cotton yield (t/ha).
2. Yields (t/ha) of wheat and faba bean, as well as, forage yield of Egyptian clover (t/ha).

2.2.2 Competitive relationships

2.2.2.1 Relative yield and land equivalent ratio (LER)

It is calculated as follows as according to [5]: 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).

2.2.2.2 Area time equivalent ratio (ATER)

It is calculated according to [6] 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.

2.2.3 Economic performance

Farmer's benefit was calculated by determining each of total return, costs and net returns of intercropping cultures, as well as, solid plantings according to [7]:

2.2.3.1 Total return / ha (USD)

Total return = (yield a x price a + yield b x price b). The prices were presented by [8], as well as, market prices.

2.2.3.2 Net return / ha (USD)

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

2.3 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. Least Significant Difference (LSD) was used to test the differences between treatment means at 5% level of probability as described by [9]. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimantal seasons was carried out.

3. RESULTS AND DISCUSSION

3.1 Seed Cotton Yield

3.1.1 Cotton cultivars

Seed cotton yield was affected significantly by the two cotton cultivars in the combined data across 2010 and 2011 seasons (Table 2). In all cropping systems, cotton cultivar Giza 86 had higher seed cotton yield than Giza 90. These may be due to some varietal differances of each cultivar which formed its canopy could be interacted with the environmental conditions that reflected finally on seed cotton yield (Table 2).

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 [10]. Accordingly, cotton cultivar Giza 86 was more adapted to environmental conditions of the experiment because it has some genetic characters which suitable for environmental conditions of North and East Delta such as light intensity and temperature than cotton cultivar Giza 90 during boll formation and maturation. These results are in agreement with those of [11,4,12] who showed that cotton cultivar Giza 86 gave high yield than Giza 90 under environmental conditions of Giza, Egypt.

3.1.2 Cropping systems

Seed cotton yield was affected significantly by cropping systems (Table 2). Growing cotton with faba bean by relay intercropping system at 20th March or sequential double cropping system at 20th April gave significant increases in seed cotton yield as compared to the corresponding cropping system of wheat. Also, low density of faba bean (S_2) caused insigificant increment of cotton production (compare between S_2 and S_3)

These results could be due to relay intercropping cotton with faba bean decreased inter-specific competition between the two species for basic growth resources as compared with those of wheat. Also, it seems that faba bean and Egyptian clover fixed most of their N requirements from the atmosphere and do not compete with cotton for N resource. Management of a crop residue can contribute to increase nutrient cycling and greater crop yields [13]. 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 results that one row of faba bean per ridge (two plants distanced at 20 cm between hills) could provide suitable space for light transmission during the seedling stage of cotton in comparison to those grown with faba bean under high plant density (S_3). It is known that the light environment surrounding plants affects seedling growth [14] 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 [15].

Growing cotton with wheat increased inter - specific competition between the two species for basic growth resources, *i.e.* light, water and nutrients from the sowing of cotton at 20th March, until harvesting wheat at 20th May. During this period (about 8 weeks), it is quite expected that

shading of wheat plants had adverse effects on cotton growth and davelopment. This effect was increased by incraesing plant density of wheat from two to three rows per ridge. Increasing plant density of wheat may led to increase in soil nutrients defeciency through its allelopathic effects for cotton growth and development compared with low density (S_4 and S_8). Also, three rows of wheat per ridge seem to be allowed lower light transmission inside cotton canopy than two wheat rows. Relay intercropping cotton with wheat at 20th March increased seed cotton yield significantly as compared with sequential double cropping system of cotton after Egyptian clover and wheat at 20th May. Clearly, these results may be due to relay intercropping cotton with wheat at 20th March furnished suitable environmental conditions that had longer period of vegetative growth to produce more dry matter accumulation through enhancing the effeciency of photosynthetic process from stem elongation stage to pollination process as compared with the late date of 20th May.

3.1.3 Response of cotton cultivars to cropping systems

Seed cotton yields per plant and per ha were affected significantly by the interaction between the two cotton cultivars and cropping systems (Table 2). Relay intercropping cotton cultivar Giza 86 with low density of faba bean gave the highest value of seed cotton yield than other systems. Also, cotton cultivar Giza 86 recorded higher seed cotton yields than the other cultivar in all cropping systems except growing it in sequential systems at 20th May after wheat or Egyptian clover. These results reveal that cotton cultivar Giza 90 was more tolerant for delaying sowing date than cultivar Giza 86.

Table 2. Seed cotton yield (t/ha) as affected by cotton cultivars, cropping systems and their interaction (combined data across 2010 and 2011 seasons)

Cropping systems	Seed cotton yield (t/ha)		
	Giza 86	Giza 90	Mean
(S_1) Solid cotton after Egyptian clover at 20th March (2 cuts)	3.46	3.11	3.28
(S_2) Intercropping cotton with faba been at low density (one side /ridge) at 20th March	3.59	3.10	3.34
(S_3) Intercropping cotton with faba been at high density (two sides/ridge) at 20th March	3.35	2.88	3.11
(S_4) Intercropping cotton with wheat at low density (two rows/ridge) at 20th March	3.03	2.31	2.67
(S_5) 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
(S_6) Solid cotton after Egyptian clover at 20th April (3 cuts)	2.68	2.42	2.55
(S_7) Solid cotton after faba been at low density (one side/ridge) at 20th April	3.15	2.76	2.95
(S_8) 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
(S_9) Solid cotton after Egyptian clover at 20th May (4 cuts)	1.42	1.47	1.44
(S_{10}) Solid cotton after wheat at low density (two rows/ridge) at 20th May	1.61	1.62	1.61
(S_{11}) 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 systems	2.68	2.38	2.53
Sig.cotton cultivars (A)			**
LSD 0.05 Cropping systems (B)			0.58
LSD 0.05 Interaction (AB)			0.82

3.2 Yield of Wheat Grains and Faba Bean Seeds

3.2.1 Cotton cultivars

There were no significant effects of cotton cultivars on the productiviy of winter crops (wheat and faba bean).

3.2.2 Cropping systems

3.2.2.1 Productivity of wheat crop

Grain yield of wheat were affected significantly by cropping systems (Table 3). 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 high competition between cotton and wheat plants for light, nutrients and available water. These results are in agreement with those obtained by [16,17,18,4,19].

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

3.2.2.2 Productivity of faba bean crop

Seed yield 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 inter-specific competition between cotton and faba bean plants for light, nutrients and available water (Table 3).

With respect to faba bean plant density, seed yield 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 density (one side). The increasing in seed yield was quite expected as a result of increasing stand of faba bean as compared by low densiy. The results are in agreement with those reported by [20,21,22,23,24].

3.2.3 Response of cotton cultivars to cropping systems

The interaction between cotton cultivars and cropping systems had non-significant effects on grain yield of wheat, as well as, faba bean seed yields (Table 3).

3.3 Productivity of Egyptian Clover

In Egypt, cotton and Egyptian clover are grown in sequential solid cropping system at different planting dates for cotton from March to May. Forage yield of Egyptian clover recorded 26.19, 41.65 and 57.12 t/ha of cropping systems (S_1, S_6 and S_9), respectively, as a result of increasing number of cuts and growing cycles (Table 3).

3.4 Competitive Relationships

3.4.1 Relative yield and land equivalent ratio (LER)

Relative yield of intercropping cotton with faba bean or wheat was affected significantly by cotton cultivars (Table 4). Cotton cultivar Giza 86 had higher values of relative seed cotton yield than the 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 4) where it reached 8%. The corresponding value of intercropping cotton with wheat increased to 178% as compared to 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 and yield production.

Also, relative seed cotton yield of intercropping cotton with low density of faba bean or wheat in S_2 and S_4 systems had higher values as compared to high densities of these crops at S_3 and S_5 systems. These results may be due to there was low inter-specific competition between cotton and faba bean or between cotton and wheat for basic growth resources at low density.

In regard to relative yields of winter crops (faba bean and wheat), relative yield of faba bean and wheat was not affected significantly by cotton cultivars (Table 4). Relative yield of faba bean was decreased significantly 20% by relay intercropping with cotton than that of sequential double cropping system (S_2 and S_3 with S_8). On the other hand, relative yield of wheat did not differ significantly by relay intercropping cotton as compared to solid culture (S_4 and S_5 with S_{11}).

Values of LERs were estimated by using data of relay intercropping compared with solid double cropping systems of those crops (Table 4). LER was not affected significantly by cotton cultivars in case of faba bean, but the converse was true with wheat (Table 4). Generally, cotton cultivar Giza 86 had higher values of LER than those of

Table 3. Yield of preceding winter crops (faba bean, wheat and Egyptian clover) as affected by cotton cultivars, cropping systems and their interaction (combined data across 2009/2010 and 2010/2011 seasons)

Characters	Seed yield of faba bean (t/ha)			Grain yield of wheat (t/ha)			Forage yield of Egyptian clover (t/ha)
Cropping systems	**Giza 86**	**Giza 90**	**Mean**	**Giza 86**	**Giza 90**	**Mean**	
Intercropping cotton with faba bean (S_2) / wheat (S_4) at 20th March (low density)	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 density)	2.84	2.78	2.81	4.84	4.87	4.86	---
Solid faba bean(S_7) / wheat(S_{10}) at 20th April and 20th May (low density)	3.12	3.08	3.10	5.22	5.29	5.25	---
Solid faba bean(S_8)/ wheat (S_{11}) at 20thApril and 20th May (high density)	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.			
LSD 0.05 Cropping sys (B)	0.21			0.39			1.16
LSD 0.05 Interaction (AB)	N.S.			N.S.			

**Cotton was grown after harvesting Egyptian clover as solid plantings*

cultivar (Giza 90). It is important to mention that varietal differences between the cotton cultivars played a major role in LER value under environmental conditions of the study.

With respect to faba bean, LER was decreased significantly 10% by intercropping cotton with faba bean (S_2 and S_3) as compared to sequential double cropping system (S_8). In regard to intercropping cotton with wheat, LER increased significantly 74% than that of sequential double cropping system "S_{11}" (Table 4). It seems that the sowing date of faba bean had adverse effects on seed cotton yield per ha compared to the sowing date of wheat under intercropping conditions. These results could be due to the planting date of wheat furnished suitable plant growth resources for cotton which could reflect on high seed germination, the timely appearance of seedling and the optimum development of the root system in comparison with the other dates. On the other hand, LER was not affected by the interaction between cotton cultivars and cropping systems in case of faba bean but the converse was true with wheat or after Egyptian clover. Intercropping cotton cultivar Giza 86 with low plant density of wheat (S_4) gave the highest LER as compared with the others. These data indicate that cropping systems responded differently to cotton cultivars for LER.

3.4.2 Area time equivalent ratio (ATER)

Results of ATER were calculated according to [6]. Values of ATER were less than LER. With respect to faba bean crop, ATER was not affected significantly by cotton cultivars, but it was affected significantly by cropping systems (Table 5). In general, intercropping cotton with wheat (S_4 and S_5) had higher ATER compared to sequential double cropping system (S_{11}). Also, intercropping cotton with faba bean (S_2 and S_3) had higher values of ATER compared to sequential double cropping system (S_8). This mean that yield advantage was exhibited and land usage efficiency was increased by 65 and 4% in relay intercropping cotton with wheat or faba bean, respectively. Obviously, sowing date of intercrops played a major role in their relative yields.

Table 4. Relative yields and LERs of relay intercropped cotton with faba bean and wheat, as compared by double cropping system of winter crops (combined data 2009/2010 and 20101/2011 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 (recommended 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)		*			N.S.			N.S.	
LSD 0.05 Cropping systems (B)		*			*			*	
LSD 0.05 Interaction (AB)		0.09			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)		N.S.			N.S.			*	
LSD 0.05 Cropping systems (B)		*			N.S.			*	
LSD 0.05 Interaction (AB)		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)		*						*	
LSD 0.05 Cropping systems (B)		*						*	
LSD 0.05 Interaction (AB)		0.09						0.12	

Table 5. 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 2009/2010 and 2010/2011 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)		*			N.S.			N.S.	
LSD 0.05 Cropping systems (B)		*			*			*	
LSD 0.05 Interaction (AB)		0.09			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)		*			N.S.			*	
LSD 0.05 Cropping systems (B)		*			N.S.			*	
LSD 0.05 Interaction (AB)		N.S.			N.S.			0.06	

Table 6. 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

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

Treatment	Crops	Total return			Costs		
		Giza 86	Giza 90	Mean	Giza 86	Giza 90	Mean
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)	Egyptian clover	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)	Egyptian clover	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)	Egyptian clover	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
	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

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 7. Net returns in Dollar (USD) for two Egyptian cotton cultivars grown under different cropping systems with faba bean, wheat and Egyptian clover

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
	Total	1366.0	1480.0	1422.0
Solid cotton after Egyptian clover – 2 cuts at 20th March (S_1)	Egyptian clover	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)	Egyptian clover	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)	Egyptian clover	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

ATER was influenced significantly by the interaction between cultivars and cropping systems. Intercropping cotton cultivar Giza 86 with low density of wheat (S_4) gave the highest ATER compared to the others. These results may be attributed to relative yield of Giza 86

interacted positively with low wheat plant density per unit area.

With respect to intercropping cotton with wheat, values of ATER were affected significantly by cotton cultivars, cropping systems and the interaction between them. Giza 86 had higher values of ATER than Giza 90 (Table 5). 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).

3.5 Economic Performance

The results revealed that cotton cultivar Giza 86 had higher values of total and net returns than cotton cultivar Giza 90. In regard to cropping systems, total and net returns of intercropping cotton after faba bean gave higher values of total and net returns (Tables 6 and 7); while, planting cotton on 20th May, harvesting gave lower values in total and net returns, *i.e.* 4,609.0 and 4,423.0, and 1,144.0 and 1,454.0 USD /ha in S_{11} and $S_{9,}$ respectively.

Net returns from cropping systems depend on the total production of crop components of cotton, faba bean, wheat and Egyptian clover, as well as, variable and fixed costs. Net return of cotton decreased with delay in planting from March to May. These results were in agreement with those obtained by [25,26,17,18].

4. CONCLUSION

The finding of this study is useful to increase cotton production in Egypt by relay intercropping cotton with faba bean and wheat at 20th March and growing cotton after faba bean at 20th April. These cropping systems produced high production of seed cotton with good quality, in addition to the increases of land equivalent ratio and economic returns. These new cropping systems will encourge Egyptian farmers to grow cotton in their fields.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/16322