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IMPACT OF DIFFERENT CROPPING SYSTEMS ON SEED YIELD AND QUALITY OF EGYPTIAN COTTON

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Abstract

In recent years, scientific studies have focused extensively on saturated fatty acid reduction in edible oils and potential benefits of unsaturated fatty acids with respect to health outcomes. A two-year study was carried out at Sids Agricultural Research Station, Beni Sweif government, Agricultural Research Center (ARC), Egypt, during 2015/2016 and 2016/2017 seasons to evaluate seed, protein and oil yields, as well as oil quality of Egyptian cotton under different cropping systems. The treatments were the combinations between four winter cropping systems (double cropping systems of Egyptian clover and cotton, relay intercropping cotton with faba bean, onion or wheat) and three summer cropping systems (sole cotton, intercropping cowpea or sesame with cotton). The treatments were compared in a split plot design with three replications. In the winter season, the legumes had positive effects on seed cotton yield and 100-seed weight, meanwhile intercropping cotton with wheat caused significant reduction in seed cotton yield and 100-seed weight than others. In the summer season, Intercropping cowpea with cotton did not affect significantly seed cotton yield and 100-seed weight compared to sole cotton, meanwhile intercropping sesame with cotton had negative effects on seed cotton yield and 100-seed weight. The interaction between winter and summer cropping systems was significant for 100-seed weight in the second season only. In the winter season, the legumes increased protein and oil yields of cotton plants. In the winter season, intercropping cotton with wheat or onion significantly increased plamitic and stearic acids in cotton seed oil compared to others. In the summer season, sole cotton resulted in an increase in saturated fatty acids in cotton seed oil compared to intercropped cotton with sesame. Intercropping sesame with cotton significantly increased oleic and linoleic acids in cotton seed oil. The interaction between winter and summer cropping systems was significant for seed protein and oil contents in cotton plants. Intercropping sesame with cotton after Egyptian clover cutting achieved high seed cotton, protein and oil yields per ha with an increase in unsaturated fatty acids of edible oil.

Key words : Cotton, Cropping systems, Seed yield, Protein yield, Oil yield, Oil composition.

Introduction

Cotton (*Gossypium barbadense* L.) is valued for its oil (15 - 20%) which are used as vegetable oil and soap industries and cotton seed cake is very protein rich cotton seed cake used as cattle feed and as manure. Cotton seed oil is an important source of fat. According to Downey and Rimmer (1993), low content of saturated fatty acids is desirable for edible uses, and higher levels of linoleic acid and oleic acid are considered good for oil quality. Although higher levels of saturated fatty acids contribute functionality in food systems, they also contribute negatively to serum cholesterol profiles (Zock *et al.*, 1994). Cotton seed oil can be partially hydrogenated, which reduces the level of 18:2 and improves the oil's stability, but the process also forms undesirable trans-fatty acids that raise serum low-density lipoprotein cholesterol levels (Sacks and Katan, 2002). Moreover, Dowd *et al.*, (2010) showed that the oxidative stability of cotton seed oil can be lower than for other vegetable oils because of its high concentration of linoleic acid (18:2). They added that the concentration of palmitic acid (16:0), a saturated fatty acid, is higher in cotton seed oil (~24%) than in many other vegetable oils. Also, cotton seed meal is classed as a protein supplement in the feed trade; it is almost as important as soybean meal. Particularly, the amount of linters left on the seeds varies from 4 to 8%, except for seeds of Egyptian cotton varieties, such as the American Pima cotton, which are naturally without linters (NCPA, 2012).

According to Longhurst (2018), cotton seed oil contains high concentrations of vitamin E, fatty acids, and antioxidants that have many benefits for human skin including moisturizing, anti-aging and anti-inflammatory properties. Certain fatty acids increase your skin’s permeability. This allows your skin to better absorb other ingredients for better results. Linoleic acid, which is one of the fatty acids in cottonseed oil, is a common ingredient in skin care products. It’s also used in antidandruff shampoos and after-sun creams because of its anti-inflammatory properties. The unsaturated fats in cottonseed oil may help lower your LDL (low-density lipoproteincholesterol ‘bad cholesterol’) and increase your HDL (high-density lipo-protein-cholesterol ‘good cholesterol’). This can improve blood pressure and reduce the risk of heart disease and stroke. However, cotton seed oil is also higher in saturated fat than other vegetable oils, which can have the opposite effect. There are other, more heart-friendly options available. Thus, intercropping could consider to be an effective and potential way of increasing quality of cotton seed oil. Intercropping can help in increasing crop productivity particularly at small farms of Egypt (Metwally, 1999). Cotton production can be increased by horizontally or by vertically because total crop productivity and net return per unit area are higher in intercropping than sole culture. Therefore, the objective of this investigation was to evaluate seed, protein and oil yields, as well as oil quality of Egyptian cotton under different cropping systems.

Materials and Methods

A two-year study was carried out at Sids Agricultural Research Station, Beni Sweif governorate (Lat. 29°12' N, Long. 31°01' E, 32 m.a.s.l.), Egypt, during 2015/2016 and 2016/2017 seasons. Chemical analyses of the soil (0-30 cm) were done by Water, Soil and Environment Research Institute, ARC (Table 1) according to Jackson (1958) and Chapman and Pratt (1961) before growing of the winter crops. Soil texture is clay. Furrow irrigation was the irrigation system in the region. Cultivars of winter field crops were Giza 6 for Egyptian clover, Giza 843 for faba bean, Giza 6 improved for onion and Misr 1 for wheat. Cultivars of summer filed crops were Giza 95 “ extra-long staple” for cotton, Cream 1 for cowpea and Shandweel 3 for sesame. Egyptian clover and cowpea seeds were kindly provided by Forage Crops Research Department, Field Crops Research Institute, ARC. Faba bean seeds were kindly provided by Food Legumes Research Department, Field Crops Research Institute, ARC. Onion transplants were kindly provided by Onion Research Department in Sids Agricultural Research Station, Field Crops Research Institute, ARC. Wheat grains were kindly provided by Wheat Research Department, Field Crops Research Institute, ARC. Cotton seeds were kindly provided by Cotton Research Institute, ARC. Sesame seeds were kindly provided by Oil Crops Research Department, Field Crops Research Institute, ARC.

Table 1: Soil chemical properties of Sids location before growing the winter crops in the two seasons.

Depth (0 – 30 cm)	Growing season	
	First season	Second season
pH	8.10	8.55
Available N ppm	12.60	13.70
Available P ppm	26.00	25.00
Available K ppm	178.00	163.00

In the two winter seasons, Egyptian clover and faba bean seeds were inoculated by *Rhizobium trifolii* and *Rhizobium leguminosarum*, respectively, before seeding it and Arabic gum was used as a sticking agent. In the two summer seasons, cowpea seeds were inoculated by *Rhizobium melitota* before seeding it and Arabic gum was used as a sticking agent. Calcium super phosphate (15.5% P_2O_5) was applied at rate of 476 kg per ha during soil preparation in the two winter seasons. Mineral N fertilizer was applied at rate of 35.7 kg N per ha for Egyptian clover, 17.8 and 35.7 kg N per ha for faba bean, 191.3 and 285.6 kg N per ha for onion and 119.5 and 178.5 kg N per ha for wheat under intercropping and sole cultures, respectively. Also, mineral N fertilizer for cotton plants was applied at rate of 142.8 kg N per ha in two equal doses at 45 and 60 days from cotton sowing, meanwhile mineral N fertilizer for cowpea plants was applied at rate of 17.8 and 35.7 kg N per ha under intercropping and sole cultures, respectively, in one equal dose at 25 days from cowpea sowing. Mineral N fertilizer for sesame plants was applied at rate of 35.7 and 71.4 kg N per ha under intercropping and sole cultures, respectively, in two equal doses at 25 and 40 days from sesame sowing. Mineral K fertilizer was applied for all the tested crops as recommended for each crop. (Table 2) shows sowing and harvest dates of winter and summer field crops in the two growing seasons.

The experiment included twelve cropping systems

Table 2: Sowing and harvest dates of all the studied field crops in the two seasons.

Crop	Season			
	First season		Second season	
	Sowing date	Harvest date	Sowing date	Harvest date
Egyptian clover	21st October	11th March	18th October	7th March
Faba bean	21st October	29th April	18th October	26th April
Onion	21st October	14th April	18th October	12th April
Wheat	21st October	8th May	18th October	5th May
Cotton	22nd March	16th September	18th March	13th September
Cowpea	14th May	27th July	11th May	24th July
Sesame	14th May	30th August	11th May	28th August

(Fig. 1) as follows:

Egyptian clover seeds were broadcasted at the rate of 47.6 kg per ha. After the third cutting of Egyptian clover, cotton seeds were grown in two sides of the bed, two plants together distanced at 25 cm. This cropping system was expressed as Egyptian clover/cotton in the winter season and sole cotton in the summer season (conventional cropping system).

Egyptian clover seeds were broadcasted at the rate of 47.6 kg per ha. After the third cutting of Egyptian clover, cotton seeds were grown in two sides of the bed, two plants together distanced at 25 cm. Two rows of cowpea seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as Egyptian clover/cotton in the winter season and cotton+cowpea in the summer season.

Egyptian clover seeds were broadcasted at the rate of 47.6 kg per ha. After the third cutting of Egyptian clover, cotton seeds were grown in two sides of the bed, two plants together distanced at 25 cm. One row of sesame seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as Egyptian clover/cotton in the winter season and cotton+sesame in the summer season.

Two rows of faba bean seeds were grown in middle of the bed, two plants together distanced at 15 cm. Cotton seeds were grown in two sides of faba bean beds, two plants together distanced at 25 cm. This cropping system was expressed as faba bean+cotton in the winter season. After faba bean harvest, cotton continued alone in the summer season (sole cotton).

Two rows of faba bean seeds were grown in middle of the bed, two plants together distanced at 15 cm. Cotton seeds were grown in two sides of faba bean beds, two plants together distanced at 25 cm. Two rows of cowpea seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as faba bean+cotton in the winter season and cotton +cowpea in the summer season.

Two rows of faba bean seeds were grown in middle of the bed, two plants together distanced at 15 cm. Cotton seeds were grown in two sides of faba bean beds, two plants together distanced at 25 cm. One row of sesame seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as faba bean+cotton in the winter season and cotton+sesame in the summer season.

Four rows of onion transplants were grown in middle of the bed, one plant distanced at 10 cm. Cotton seeds were grown in two sides of onion beds, two plants together distanced at 25 cm. This cropping system was expressed as onion+cotton in the winter season. After onion harvest, cotton continued alone in the summer season (sole cotton).

Four rows of onion transplants were grown in middle of the bed, one plant distanced at 10 cm. Cotton seeds were grown in two sides of onion beds, two plants together distanced at 25 cm. Two rows of cowpea seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as onion+cotton in the winter season and cotton +cowpea in the summer season.

Four rows of onion transplants were grown in middle of the bed, one plant distanced at 10 cm. Cotton seeds were grown in two sides of onion beds, two plants together distanced at 25 cm. One row of sesame seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as onion+cotton in the winter season and cotton+sesame in the summer season.

Four rows of wheat grains were drilled at the rate of 119.0 kg per ha in middle of the bed. Cotton seeds were grown in two sides of wheat beds, two plants together distanced at 25 cm. This cropping system was expressed as wheat+cotton in the winter season. After wheat harvest, cotton continued alone in the summer season (sole cotton).

Four rows of wheat grains were drilled at the rate of 119.0 kg per ha in middle of the bed. Cotton seeds were grown in two sides of wheat beds, two plants together distanced at 25 cm. Two rows of cowpea seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as wheat+cotton in the winter season and cotton+cowpea

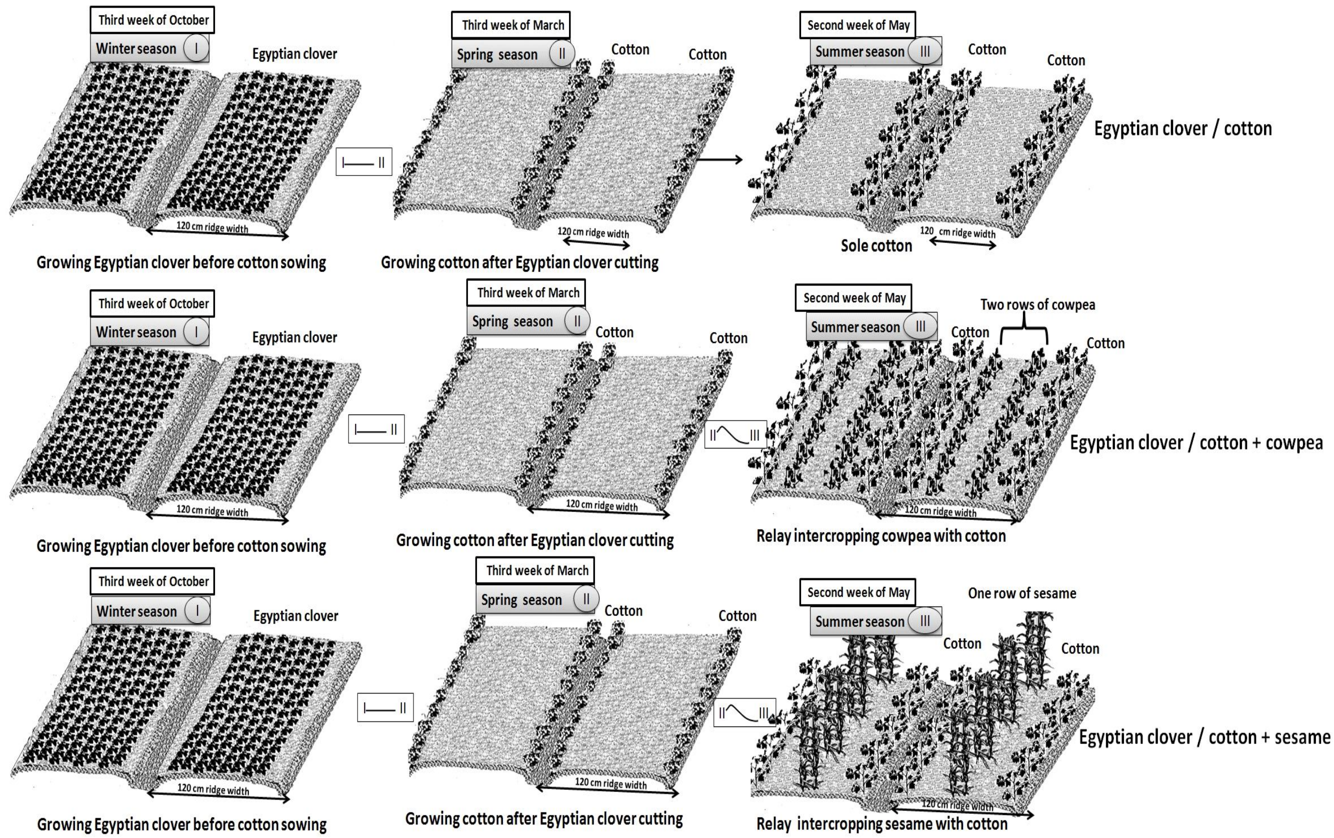
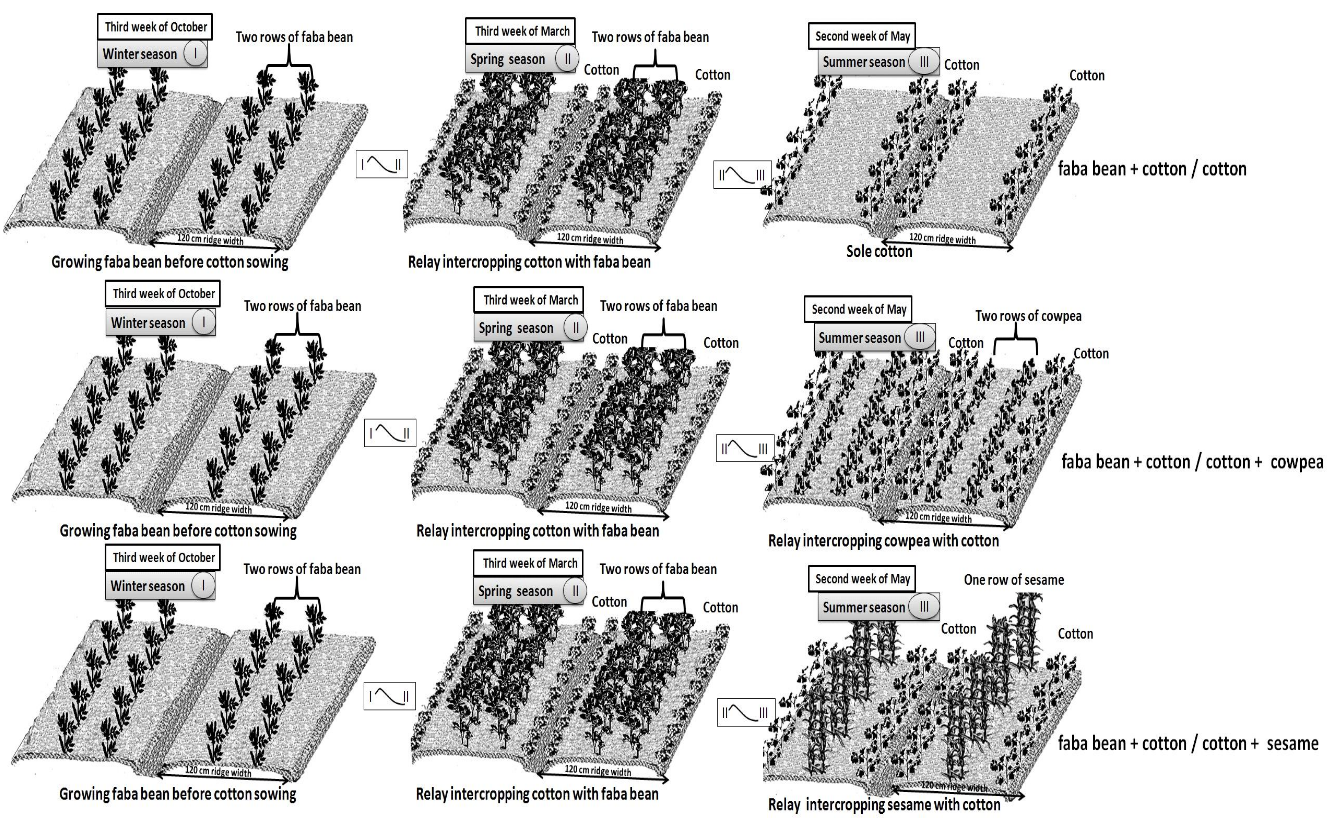


Fig. 1: Growing cotton plants in different cropping systems.



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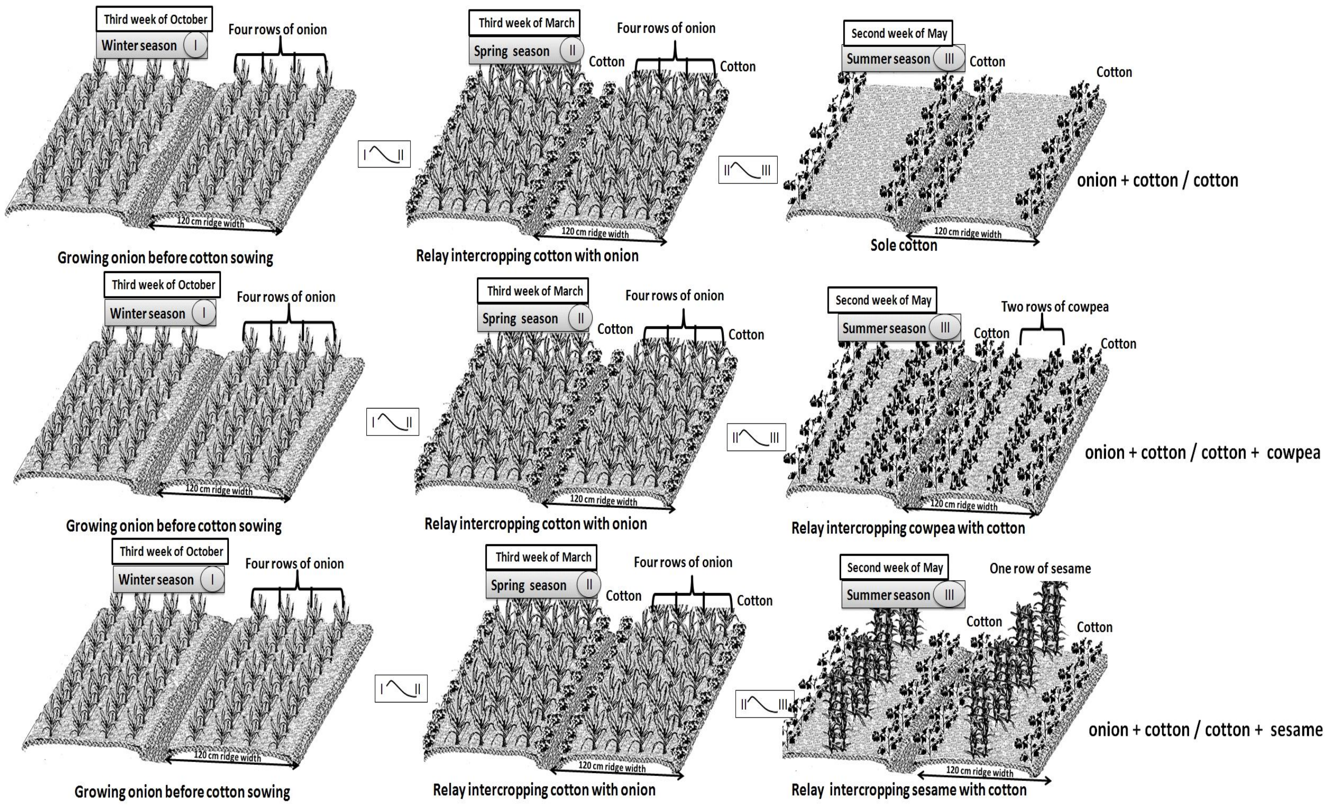

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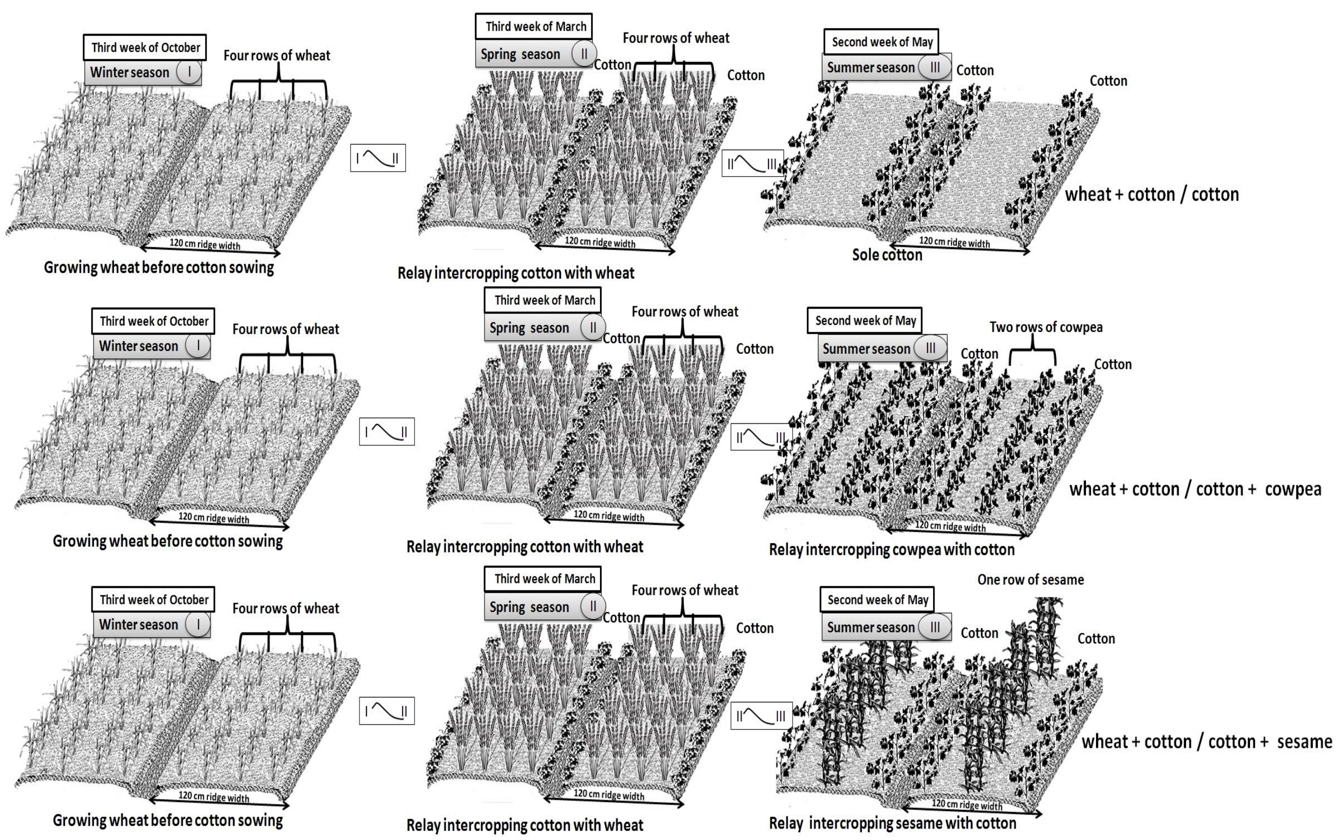

Fig. 1: Continued....

in the summer season.

Four rows of wheat grains were drilled at the rate of 119.0 kg per ha in middle of the bed. Cotton seeds were grown in two sides of wheat beds, two plants together distanced at 25 cm. One row of sesame seeds were grown in middle of cotton beds, two plants together distanced at 20 cm. This cropping system was expressed as wheat+cotton in the winter season and cotton+sesame in the summer season.

In addition to:

Sole Egyptian clover or wheat by broadcasting Egyptian clover seeds or drilling wheat grains at the rate of 47.6 or 119.0 kg per ha, respectively. With respect to Egyptian clover 5 cuts, the fifth cutting was done at first week of May in the two seasons.

Sole onion or faba bean by growing three or two rows in ridges, one or two plants together distanced at 10 or 25 cm, respectively.

Sole cowpea or sesame by growing two rows in ridges, two plants together distanced at 20 cm.

The treatments were the combinations between four winter cropping systems and three summer cropping systems. The twelve cropping systems were compared in a split plot design with three replications. Four winter cropping systems were randomly assigned to the main plots, while three summer cropping systems were allocated in subplots. Sub-plot area was 21.6 m^2. With regarding to intercropping systems and sole cultures of wheat and Egyptian clover, each plot contained six beds, each bed was 3.0 m in length and 1.2 m in width. In case of sole cultures of faba bean, onion, cowpea and sesame, each plot contained twelve ridges, each ridge was 3.0 m in length and 0.6 m in width.

The studied characters

The following traits were measured on ten guarded plants from each sub-plot at harvest; seed cotton yield per plant (g) and 100-seed weight (g). Seed cotton yield per ha (t) was recorded on the basis of sub-plot area by harvesting all plants of each sub-plot and converted to yield per ha. Chemical compositions of crude protein and oil content were analyzed according to A.O.A.C. (1995) methods. Crude protein content was calculated by multiplying total nitrogen by 6.25 (Sadasivam and Manickam, 1996). Fatty acids were separated according to Vogel (1975) and identified by Gas Liquids Chromatography, Trace GC Ultra, Thermo Scientific (GLC) apparatus. These analyses were done by the Regional Center for Food & Feed, ARC, Giza, Egypt. Oil yield per ha (ton) was calculated by multiplying seed oil content (%) by seed yield per hectare (kg). Protein yield per ha (ton) was calculated by multiplying seed protein content (%) by seed yield per ha (ton)

Statistical analysis

Analysis of variance of the obtained results of each season was performed. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% (Gomez and Gomez, 1984).

Results and Discussion

Winter cropping systems

Winter cropping systems affected significantly seed cotton yield per ha, 100 – seed weight, seed oil and protein contents, oil and protein yields per ha in the two growing seasons (Tables 3 and 4). Egyptian clover/cotton sequential double cropping system was superior to all relay intercropping systems for seed cotton yield per ha, 100-seed weight, seed protein content, oil and protein yields per ha followed by relay intercropping systems faba bean + cotton and onion + cotton. Egyptian clover/ cotton increased seed cotton yield per ha by 32.46 and 24.32%, 100-seed weight by 3.27 and 6.33%, seed protein content by 5.41 and 5.30%, oil yield per ha by 30.43 and 20.33% and protein yield per ha by 39.21 and 32.30%, in the first and second seasons, respectively, compared with wheat + cotton (Tables 3 and 4). The positive effect of Egyptian clover/cotton on seed cotton yield could be due to there was no-overlapping between the Egyptian clover and cotton for basic growth resources. These results are in the same context with Gomaa *et al*., (1981) who reported a decrease in seed oil contents by increasing nitrogen (N) application rate. Also, Egelkraut *et al*., (2004) found that the N concentration in the seed was increased by increasing rates of N fertilizer applied. Sawan *et al*., (2007) proved that the seed oil content was decreased with soil application of N. Also, Aslam *et al.* (2013) indicated that application of highest dose of N produced the maximum seed cotton yield per ha, meanwhile application of lowest dose of N gave significantly the lowest seed cotton yield per ha. Finally, Main *et al.*, (2013) showed that higher applied N rates increased seed protein and seed oil content decreased.

With respect to fatty acid composition in oil of seed cotton, saturated and unsaturated fatty acids in oil of seed cotton were significantly affected by winter cropping systems in both seasons (Table 5). Relay intercropping wheat with cotton had the highest values of palmitic and stearic acids (saturated fatty acids), meanwhile it had

Table 3: Effect of winter and summer cropping systems, as well as, their interaction on seed cotton yield per ha, 100-seed weight, seed oil and protein contents, as well as, oil and protein yields per ha in the first season.

Winter crop		Seed cotton yield per ha (ton)	100-seed weight (g)	Seed oil content (%)	Seed protein content (%)	Oil yield per ha (ton)	Protein yield per ha (ton)
1st season							
Egyptian clover	Sole cotton	3.22	8.59	19.72	23.27	0.63	0.74
	Cotton + cowpea	3.03	8.54	19.65	23.35	0.59	0.70
	Cotton + sesame	2.93	8.42	19.54	23.46	0.57	0.68
Mean		3.06	8.52	19.63	23.36	0.60	0.71
Faba bean	Sole cotton	2.94	8.41	19.89	22.99	0.58	0.67
	Cotton + cowpea	2.91	8.37	19.74	23.06	0.57	0.67
	Cotton + sesame	2.80	8.30	19.68	23.18	0.55	0.64
Mean		2.88	8.36	19.77	23.07	0.56	0.66
Onion	Sole cotton	2.88	8.39	20.18	22.4	0.58	0.64
	Cotton + cowpea	2.69	8.32	20.03	22.5	0.53	0.60
	Cotton + sesame	2.26	8.14	19.87	22.67	0.44	0.51
Mean		2.61	8.28	20.02	22.52	0.52	0.58
Wheat	Sole cotton	2.44	8.35	20.35	22.08	0.49	0.53
	Cotton + cowpea	2.34	8.28	20.22	22.16	0.47	0.51
	Cotton + sesame	2.15	8.11	20.15	22.26	0.43	0.47
Mean		2.31	8.25	20.24	22.16	0.46	0.51
Sole cotton		2.87	8.43	20.03	22.68	0.57	0.65
Cotton + cowpea		2.74	8.37	19.91	22.76	0.54	0.62
Cotton + sesame		2.53	8.24	19.81	22.89	0.50	0.58
L.S.D. at 5% level							
Winter crop		0.38	0.25	0.12	0.15	0.05	0.07
Summer crop		0.22	0.06	0.08	0.07	0.04	0.04
Interaction		N.S.	N.S.	0.15	0.21	N.S.	N.S.

the lowest oleic and linoleic acids (unsaturated fatty acids) compared to the others in both seasons. These results may be due to wheat plants furnished warm environment for cotton plants which increased saturated fatty acids in oil of seed cotton. In other words, palmitic and stearic acids (saturated fatty acids) in oil of seed cotton were significantly increased as a result of high temperature during early growth stages compared to the other cropping systems. Conversely, Egyptian clover/cotton sequential double cropping system significantly increased oleic and linoleic acids (unsaturated fatty acids) in oil of seed cotton compared to the others in both seasons. These results may be due to canopy structure of cotton plant after Egyptian clover was relatively greater than the other cropping systems as a result of Egyptian clover residues (Lamlom *et al.,* 2018).

Thus it is expected that growing cotton plants after Egyptian clover decreased solar radiation penetration and increased moisture into cotton canopy which reflected positively on percentage of unsaturated fatty acids in cotton seed oil.

Similar results were obtained by Sawan *et al.*, (2006) who found that the total unsaturated fatty acids were increased by raising N-rate.

Summer cropping systems

Summer cropping systems significantly affected seed cotton yield per ha, 100 – seed weight, seed oil and protein contents, oil and protein yields per ha in the two growing seasons (Tables 3 and 4). Sole cotton had significant increase in seed cotton yield per ha, 100-seed weight, seed protein content, oil and protein yields per ha followed by cotton + cowpea then cotton + sesame in both seasons. Sole cotton increased seed cotton yield per ha by 13.43 and 10.66%, 100-seed weight by 2.30 and 2.92%, seed oil content by 1.11 and 1.32%, oil yield per ha by 14.00 and 13.79% and protein yield per ha by 12.06 and 8.69%, in the first and second seasons, respectively, compared with cotton + sesame (Tables 3 and 4).

It is worthy to note that there were no significant

Table 4: Effect of winter and summer cropping systems, as well as, their interaction on seed cotton yield per ha, 100-seed weight, seed oil and protein contents, as well as, oil and protein yields per ha in the second season.

Winter crop		Seed cotton yield per ha (ton)	100-seed weight (g)	Seed oil content (%)	Seed protein content (%)	Oil yield per ha (ton)	Protein yield per ha (ton)
1st season							
Egyptian clover	Sole cotton	3.78	9.86	19.61	23.32	0.74	0.88
	Cotton + cowpea	3.70	9.74	19.50	23.42	0.72	0.86
	Cotton + sesame	3.47	9.58	19.38	23.57	0.67	0.81
Mean		3.68	9.73	19.49	23.43	0.71	0.86
Faba bean	Sole cotton	3.26	9.43	19.75	23.10	0.64	0.75
	Cotton + cowpea	3.18	9.40	19.60	23.20	0.62	0.73
	Cotton + sesame	2.96	9.17	19.51	23.34	0.57	0.69
Mean		3.17	9.33	19.62	23.21	0.62	0.73
Onion	Sole cotton	3.20	9.40	20.08	22.60	0.64	0.72
	Cotton + cowpea	3.06	9.35	19.94	22.67	0.61	0.69
	Cotton + sesame	2.80	9.13	19.77	22.81	0.55	0.63
Mean		3.05	9.29	19.93	22.69	0.60	0.69
Wheat	Sole cotton	3.07	9.28	20.24	22.14	0.62	0.67
	Cotton + cowpea	2.92	9.17	20.11	22.25	0.58	0.64
	Cotton + sesame	2.78	9.00	20.00	22.36	0.55	0.62
Mean		2.96	9.15	20.11	22.25	0.59	0.65
	Sole cotton	3.32	9.49	19.92	22.79	0.66	0.75
	Cotton + cowpea	3.21	9.41	19.78	22.88	0.63	0.73
	Cotton + sesame	3.00	9.22	19.66	23.02	0.58	0.69
L.S.D. at 5% level							
Winter crop		0.12	0.14	0.09	0.13	0.11	0.14
Summer crop		0.11	0.14	0.06	0.06	0.05	0.06
Interaction		N.S.	0.28	0.11	0.17	N.S.	N.S.

differences between sole cotton and cotton + cowpea for all the studied cotton traits in both seasons. These results show that sole cotton gave yield identical to that of intercropping cotton with cowpea. These results confirmed by Vaiyapuri *et al.,* (2008) who reported that cowpea did not affect the seed cotton yield. The positive competitive effect of cotton + cowpea pattern may be due to this cropping system decreased interspecific competition between the intercrops for above-ground conditions especially light intensity. Cutting cowpea plants at 45 and 75 days from cowpea sowing led to increase in light penetration within cotton canopy which reflected positively on cotton above ground biomass during boll formation and maturation (Lamlom *et al.,* 2018).

From the other point, intercropping sesame with cotton may be decreased solar radiation into cotton canopy where shading increased interspecific competition between the intercrops for above-ground conditions especially light intensity which reflected negatively on seed cotton yield (Attia and Seif El-Nasr, 1993). Also, intercropping sesame with cotton decreased seed oil content and increased seed protein content may be due to shading of sesame effects alter the balance of carbon and nitrogen in intercropped cotton plants (Fengjuan *et al.,* 2013).

With respect to fatty acid composition in cotton seed oil, saturated and unsaturated fatty acids in oil of seed cotton were significantly affected by the summer cropping systems in both seasons (Table 5). Sole cotton had the highest values of palmitic and stearic acids (saturated fatty acids), meanwhile it had the lowest oleic and linoleic acids (unsaturated fatty acids) compared to the others in both seasons. It is important to mention that there were no significant differences between sole cotton and intercropping cowpea with cotton for fatty acid composition in oil of seed cotton in both seasons. These results may be due to sole cotton furnished warmer environment for cotton germplasm than the other cropping systems which led to different in fatty acid composition in cotton seed oil. In other words, oleic and

Table 5: Effect of winter and summer cropping systems, as well as, their interaction on saturated and unsaturated fatty acids in cotton seed oil in both seasons.

Winter crop	Summer crop	Saturated fatty acids (%)				Unsaturated fatty acids (%)			
		Palmitic		Stearic		Oleic		Linoleic	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Egyptian clover	Sole cotton	20.96	20.76	2.52	2.46	22.97	23.10	55.11	55.29
	Cotton + cowpea	20.88	20.66	2.41	2.33	23.13	23.24	55.21	55.38
	Cotton + sesame	20.76	20.50	2.31	2.17	23.22	23.34	55.32	55.50
Mean		20.86	20.64	2.41	2.32	23.10	23.22	55.21	55.39
Faba bean	Sole cotton	21.12	21.00	2.78	2.70	22.79	22.97	54.96	55.14
	Cotton + cowpea	21.04	20.91	2.69	2.61	22.90	23.09	55.08	55.24
	Cotton + sesame	20.92	20.77	2.57	2.45	23.09	23.19	55.17	55.36
Mean		21.02	20.89	2.68	2.58	22.92	23.08	55.07	55.24
Onion	Sole cotton	21.43	21.22	3.07	2.99	22.62	22.69	54.70	54.83
	Cotton + cowpea	21.31	21.13	2.96	2.88	22.71	22.81	54.80	54.96
	Cotton + sesame	21.18	20.99	2.81	2.74	22.84	22.93	54.93	55.09
Mean		21.30	21.11	2.94	2.87	22.72	22.81	54.81	54.96
Wheat	Sole cotton	21.55	21.37	3.17	3.09	22.39	22.57	54.49	54.59
	Cotton + cowpea	21.44	21.25	3.06	2.98	22.50	22.65	54.58	54.71
	Cotton + sesame	21.30	21.10	2.95	2.87	22.60	22.77	54.71	54.81
Mean		21.43	21.24	3.06	2.98	22.49	22.66	54.59	54.70
Sole cotton		21.26	21.08	2.88	2.81	22.69	22.83	54.81	54.96
Cotton + cowpea		21.16	20.98	2.78	2.70	22.81	22.94	54.91	55.07
Cotton + sesame		21.04	20.84	2.66	2.55	22.93	23.05	55.03	55.19
L.S.D. at 5% level									
Winter crop		0.22	0.26	0.19	0.25	0.22	0.22	0.25	0.24
Summer crop		0.12	0.14	0.12	0.14	0.13	0.12	0.14	0.13
Interaction		0.26	0.31	0.23	0.28	0.26	0.25	0.29	0.29

linoleic acids (unsaturated fatty acids) in cotton seed oil were significantly decreased as a result of high temperature and low moisture in sole cotton compared to the other cropping systems. Conversely, sesame + cotton significantly increased oleic and linoleic acids (unsaturated fatty acids) in oil of seed cotton compared to the others in both seasons. These results may be due to intercropping sesame with cotton reduced temperature around cotton canopy which reduced evapotranspiration from cotton environment. Increased temperature and reduced moisture have been reported to decrease the relative proportion of 18:2 and 18:3 in soybean oil (Wlof *et al.,* 1982 and Dornbos and Mullen, 1992).

The interaction between winter and summer cropping systems

The interaction between winter and summer cropping systems affected significantly 100-seed weight in the second season only, seed oil and protein contents, saturated and unsaturated fatty acids in oil of seed cotton in both seasons (Tables 3 and 4). Egyptian clover/cotton had the highest 100-seed weight compared to the other cropping systems in the second season only. It is important to mention that there were no significant differences between the cropping systems; Egyptian clover/cotton and Egyptian clover/cotton + cowpea for 100-seed weight. These results may be due to Egyptian clover residues enhanced soil nitrogen availability which interacted positively with environmental conditions especially solar radiation to increase dry matter accumulation into cotton tissues. Nitrogen is an essential nutrient in creating the plant dry matter, as well as, many energy-rich compounds that regulate photosynthesis and plant production (Wu *et al.,* 2013). Hence, sole cotton or cowpea + cotton does not appear favorable for human health.

Meanwhile, Egyptian clover/cotton + sesame had the highest seed protein content and the lowest seed oil content compared to the others in both seasons. These results may be due to Egyptian clover residues enhanced soil nitrogen availability which interacted negatively with shading effects on sesame to decrease photosynthesis process in intercropped cotton plants. The photosynthesis of subtending leaves was limited by shading during flowering and boll formation stages (Bondada and Oosterhuis, 2001). Consequently, intercropping sesame with cotton decreased dry matter accumulation in cotton plants. Less assimilate from leaf tissue was transported to fiber, and more was retained by the seed under shading (Fengjuan *et al.,* 2013) which explained increasing seed protein content.

With respect to fatty acid composition in cotton seed oil, Egyptian clover/cotton + sesame had the highest unsaturated fatty acids (oleic and linoleic) and the lowest saturated fatty acids (palmitic and stearic) in cotton seed oil compared to the others in both seasons (Table 5). These results may be attributed to Egyptian clover residues enhanced soil N availability which increased total unsaturated fatty acids in cotton seed oil. The total unsaturated fatty acids were increased by raising N-rate (Sawan *et al.,* 2006). This increase was improved by intercropping sesame with cotton where shading effects decreased seed oil content which decreased saturated fatty acids in cotton seed oil. Lower levels of palmitic and stearic acids and higher levels of oleic and linoleic acids would be ideal for human health.

These results suggest that seed oil and protein contents, as well as fatty acid composition in cotton are greatly influenced by changing the cropping systems

Conclusion

It could be concluded that protein content, oil content and fatty acid composition are important quality characters of cotton seed. Egyptian clover/cotton + sesame had high levels of unsaturated fatty acids and low levels of saturated fatty acids in cotton seed oil without any significant reduction in seed cotton yield per ha. Intercropping sesame with cotton after Egyptian clover cutting achieved high quality in cotton seed oil which can reduce level of blood cholesterol that is responsible for heart diseases.

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