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Effect of Foliar Spraying with Anti-Transpirants Natural Materials under Different Irrigation Intervals on Productivity and Quality of Cotton Plant cv. Super Giza 86

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ABSTRACT

Two field experiments were carried out at El-Gemmeiza Agricultural Research Station, El-Gharbia Governorate, Egypt during 2018 and 2019 seasons to study the effect of irrigation intervals, spraying with two anti-transparent natural plants extract and their interactions on cotton plants using a strip plot design in three replicates. Data indicated that irrigation every 14 days as well as foliar feeding with the combination between licorice root extract and ring seeds extract at 8 g powder/L three times (at squaring stage, flowering initiation, and 15 days later) significantly increased mineral nutrients, photosynthetic pigments, total carbohydrates, total sugars, and free amino acids in the leaves. Fiber length in the 2nd season, growth parameters, earliness measurements (except boll shedding% which decreased), seed cotton yield feddan^{-1} and its components in both seasons and lint strength in the 1st season were also increased. On the other hand, it was found a significant decrease in phenolic and proline content as the combined analysis between the two growing seasons as well as number of total flowers per plant and micronaire reading due to irrigation at 14 days interval and foliar feeding with the combination between licorice root extract and ring seeds extract at 8 g powder/L and their interaction in one season only. It could be concluded that combined addition treatments of licorice root extract and ring seeds extract as foliar spraying at the two levels examined gave best results under different irrigation intervals used on productivity and quality of cotton plants. These natural compounds can be used safely to reduce the negative impact of drought and recommended to use when water scarcity becomes widespread under conditions like El-Gemmeiza location.

Keywords: Egyptian cotton, Licorice extract, ring seeds extract, photosynthetic pigments, irrigation interval

1. Introduction

Egyptian cotton (*Gossypium barbadense,* L.) occupies a privileged position for its high-quality recipes and the stability of its presence overseas markets for long periods due to its fame in the markets. It is a mainstay of Egypt's textile industry, garments, and the oil production. The plants consume ~99% of the water which supply to them for transpiration and replenish the lost water through extracted it from the soil to avoid the water stress, to alleviate the degree of cellular damage and to keep water balance between water absorption and water lost by transpiration through the day light. Drought induces reduction of water level in the plant tissues, water potential, and subsequently reduces leaf elongation, leaf photosynthesis rate, photosynthetic pigment contents and damages photosystem II, alters protein synthesis, nitrogen metabolism and cell membrane properties leading to a reduction in plant productivity (Saneoka *et al*., 2004). The lack of irrigation response is most likely due to excess water around the root zone. This situation will presumably cause hypoxia, nutrient leaching and lower water uptake resulting in the redistribution of energy allocation within the plant that leads to higher vegetative growth at the expense of reproductive growth (Feng *et al*., 2014). Too much water can also be detrimental and can cause shedding because of inadequate aeration in heavy soils or leaching of nutrients in sandy soils and promoting excessive vegetative growth). This abiotic stress (hypoxia, lower

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water, and nutrient uptake) can trigger more vegetative growth in cotton as a perennial species. In addition, boll formation and boll development stages in cotton started in July and August which may be affected by the vegetative phase, resulting in lower cellulose deposition in the developing fibers. At the same time, the lack of water in the soil and high air temperatures together adversely affect the physiological and biochemical processes bring to a decrease of yield and quality of cotton plants. Under El-Matattana Agricultural Station, Luxor Governorate, Hamoda (2010) reported that prolonging the irrigation interval to 21 day caused significant reduction in vegetative growth, number of open bolls plant^{-1}, boll weight, seed index, seed cotton yield feddan^{-1}, fiber length and strength, while lint% and earliness% were significantly increased. He added that irrigation every 15-day increased plant height, number of fruiting branches plant^{-1} and gave high fiber quality. Emara *et al.* (2015) found that increasing irrigation intervals to 4 weeks significantly decreased plant height at harvest and its number of fruiting branches, number of open bolls plant^{-1}, boll weight and seed cotton yield fed^{-1}. Whereas, monopodia/plant, earliness%, seed index, lint% and fiber properties were not affected. Ergashovich *et al.* (2020) reported that drought decreased cotton growth and development, expansion of leaf surfaces and pure productivity of photosynthesis, weight of cotton boll, the yield, and its quality. As a result, partial shedding of crop organs and leaves was observed.

Shortage water and limited water sources as well as the cost of irrigation pumping, and inadequate irrigation scheme capacity are represented true challenge that force Egypt to reduce irrigation applications. At the present time, where the water problem is serious, it is important to introduce water-saving agrotechnology. Among them, the applications of natural and organic materials such as licorice root extract and ring seeds extract (fenugreek seeds extract). The potential of the licorice root extract and ring seeds extract to supply nutrients; hormones and capable of mobilizing nutritive elements from no usable form to usable form through biological processes which simulates cell division and enlargement as well as the synthesis of protein, nucleic acid in addition, to its capability in induction of endogenous hormones like GA_3 and IAA. Much attention as a natural safety fertilizer which releases CO_2 reflected in improving net photosynthesis and causes various promoted effect on plants (Larson *et al.,* 1962).

Natural and safety substances have been used in a great scale as fertilizers to improve plant growth, yield, and quality of many crops. They have been also extensively used as an environmentally friendly approach to decrease the use of inorganic fertilizers, enhance soil fertility status and crop production (Ram Rao *et al*., 2007). Elrys and Merwad (2017) mentioned that green approaches for enhancing plant growth and production using natural occurring materials are highly needed such as licorice root extract and ring seeds extract (fenugreek seeds extract).

The natural materials as foliar spraying through the growing season of cotton are a good tool to increase cotton plant tolerance and get the cotton plant to survive the water stress periods to continue vegetative and fruiting stages successfully. Every effort which contributes to avoid water stress and economic production of the crop should support cotton's position. So, the present study was designed to answer two specific questions; First, is it possible to increase cotton growth and productivity under prolonged irrigation interval? The second question: what is the possibility of using natural materials to reduce water stress effect?

Thus, the objective of this study was to assess the proper irrigation interval and the effect of licorice root extract and ring seeds extract (fenugreek seeds extract) as an anti-transpirant natural materials on Egyptian cotton cultivar Super Giza 86 (*Gossypium barbadense*, L.) under the environmental conditions of El-Gharbia Governorate and when water scarcity becomes widespread. Leaves chemical composition, growth traits, earliness traits, seed cotton yield and its components and fiber quality were evaluated.

2. Materials and Methods

Two field experiments were carried out on clay loamy and clayey soil at El-Gemmeiza Agricultural Research Station, El-Gharbia Governorate, Egypt during the two growing seasons of 2018 and 2019. The experiment was laid out as a strip plot design and replicated three times in both seasons, where the horizontal plots were assigned to irrigation intervals and anti-transpirant natural materials used as vertical plots.

A- Irrigation intervals:

a_1- Irrigation every 14 day as a control (the recommended interval).

a_2- Irrigation every 21 day.
a_3- Irrigation every 28 day.

B- Foliar application of anti-transpirant natural materials used:
b_1-Without application (spraying with tap water, serving as a control).
b_2- Foliar spraying with 4 g licorice root powder/L.
b_3- Foliar spraying with 8 g licorice root powder /L.
b_4- Foliar spraying with 4 g fenugreek seeds powder)/L.
b_5- Foliar spraying with 8 g fenugreek seeds powder /L.
b_6- Foliar spraying with 4 g licorice root powder /L + 4 g fenugreek seeds powder /L.
b_7- Foliar spraying with 8 g licorice root powder /L + 8 g fenugreek seeds powder /L.

These substances were chosen for their beneficial effects as they contain minerals and some plant growth regulators which affect the plants positively.

Foliar spraying coincides with the planting physiology stages [squaring stage, flowering initiation and 15 days later].

Sowing date was 10th April after sugar beets (*Beta vulgaris*, L.) and Egyptian clover (*Trifolium alexandrinum*, L.) "berseem" in the first and second seasons, respectively.

The first source of these natural plants is licorice or liquorice (*Glycyrrhiza glabra,* L.; Fabaceae). The second source of these natural plants is fenugreek or ring seeds (*Trigonella foenum graecum,* L.; Fabaceae). The components of these sources are shown in Tables, 1 and 2.

Table 1: *The main components of licorice root powder.

Ingredients	%	Ingredients	µg/g
Humidity	12	Potassium	1230
Total ash	7.85	Sodium	700
Ash dissolved in water	4.55	Calcium	520
Ash dissolved in acid	2.51	Magnesium	230
Ash is not dissolved in acid	0.79	Phosphor	350
Extracted dissolved in water	32.60	Manganese	5
Protein	5.20	Iron	35
Reducing sugars	2.25	Zinc	50.2
Oil	3.75	Copper	5
Acidity based on nitric acid	0.80	Cobalt	0.07
Klycerasin glycyrrhizin	4.22	In addition to, triterpene saponins, phenolic compounds, amino acids, vitamins and stimulating photohormones	
Tannin	3.66		
Raw fiber	24.42		

*As reported by Rawlings *et al*. (1994); Newall *et al*. (1996); Shibata, (2000); Laroche *et al.* (2001); Shabani *et al.* (2009) and El-Morsy *et al*. (2017).

Table 2: **The main components of fenugreek (ring seeds) powder.

Ingredients	%	Ingredients	µg/g
Humidity	9.82	Potassium	240.19
Total ash	5.58	Sodium	68.02
Ash dissolved in water	2.51	Magnesium	3.19
Ashes dissolved in acid	2.10	Manganese	2.76
The extract dissolved in water	34.96	Iron	1.07
Protein	22.80	Zinc	1.58
Reducing sugars	7.76	Copper	0.17
Fixed oils	6.25	In addition to, vitamins such as A, C and B6, fat, dietary fiber quercetine, trigonelline, amino acids such as, folic acid, niacin, thiamin leucine, valine, lysine and phenylalanine,	
Volatile oils	1.04		
Fiber	5.19		
Gel	26.20		
Flavonoids such as saponins (4.63 g/100 g), phytic acid and polyphenols			

**As reported by Nour and Magboul (1986); Sharma *et al*. (1996); Hounsome *et al.* (2008); Kowalczyk and Zielony, (2008); Liu *et al*. (2008); Sangeetha, (2010); Abo Sedera *et al.* (2010) and Naidu *et al*. (2011).

2.1. Preparation and application of anti-transpirant natural materials used

Licorice root and fenugreek seeds were extracted by weighting 4 and 8 g dried material, soaked in distilled water at 50°C for 24 h, filtered and justed by distilled water to one liter. The two extracts were applied as a foliar spray at a rate of 4g powder/L and 8g powder/L at three times (at the squaring stage, flowering initiation and 15 days later). Spraying on the cotton leaves was done using hand operated sprayer compressed at a low volume of 200 liter per feddan. The lower leaf surface was sprayed until wetted. Tween 20 (0.5%) was used as a wetting agent.

Before sowing, soil samples represented surface layer (0-30 cm) from five spots across, were collected in a zigzag pattern, mixed, and analyzed according to Estefan *et al.* (2013) and the data are depicted in Table, 3.

Table 3: The properties of the experimental soil in the two seasons.

Particulars	Optimal Value (Ankerman and Large, 1974)	Season 2018	Season 2019
Mechanical analysis			
Clay%		38.0	44.2
Silt%		38.0	33.0
Sand%		24.0	22.8
Texture		Clay loam	Clayey
Chemical analysis			
pH (1 soil: 2.5 distilled water suspension using an automated pH analyzer)	6.7-7.3	8.0	8.1
EC ds/m (1 soil: 2.5 distilled water extract at 25 ˚C using electrical conductivity meter)	1.5	0.37	0.99
Organic matter %	2.6-3	1.23	1.40
Total N(mg/100g)	30-60	43.05	49.00
Available P (mg/100g)	1.2-2.7	1.19	1.28
Available K (mg/100g)	21-30	21.5	31.0
Available Mg (mg/100g)	30-180	19	23
Available Fe (ppm)	10-16	6.0	12.4
Available Mn (ppm)	8-12	2.1	3.9
Available Zn (ppm)	1.5-3.0	0.70	1.12
Available Cu (ppm)	0.8-1.2	0.9	1.7

In both seasons, the experimental sub- plot area was 24.5 m^2, (5 m length x 4.9 m width) included 7 ridges of 0.70 m in between. The two outer ridges were left as borders. The net plot area was 17.5 m^2. Hills were 25 cm apart and sowing seeds of cotton cultivar Super Giza 86 from Cotton Research Institute were sown on the tribal side of the ridge (20 hills $ridge^{-1}$). Seedlings were hand thinning at 2 leaf stage to leave two vigor's seedlings $hill^{-1}$, providing plant density of 48,000 plant fad^{-1}.

As recommended (Cotton Research Institute, Egypt), phosphorus fertilizer was added as calcium super phosphate (15.5% P_2O_5) at the rate of 22.5 kg P_2O_5/fed during soil preparation. Nitrogen fertilizer at the rate of 45 kg N/fed was applied as urea (46% N) in two equal portions after thinning before irrigation and after 15 days (at the next irrigation). Potassium fertilizer in the form of Potassin-P was applied as foliar spraying at the rate of 1 liter/fed three times (at the squaring stage, flowering initiation and 15 days later).

The irrigation treatments were start after the second irrigation. Other cultural practices were carried out as recommended for conventional cotton cultivation in the local production district as recommended by Cotton Research Institute, Agricultural Research Centre, Egypt.

2.2. Studied characters

2.2.1. Chemical constituents

In 2018 and 2019 seasons, twenty leaves (4^{th} upper leaf) were randomly taken from plants of each sub-plot after 15 days from the last spraying of anti-transpiration materials (116 days old) to determine the following traits:

1- Concentrations of N, P, K, Ca, Mg and Na (as %), Fe, Zn, Mn and Cu (in ppm) according to Cottenie *et al.* (1982), 2-Photosynthetic pigments; Chlorophyll (a), (b), total chlorophyll and carotenoids (mg/g dry weight) using the method of Vernon and Selly (1966), 3-Total carbohydrates and sugars concentrations (ug/g dry weight) (Umbriet *et al*., 1969), 4- Free amino acids (mg/g dry weight) according to the methods of Lowry *et al.* (1951). 5- A phenolic compound (mg/100 g dry weight) using the method described by Daniel *et al.* (1972) and 6- Proline concentration (ug/g dry weight) (Bates *et al.,* 1973). Data was taken as the combined analysis between the two-growing seasons.

2.2.2. Growth parameters

In both seasons (2018 and 2019), six guarded plants were taken at random from each sub-plot carefully after 15 day from the last spraying (116 days old) to determine dry weight of assimilatory parts/plant. The above ground parts were washed, dried to a constant weight in a forced air oven at 70 °C and calculated. Leaf area (dm^2 $plant^{-1}$) was determined using disc method (Johnson, 1967). at harvesting, ten representative plants from each sub-plot were taken at random to determine final plant height (cm) and its numbers of fruiting and vegetative branches**.**

2.2.3. Earliness attributes

From ten representative plants, the following attributes were determined according to Richmond and Radwan (1962) and Kadapa (1975); 1. Total flowers number $plant^{-1}$, 2. Total bolls number set $plant^{-1}$, 3. Boll retention (setting) as percentage of total bolls number set $plant^{-1}$ to total flowers number $plant^{-1}$, 4. Boll shedding percentage = (100 - boll setting %) and 5. Earliness index (percentage of the first picking).

2.2.4. Seed cotton yield and its contributory characters

At harvesting, ten representative plants were taken to determine the following yield contributory characters; 1- Number of open bolls $plant^{-1}$, 2- Boll weight (g), 3- Seed cotton yield $plant^{-1}$, 4-Lint percentage as percentage of lint cotton to seed cotton after ginning and 5-Seed index. The seed cotton yield $feddan^{-1}$ was estimated as the weight of seed cotton in kilograms picked twice from the inner five ridges of each sub-plot and transformed to kentars per feddan (one kentar =157.5 kg seed cotton and one feddan = 4200.83 m^{-2}).

2.2.5. Fiber quality

Samples of cotton lint were taken from each sub-plot after ginning seed cotton yield on a laboratory gin stand. All fiber tests for the samples were made at the laboratories of the Cotton Technology Research Division, Cotton Research Institute according to A.S.T.M. (2012). Traits included fiber upper half mean length (mm) and length uniformity index (%)measured by a digital fibrograph instrument 630, fiber fineness (micronaire reading) measured by a micronaire instrument 675, and fiber strength (Pressley index) measured by the Pressley instrument.

2.3. Statistical analysis

All data were subjected to statistical analysis as outlined by Steel *et al.* (1997). The treatments means were compared using LSD at 0.05 level of probability (Waller and Duncan, 1969).

3. Results and Discussion

3.1. Chemical constituents

3.1.1. Mineral concentrations

3.1.1.1. Effect of irrigation intervals

Data in Tables, 4 and 5 showed that the concentrations of N, P, K, Ca, Mg, Na*,* Fe, Zn, Mn, and Cu were increased in the cotton leaves due to the irrigating of cotton plants every 14 days followed by those irrigated every 21 days and at last by those irrigated every 28 days. These results indicated that irrigation every 14 days is proper period for cotton cultivar Super Giza 86, where irrigation water applied less or more the optimum requirement of a crop adversely affects physiological and biochemical processes and results in limited absorption of the inorganic nutrients. Drought as a limiting factor for root growth leads to a lower nitrate mobility in the soil, transport of mineral nutrients from the root to the shoot, transpiration rates and changing function of membrane transporters, physicochemical properties of soils (Ahanger *et al*., 2016) In addition, it was found that drought induced early closure of stomata, thus reduced transpiration rate and reduced availability and transport of nutrients in the soil matrix and plant tissues (Silva *et al*., 2011). Zinc uptake by the plant root is decreased by low water availability in the soil since under these conditions zinc mobility in the soil is impeded (Marschner, 1995). Drought stress reduces the transfer of phosphorus from the soil to the root and its subsequent transport to the stem (Cramer *et al*., 2009).

Potassium availability for plants is lowered under drought and that limits its uptake by the root ultimately affecting its root-shoot translocation (Wang *et al*., 2013). Similarly, drought decreased manganese availability (Hu and Schmidhalter, 2005), content and availability of iron and Fe^{2+}/Fe^{3+} ratio due to the increased O_2 levels in soil, where O_2 reduces available iron for plant uptake because Fe^{3+} is less soluble than Fe^{2+} (Sardans *et al*., 2008), mobility of nitrogen in the soil, thus plants exposed to/or facing drought stress will also face nitrogen deficiency (Ahanger *et al*., 2016). Garg (2003) reported that lowered absorption nutrients can result from interference in nutrient uptake and unloading mechanism and reduced transpiration flow.

Table 4: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on leaves macronutrients and Na constituents (Data was taken as the combined analysis between the two-growing seasons).

Treatments	Traits	N	P	K	Ca	Mg	Na
				%			
A-Irrigation intervals:							
a_1- 14 day		3.40	0.32	3.09	1.51	0.449	0.334
a_2- 21 day		2.82	0.27	3.01	1.38	0.427	0.324
a_3- 28 day		2.68	0.25	2.98	1.28	0.406	0.313
LSD at 5%		**0.08**	**0.03**	**0.01**	**0.04**	**0.006**	**0.002**
B-Levels of anti-transpiration materials:							
b_1- Without application (control)		2.53	0.24	2.95	1.12	0.349	0.268
b_2- 4 g Licorice roots powder/L		2.62	0.25	2.99	1.22	0.376	0.274
b_3- 8 g Licorice roots powder /L		2.96	0.28	3.02	1.48	0.473	0.340
b_4- 4 g Fenugreek powder /L		2.81	0.27	3.01	1.38	0.411	0.332
b_5- 8 g Fenugreek powder /L		3.14	0.29	3.05	1.30	0.390	0.327
b_6- (b_2 + b_4)		3.24	0.30	3.07	1.57	0.488	0.357
b_7- (b_3 + b_5)		3.46	0.33	3.11	1.65	0.503	0.367
LSD at 5%		**0.06**	**0.02**	**0.01**	**0.02**	**0.009**	**0.009**
AXB Interaction:							
	b_1	3.04	0.28	3.04	1.25	0.380	0.280
	b_2	3.14	0.30	3.05	1.30	0.397	0.287
	b_3	3.38	0.32	3.09	1.60	0.500	0.350
a_1	b_4	3.31	0.31	3.07	1.50	0.417	0.340
	b_5	3.55	0.33	3.12	1.40	0.400	0.337
	b_6	3.65	0.34	3.13	1.70	0.517	0.367
	b_7	3.70	0.36	3.15	1.80	0.530	0.377
	b_1	2.29	0.22	2.93	1.10	0.347	0.270
	b_2	2.41	0.24	2.97	1.20	0.370	0.277
	b_3	2.87	0.27	3.01	1.50	0.470	0.340
a_2	b_4	2.65	0.26	2.99	1.35	0.420	0.330
	b_5	2.97	0.27	3.02	1.30	0.390	0.327
	b_6	3.09	0.29	3.05	1.55	0.490	0.357
	b_7	3.50	0.32	3.11	1.65	0.500	0.367
	b_1	2.26	0.22	2.89	1.00	0.320	0.253
	b_2	2.33	0.22	2.95	1.15	0.360	0.260
	b_3	2.63	0.26	2.98	1.35	0.450	0.330
a_3	b_4	2.48	0.25	2.98	1.30	0.397	0.327
	b_5	2.92	0.27	3.01	1.20	0.380	0.317
	b_6	2.99	0.27	3.04	1.45	0.457	0.347
	b_7	3.19	0.30	3.06	1.50	0.480	0.357
LSD at 5%		**0.05**	**0.01**	**0.01**	**NS**	**0.011**	**NS**

Table 5: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on leaves micronutrients constituents (Data was taken as the combined analysis between the two-growing seasons).

Treatments	Traits	Fe	Zn	Mn	Cu
		ppm			
A-Irrigation intervals:					
a_1- 14 day		102.19	31.87	37.69	13.20
a_2- 21 day		96.69	30.07	33.88	10.04
a_3- 28 day		93.52	28.41	32.09	9.20
LSD at 5%		**0.25**	**0.13**	**0.24**	**0.01**
B-Levels of anti-transpiration materials					
b_1- Without application (control)		77.27	21.38	25.02	6.50
b_2- 4 g Licorice roots powder/L		83.14	26.20	26.93	8.22
b_3- 8 g Licorice roots powder /L		104.10	30.97	38.12	12.18
b_4- 4 g Fenugreek powder /L		98.01	29.22	35.87	11.13
b_5- 8 g Fenugreek powder /L		91.73	28.07	32.62	10.58
b_6- ($b_2 + b_4$)		107.98	35.72	40.86	13.08
b_7- ($b_3 + b_5$)		120.05	39.28	42.45	13.98
LSD at 5%		**2.68**	**0.24**	**0.63**	**0.12**
AXB Interaction:					
a_1	b_1	81.20	23.85	27.50	7.30
	b_2	85.40	28.05	30.30	9.15
	b_3	113.50	33.40	40.50	15.10
	b_4	103.10	30.60	38.60	14.10
	b_5	95.50	29.90	36.50	13.75
	b_6	114.25	36.65	43.95	16.20
	b_7	122.40	40.65	46.50	16.80
a_2	b_1	77.75	20.85	25.15	6.20
	b_2	84.70	26.45	26.50	7.90
	b_3	101.45	30.55	38.35	11.20
	b_4	96.15	29.50	35.50	9.75
	b_5	91.45	27.70	30.85	9.20
	b_6	105.90	35.85	40.28	12.45
	b_7	119.44	39.60	40.50	13.55
a_3	b_1	72.85	19.45	22.40	6.00
	b_2	79.32	24.10	24.00	7.60
	b_3	97.35	28.95	35.50	10.25
	b_4	94.77	27.55	33.50	9.55
	b_5	88.25	26.60	30.50	8.80
	b_6	103.80	34.65	38.35	10.60
	b_7	118.30	37.60	40.35	11.60
LSD at 5%		**1.91**	**0.46**	**0.52**	**0.16**

Attia *et al.* (2017) reported that irrigation intervals exhibited significant differences in leaves concentrations of nitrogen, phosphorus, and potassium, where the highest percentage of these nutrients in consideration resulted from irrigating cotton plants every 21 days followed by irrigation every 28 days and at last irrigation every 14 days.

3.1.1.2. Effect of anti-transpirants used

Data in Tables, 4 and 5 showed that, foliar feeding with licorice root extract and fenugreek seeds (ring seeds) extract each alone at the two levels examined or in combination significantly increased the concentrations of N, P, K, Ca, Mg, Na, Fe, Zn, Mn and Cu in the leaves of cotton compared with the control. The highest values of these elements were obtained from foliar feeding with the combination between licorice root extract and ring seeds extract at the high level (8 g powder/L).

The positive effect of foliar feeding with these extracts on the concentration of these elements is mainly due to the presence of these nutrients in the extracted treatments (Tables, 1 and 2), The effect of licorice root extract in increasing of endogenous hormones like GA in treated plants which increased the metabolic process's role and its effect on mineral content in tissue (Faraj and Ghaloom, 2012).

Licorice positive effect may be returned to its benefits in activating photosynthesis process by increasing the release of carbon dioxide (Larson *et al.,* 1962). Zuhair (2010) stated that licorice increased total chlorophyll content. Phosphorus is a nutrient related to the energy supply used in the production of photoassimilates (Uchida, 2000).

3.1.1.3. Interaction effect

Data in Tables, 4 and 5 showed that cotton plants irrigated every 14 days and received 8 g/L liquorice root powder plus 8 g/L fenugreek powder gave the highest values of mineral elements evaluated (3.70% N, 0.36% P, 3.15% K and 0.530% Mg, 122.40 ppm Fe, 40.65 ppm Zn, 46.50 ppm Mn and 16.80 ppm Cu). The lowest values (2.26% N, 0.22% P, 2.89% K and 0.320% Mg, 72.85 ppm Fe, 19.45 ppm Zn, 22.40 ppm Mn and 6.00 ppm Cu) were recorded from the plants irrigated every 28 days and untreated with natural extracts used. However, concentrations of Na and Ca did not affect by the interaction.

3.2. Photosynthetic pigments, total sugars, total carbohydrates, free amino acids, phenols, and proline content

3.2.1. Effect of irrigation intervals

Irrigation intervals exhibited significant differences in the concentrations of photosynthetic pigments in the cotton leaves. The highest values were recorded with cotton plants irrigated every 14 days followed by those irrigated every 21 days. The same table showed that irrigation intervals exhibited significant differences in leaf content of total sugars, total carbohydrates, and free amino acids, in favor of cotton plants irrigated every 14 days, while the lowest values recorded from cotton plants irrigated every 28 days. The reverse trend was obtained regarding phenols and proline content. These results may be due to that the presence of K at a high level in treated plants can reverse the dehydration effects of drought on photosynthesis. It stimulated translocation of photo-assimilates towards reproductive organs rather than vegetative organs in cotton (Makhdum *et al*., 2007). K plays an important role in the function of stomata which affected by water loss from the plant *via* transpiration. One of the reasons for this decline under water deficit might be reduced g_s due to disruption in osmotic potential of the guard cells. This reduction in g_s resulted in decreased CO_2 supply to chloroplasts and decline of P_n in water-stressed plants (Flexas *et al*., 2004). The decline of P_n in cotton leaves under severe drought by non-stomatal factors, including limited gas diffusion in mesophyll cells, reduced CO_2 solubility, and reduction in Rubisco affinity to CO_2. Plants exposed to water deficit decreased carbon assimilation while carbohydrate accumulated in their leaves (Hummel *et al*., 2010). Water stress appeared to reduce both carboxylation and electron transport processes in the chloroplast. One explanation may be that CO_2 assimilation was enhanced by high K supply in drought stressed plants that promoted stomatal opening and Rubisco activity. In water stressed plants P_n is inhibited, resulting limited production of photo-assimilates meanwhile, stored reserves *i.e.*, starch is depleted due to continuous respiration in plants (Galmés *et al.,* 2007). Komor (2000) reported that export rate of sucrose towards sink organs depends upon the current photosynthetic rate and sucrose concentration in the leaves. In drought stress plants accumulated sugars especially sucrose in leaves to reduce osmotic potential for limiting moisture loss from leaves and minimized its export. Limited photosynthesis and sucrose accumulation in the leaves hindered the export rate of sucrose to the sink organs and influenced the reproductive development in drought stressed plants (Farooq *et al*., 2009).

3.2.2. Effect of anti-transpirants used

Compared to the control (not using licorice root extract or fenugreek seed extract), leaves photosynthetic pigments content was significantly increased by increasing the concentration of foliar application with liquorice root extract and fenugreek extract each alone or in combination. The highest photosynthetic pigments content in cotton leaves was recorded at the combination between licorice root extract and ring seeds extract either at the low or high levels (4 g powder/L or 8 g powder/L). The control treatment gave the lowest values in this respect. Meanwhile, there was a significant decrease in phenols and proline content at the same levels.

The results in Table, 7 showed an increase in total sugars, total carbohydrates and free amino acids concentrations in the cotton leaves due to natural extracted treatments. The highest values were recorded at the combination between licorice root extract and fenugreek extract at both levels. The same table indicated that control gave the highest values of phenols and proline content in cotton leaves. Proline is a solute that improves the protection against a variety of abiotic stresses and its accumulation provides precursors necessary for phenolic biosynthesis in the shikimic acid pathway *via* increasing the ratio of NADP+/NADPH that in turn promotes the oxidative pentose phosphate pathway (Cheynier *et al*., 2013).

This improvement may shed the light on the effective role of phenolics found in fenugreek seed extract in improvement plant as an antioxidant status.

The positive effect of licorice may be returned to its benefits in activating photosynthesis process by increasing the release of carbon dioxide (Larson *et al.*, 1962). The inverse trend was obtained about the leaf's proline concentration.

Table 6: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on leaves photosynthesis pigments concentration (Data was taken as the combined analysis between the two-growing seasons).

Treatments	Traits	Chlorophyll a	Chlorophyll b	Total Chlorophyll	Carotenoids
		(mg /g d.wt)			
A-Irrigation intervals:					
a_1- 14 day		5.74	1.92	7.65	2.00
a_2- 21 day		4.58	1.47	6.05	1.54
a_3- 28 day		4.40	1.35	5.75	1.44
LSD at 5%		**0.03**	**0.05**	**0.05**	**0.03**
B-Levels of anti-transpiration materials:					
b_1- Without application (control)		4.00	1.28	5.28	1.32
b_2- 4 g Licorice roots powder/L		4.46	1.37	5.83	1.47
b_3- 8 g Licorice roots powder /L		4.74	1.55	6.29	1.61
b_4- 4 g Fenugreek powder /L		4.71	1.53	6.24	1.58
b_5- 8 g Fenugreek powder /L		5.17	1.64	6.81	1.68
b_6- ($b_2 + b_4$)		5.41	1.73	7.14	1.85
b_7- ($b_3 + b_5$)		5.84	1.95	7.79	2.10
LSD at 5%		**0.03**	**0.03**	**0.06**	**0.06**
AXB Interaction:					
a_1	b_1	5.01	1.55	6.56	1.57
	b_2	5.30	1.63	6.93	1.87
	b_3	5.67	1.98	7.65	2.05
	b_4	5.49	1.95	7.44	1.99
	b_5	6.02	2.06	8.08	2.14
	b_6	6.30	2.11	8.41	2.16
	b_7	6.37	2.15	8.52	2.25
a_2	b_1	3.67	1.16	4.83	1.18
	b_2	4.09	1.30	5.39	1.31
	b_3	4.30	1.36	5.66	1.39
	b_4	4.50	1.39	5.89	1.40
	b_5	4.75	1.45	6.20	1.47
	b_6	5.04	1.57	6.61	1.87
	b_7	5.73	2.05	7.78	2.13
a_3	b_1	3.31	1.13	4.44	1.21
	b_2	4.00	1.19	5.19	1.24
	b_3	4.25	1.31	5.56	1.38
	b_4	4.15	1.26	5.41	1.36
	b_5	4.74	1.41	6.15	1.42
	b_6	4.89	1.51	6.40	1.54
	b_7	5.43	1.65	7.08	1.93
LSD at 5%		**0.08**	**0.05**	**0.08**	**0.06**

Table 7: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on leaves chemical contents (Data was taken as the combined analysis between the two-growing seasons).

Traits		Total carbohydrates	Total sugars	Free amino acids	Phenols	Proline
Treatments		**ug/g dry weight**		**mg/g dry weight**	**mg/100 g dry weight**	**ug/g dry weight**
A-Irrigation intervals:						
a_1- 14 day		247.90	113.01	16.42	25.23	598.33
a_2- 21 day		234.61	105.53	13.05	36.43	712.41
a_3- 28 day		231.69	103.30	12.23	35.36	746.00
LSD at 5%		**0.63**	**0.89**	**0.05**	**2.36**	**20.28**
B-Levels of anti-transpiration materials:						
b_1- Without application (control)		224.57	99.27	10.99	36.88	790.49
b_2- 4 g Licorice roots powder/L		230.22	104.12	11.55	36.11	753.65
b_3- 8 g Licorice roots powder /L		237.39	107.00	14.02	34.83	692.97
b_4- 4 g Fenugreek powder /L		236.65	106.24	13.01	35.42	697.62
b_5- 8 g Fenugreek powder /L		241.73	109.08	15.08	29.63	638.99
b_6- ($b_2 + b_4$)		244.74	111.28	15.76	28.15	634.45
b_7- ($b_3 + b_5$)		251.16	113.97	16.89	25.37	590.89
LSD at 5%		**0.89**	**1.24**	**0.07**	**1.28**	**12.71**
AXB Interaction:						
a_1	b_1	238.92	107.53	14.30	33.62	673.05
	b_2	241.51	109.42	14.49	33.23	668.36
	b_3	244.23	111.35	15.95	31.50	592.97
	b_4	243.49	111.04	15.50	32.25	599.78
	b_5	251.60	113.33	17.30	17.45	551.29
	b_6	255.50	117.80	18.40	15.95	553.92
	b_7	260.04	120.64	18.98	12.59	548.91
a_2	b_1	218.53	98.37	9.60	39.16	835.16
	b_2	226.95	102.67	10.41	37.73	759.44
	b_3	234.89	106.03	13.70	36.92	741.48
	b_4	233.81	104.35	12.38	37.20	741.12
	b_5	237.54	107.09	13.98	35.80	680.48
	b_6	239.88	108.53	14.56	35.20	671.76
	b_7	250.66	111.70	16.75	33.01	557.44
a_3	b_1	216.26	91.92	9.08	37.84	863.28
	b_2	222.20	100.29	9.76	37.36	833.15
	b_3	233.04	103.64	12.40	36.05	744.45
	b_4	232.64	103.33	11.15	36.81	751.96
	b_5	236.05	106.83	13.95	35.64	685.21
	b_6	238.86	107.52	14.32	33.30	677.67
	b_7	242.79	109.58	14.95	30.50	666.33
LSD at 5%		**1.44**	**1.38**	**0.11**	**1.36**	**16.02**

The positive effect due foliar feeding with the extracted used on the photosynthesis pigments, total sugars, total carbohydrates, and free amino acids is mainly attributed to their constituents of P, K, Al, Ca, Fe, Mn, Co, Zn and Na (Table, 1). These nutrients play vital role in increasing photosynthetic pigments, where phosphorus plays an essential role in most biological processes such as transfer energy to all plant parts, cell division and the formation of chloroplasts membranes and composition of amino and nucleic acids (Rajasekar *et al*., 2017). Potassium (K) stimulates the formation of carbohydrates (Cakmak, 2005). Nitrogen is an essential nutrient in creating many energies rich compounds which regulate photosynthesis and increase plant dry matter (Hearn, 1981).

There is an optimal relationship between nitrogen content in the plant and CO_2 assimilation. This may be due to the significant increase in photosynthetic pigments (Table, 6). It was found that licorice extract enhanced the activity of apical meristem tissue which in turn led to cell division and elongation as it is rich in amino acids, vitamins and growth stimulating photo-hormones (Rawlings *et al*., 1994). Fenugreek seeds contain 45-60% carbohydrates (mainly mucilaginous fiber: galactomannans); 20.80% proteins (mainly lysine and tryptophan); 5-6.25% fixed oils (lipids); 7.76%reducing sugars; flavonoids (apigenin, luteolin and quercetin); pyridine-type alkaloids, (mainly trigonelline); steroidal saponins (trigoneoside and furostanol); phenolics (coumarin: scopoletin); steroidal sapogenins (fenugreekine) as well as volatile oils, vitamins and minerals as reported by Belguith-Hadriche *et al.* (2013). Licorice root contains 45-60% carbohydrates (mainly mucilaginous fiber: galactomannans); 5.20% proteins (mainly lysine and tryptophan); 3.75% oils (lipids);2.25% reducing sugars (7.76%); flavonoids (apigenin, luteolin and quercetin); pyridine-type alkaloids, (mainly trigonelline); steroidal saponins (trigoneoside and furostanol); phenolics (coumarin: scopoletin); steroidal sapogenins (fenugreekine), as well as volatile oils, vitamins and minerals (Belguith-Hadriche *et al.,* 2013). The Phenolics belong to a class of antioxidant compounds which act as free radicals' inhibitors and they are very essential for plants due to their quenching ability because of the existence of hydroxyl groups (Elmastas *et al*., 2006). These increases refer to LRE contents of some nutrients such as magnesium, potassium, phosphorus, zinc, and iron, in addition to their important role in the stimulation of different enzymes (Moses *et al*., 2002). Asparagine is the major transport compound in the xylem from the root to the leaves and in the phloem from the leaves to the developing seeds in a range of plants. Asparagine has a N:C ratio of 2:4, which makes it an efficient molecule for the storage and transport of nitrogen in living organisms (Lea *et al*., 2007). Licorice extract contains more than 100 different components, most important of them are glycyrrhizin, phenolic compounds, mevalonic acid which has similar effect to GA3 in reducing complex compounds to simple substance used by plants to build new proteins are essential for the growth, polysaccharide (glucose, fructose, sucrose, maltose), lignin, protein amino acid (asparagin), vitamins such as B6, B3, B2, B1, E and C, biotin, folic acid and pantothenic acid which play an effective role in improvement of the plant growth. Also, these nutrients increase the photosynthetic activity through their role in the stimulation of different enzymes increase the photosynthetic activity (Arystanova *et al.*, 2001). Al-Jebouri *et al*. (2010) indicated that spraying cucumber plant with licorice root extract increased total chlorophyll content of leaves. They added that licorice extract contains mevalonic acid that is the initiator in the synthesis of GA acid in the plants; therefore, spraying the plant with licorice extract promotes the vegetative growth of many plants. Zuhair (2010) found that licorice increased total chlorophyll content.

3.2.3. Interaction effect

The interaction treatments gave a significant effect on photosynthetic pigments content in cotton leaves (Table, 6). The plants irrigated every 14 days and received (8 g liquorice root powder /L plus 8 g fenugreek powder /L) gave the highest values in mg/g dry weight (6.37 chlorophyll a, 2.15 chlorophyll b, 8.52 total chlorophyll and 2.25 carotenoid). However, the lowest values (3.31 chlorophyll a, 1.13 chlorophyll b, 4.44 total chlorophyll and 1.21 carotenoid) were detected from the plants irrigated every 28 days and without plant extracted treatments.

In Table, 7 showed an increase in total sugars, total carbohydrates, and free amino acids concentrations. The highest level of total sugars, total carbohydrates and free amino acids concentrations were recorded with the plants irrigated every 14 days and received (8 g liquorice root powder /L plus 8 g fenugreek powder /L). Meanwhile, there was a significant decrease in phenols and proline content at the same levels.

3.3. Growth parameters

3.3.1. Effect of irrigation intervals

Irrigation intervals were significantly affected leaf area plant^{-1}, total above ground dry weight plant^{-1} at 116 days old and plant height at harvest as well as numbers of fruiting and vegetative branches plant^{-1} in both seasons (Tables, 8 and 9). The best treatment was found in irrigated plants every 14 days. The tallest plants due to water increased at irrigation every 14 days compared to the irrigation every 21 and 28 days could be explained on the basis growth stages which are highly sensitive to the plenty of water, which was reflected on increasing length of the internodes and number of nodes, which was detected through increasing number of fruiting branches (Tables, 8 and 9).

It was found that drought stress reduces plant growth by affecting photosynthesis and cell expansion processes (Zahoor *et al.*, 2017). Similarity, under drought stress, photosynthesis rate, leaf area, transpiration rate and total dry matter accumulation reduce due to stomatal and/or non-stomatal limitations, shedding of leaves and fruiting structures that leads to diminished final yield (Pettigrew, 2004).

Table 8: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on cotton plant growth parameters in 2018 season.

Treatments / Traits		LA (dm^2 $plant^{-1}$)	Total dry weight (g $plant^{-1}$)	No. of vegetative branches $plant^{-1}$	No. of fruiting branches $plant^{-1}$	Plant height (cm)
		After 116 days old		At harvest		
A-Irrigation intervals:						
a_1- 14 day		25.66	128.31	1.94	15.02	167.08
a_2- 21 day		24.57	112.00	1.41	14.51	163.50
a_3- 28 day		23.35	103.24	1.31	14.04	160.19
LSD at 5%		**0.16**	**0.72**	**0.77**	**0.11**	**0.58**
B-Levels of anti-transpiration materials:						
b_1-Without application (control)		22.43	105.14	1.14	13.42	158.18
b_2- 4 g Licorice roots powder/L		23.69	110.72	1.26	14.06	161.04
b_3- 8 g Licorice roots powder /L		24.85	115.86	1.44	14.74	162.47
b_4- 4 g Fenugreek powder /L		23.45	109.71	1.47	13.90	164.09
b_5- 8 g Fenugreek powder /L		24.56	114.62	1.64	14.74	165.06
b_6- ($b_2 + b_4$)		25.76	120.05	1.78	15.11	166.33
b_7- ($b_3 + b_5$)		26.96	125.49	2.11	15.68	167.96
LSD at 5%		**0.30**	**1.37**	**0.10**	**0.33**	**0.35**
AXB Interactions:						
a_1	b_1	23.74	119.23	1.60	14.07	160.17
	b_2	24.80	124.25	1.63	14.57	164.87
	b_3	25.48	127.29	1.83	15.03	165.80
	b_4	24.54	122.90	1.87	14.60	167.83
	b_5	25.23	126.05	2.07	15.17	168.43
	b_6	27.25	135.84	2.17	15.50	170.57
	b_7	28.60	142.58	2.40	16.23	171.90
a_2	b_1	22.49	102.90	0.93	13.50	158.53
	b_2	24.00	109.50	1.13	14.07	160.77
	b_3	24.83	113.15	1.27	14.70	162.33
	b_4	23.83	108.77	1.33	13.70	164.20
	b_5	24.62	112.33	1.43	14.83	165.20
	b_6	25.40	115.58	1.63	14.93	166.53
	b_7	26.80	121.76	2.10	15.80	166.90
a_3	b_1	21.06	93.30	0.90	12.70	155.83
	b_2	22.25	98.43	1.00	13.53	157.50
	b_3	24.24	107.14	1.23	14.50	159.27
	b_4	21.99	97.45	1.20	13.40	160.23
	b_5	23.82	105.47	1.43	14.23	161.53
	b_6	24.64	108.72	1.53	14.90	161.90
	b_7	25.47	112.14	1.83	15.00	165.07
LSD at 5%		**0.41**	**1.57**	**NS**	**NS**	**0.73**

Table 9: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on cotton plant growth parameters in 2019 season.

Treatments (Traits)		LA (dm^2 $plant^{-1}$)	Total dry weight (g $plant^{-1}$)	No. of vegetative branches $plant^{-1}$	No. of fruiting branches $plant^{-1}$	Plant height (cm)
		After 116 days old		At harvest		
A-Irrigation intervals:						
a_1- 14 day		25.17	117.37	2.06	15.12	173.00
a_2- 21 day		24.77	112.32	1.50	14.61	156.98
a_3- 28 day		23.94	106.02	1.39	14.23	155.96
LSD at 5%		**1.17**	**0.45**	**0.08**	**0.09**	**0.38**
B-Levels of anti-transpiration materials:						
b_1- Without application (control)		24.08	102.48	1.22	13.61	157.38
b_2- 4 g Licorice roots powder/L		24.30	107.93	1.34	14.21	159.58
b_3- 8 g Licorice roots powder /L		24.89	114.00	1.54	14.82	161.07
b_4- 4 g Fenugreek powder /L		24.65	106.06	1.56	14.00	162.58
b_5- 8 g Fenugreek powder /L		25.43	111.43	1.75	14.83	163.59
b_6- (b_2 + b_4)		24.30	117.86	1.89	15.26	163.86
b_7- (b_3 + b_5)		24.72	123.56	2.24	15.87	165.82
LSD at 5%		**0.41**	**0.73**	**0.10**	**0.23**	**0.48**
AXB Interaction:						
a_1	b_1	24.08	107.65	1.70	14.20	168.73
	b_2	24.70	113.19	1.74	14.77	171.17
	b_3	25.48	117.82	1.95	15.17	172.00
	b_4	25.90	111.86	1.98	14.63	173.53
	b_5	26.10	114.49	2.19	15.20	174.67
	b_6	24.39	124.66	2.30	15.63	175.13
	b_7	25.53	131.89	2.54	16.27	175.77
a_2	b_1	24.44	103.12	1.00	13.63	151.73
	b_2	25.01	109.44	1.21	14.17	154.30
	b_3	24.80	114.18	1.35	14.70	156.30
	b_4	24.75	108.21	1.42	13.80	157.53
	b_5	24.96	111.62	1.53	14.93	158.77
	b_6	24.54	117.19	1.74	15.03	158.93
	b_7	24.86	122.46	2.23	16.03	161.30
a_3	b_1	23.71	96.67	0.97	13.00	151.67
	b_2	23.19	101.16	1.07	13.70	153.27
	b_3	24.39	110.00	1.32	14.60	154.90
	b_4	23.29	98.10	1.28	13.57	156.67
	b_5	25.22	108.18	1.53	14.37	157.33
	b_6	23.97	111.72	1.63	15.10	157.50
	b_7	23.76	116.32	1.95	15.30	160.40
LSD at 5%		**0.63**	**1.70**	**NS**	**0.32**	**0.94**

Limited carbon fixation caused by stomatal closure and reduced photosynthesis under drought stress disrupts carbohydrate metabolism and dry matter partitioning processes (Chaves *et al*., 2002). An imbalance occurs between photo-assimilates accumulation and their utilization through photorespiration resulting in reduction of photo-assimilates translocation towards reproductive organs. Additionally, carbohydrate metabolizing enzymes are also down or upregulated by the sugar status of plant cell. Under drought stress, in K deficient plants, stomata cannot function properly, and moisture is lost through transpiration, which results in decreased CO_2 supply to chloroplasts and limited P_n (Flexas *et al.,* 2004). Drought stress reduces plant growth and development by affecting photosynthesis and cell expansion processes in the plant. Both stomatal and nonstomatal factors are involved in Pn reduction, which ultimately reduces photo-assimilates synthesis and portioning.

Cotton plants under drought stress conditions displayed different physiological responses for regulating growth and enzyme activities involved in photo-assimilates production and translocation towards productive parts. One of the first strategies in plants to mitigate drought stress is leaf biomass reduction, which may lead to the maintenance of cell turgor and transpiration reduction to reduce water loss (Neumann, 1995). Reduced soil water potential perturbs mobility of nitrogen in the soil, thus plants exposed to/or facing drought stress will also face nitrogen deficiency, which also reduces plant growth. Leaf dry weight showed high sensitivity to water stress. Karademir *et al.,* (2008) found that leaf area decreased approximately 30% under drought stress conditions The decline of Pn in cotton leaves under severe drought by non-stomatal factors, including limited gas diffusion in mesophyll cells, reduced CO_2 solubility, and reduction in Rubisco affinity to CO_2. Similar results were obtained by other researchers (El-Ashmouny, 2014; Emara *et al.,* 2015; El-Gabiery, 2016 and El-Shazly, 2017).

3.3.2. Effect of anti-transpirants used

The tested treatments gave a significant effect on leaf area plant^{-1}, total dry weight plant^{-1} at 116 days old and plant height at harvesting and numbers of fruiting and vegetative branches/plant in both seasons (Tables, 8 and 9), The highest values of these traits were recorded from the combination between 8 g/L liquorice root powder plus 8 g/L fenugreek powder in both seasons. The control treatment gave the lowest values in both seasons. In this respect, Cuong *et al.,* (2017) reported that licorice root extract contains a mephalonic acid which is the initiator in the synthesis of gibberellins in plants and improves vegetative growth because of stimulating the enzymes necessary for the conversion of complex compounds into compounds simple, and energy- efficient processing required for plant growth. Licorice root extract which contains many different important compounds such triterpene saponins (including glycyrrhizin), protein amino acid (asparagin), polysaccharide (glucose, fructose, sucrose, maltose) lignins, vitamins such as B1, B2, B3, B6, C and E, Biotin, folic acid, pantothenic acid and many minerals (P, K, Al, Ca, Fe, Mn, Co, Zn, Na and Si) play an important role in improving plant growth. Moreover, the availability of licorice extract on enhancing apical meristem activity which in turn led to cell division and elongation as it is rich in amino acids, vitamins and growth stimulating photo-hormones. Fenugreek seed extract and liquorice root extract improved the accumulation of flavonoids and phenolics (Moses *et al*., 2002).

Flavonoids are considered as secondary ROS-scavenging system in plants protecting them against various environmental disturbances (Fini *et al*., 2011). Accumulative effects of phenolics, flavonoids and proline due to fenugreek seed extract application noticed in this study may be attributed to the phytochemicals present in the extract (Table, 2). This improvement may shed the light on the effective role of phenolics found in fenugreek seed extract in improvement plant antioxidant status and mineral nutrients play a critical role to withstand the adverse environmental conditions (Hawkesford *et al*., 2012). Shafeek *et al.,* (2015) found an increment in the average leaf area of onion plant by foliar spraying with Licorice extract.

3.3.3. Interaction effect

The interaction treatments gave a significant effect on leaf area plant^{-1}, total dry weight plant^{-1} at 116 days old and plant height at harvest in both seasons and number of fruiting branches/plant in the second season (Tables, 8 and 9). The plants irrigated every 14 days and received (8 g/L liquorice root powder plus 8 g/L fenugreek powder) gave the highest valued of these traits. The lowest values were recorded from the plants irrigated every 28 days and untreated with any of the plant extracted examined.

3.4. Earliness attributes

3.4.1. Effect of irrigation intervals

Results in Tables, 10 and 11 showed that number of total flowers plant^{-1} was significantly increased with an increase in the irrigation intervals in the second season, in favor of irrigation every 21 days. In this concern, El-Gabiery (2016) pointed out that under El-Gemmeiza location, irrigation every 15 days significantly increased number of total flowers plant^{-1} in both seasons as compared with the other two irrigation intervals (every 30 and 45 days). El-Shazly (2017) found that under El-Gemmeiza location, irrigation every 14 days significantly increased number of total flowers/plant as compared with 21 and 28 days.

Concerning the effect of the irrigation intervals on number of total bolls set/plant, boll setting and earliness percentages. Data in the same tables showed that the differences among the irrigation intervals reached to the level of significance in both seasons, in favor of irrigation every 14 days. The inverse trend was obtained regarding boll shedding percentage.

In this regard, Hawkins *et al.* (1933) reported that drought caused extremely slow growth and the formation of small thick-walled cells. They added that drought increased the carbohydrate content, whereas decreased nitrogen content with about 100 percent abscission of young bolls. McNamara *et al.* (1940) found that young bolls shed as soil moisture was depleted and a strong tendency existed for the squares to flower. Darwish and Hegab (2000) found that yield earliness was significantly decreased by decreasing irrigation interval, Emara *et al.* (2015) found that irrigation intervals gave insignificant effect on earliness %, El-Gabiery (2016) pointed out that under El-Gemmeiza location, irrigation every 15 days significantly decreased boll setting and earliness percentages compared with 30 and 45 days. El-Shazly (2017) found that the differences among the irrigation intervals reach the level of significance, in favour of irrigation every 21 days about boll setting percentage and in favor of 30 days about earliness percentage. Snider and Virk (2021) reported that shedding can be increased by too little or too much water. It has been well documented that drought conditions can increase the rate of boll abscission. Drought causes reductions in leaf area and photosynthetic efficiency that limit the number of fruits the crop can support. The crop is particularly sensitive to drought from early flowering to peak bloom, with two-bail reductions in yield (Chastain *et al*., 2016) for dryland cotton when compared with a well-watered control.

Boll shedding in response to drought may be a mechanism that helps the plant survive and continue to grow during periods of drought. Bolls compete with roots for assimilates and restrict root growth. Eaton and Joham (1944) found that de-fruiting causes large increases in sugar content and growth of cotton roots. When root growth is restricted, water absorption by plants becomes more dependent on flow of water through the soil to the root. The movement of water through unsaturated soil, however, is very slow and, unless the roots can grow into new areas of soil, the plants will not be able to obtain enough water to prevent stress (Begg and Turner, 1976). Furthermore, the mechanical resistance of drying soil is greater than that of wet soil. Hsiao (1973) reported that the pressure potential must be adequate to permit root growth into the resistant soil, and solutes provide the major portion of the pressure potential. Hsiao *et al.* (1976) concluded that cotton cultivars with relatively indeterminate growth habit are better adapted in an environment with seasonally limited soil moisture than other cultivars with determinate growth habit. Because of their smaller boll load and less competition by bolls for available assimilates, the roots of indeterminate cultivars are probably able to grow more and extract water from a greater volume of soil than are roots of determinate cultivars.

Drought can affect fruiting and boll abscission in several ways. Water deficit decreases photosynthesis by decreasing leaf size and, thus, photosynthetic area by decreasing photophosphorylation (Boyer, 1973), causing stomatal closure (Cutler and Rains, 1977), decreasing the synthesis and activity of photosynthetic enzymes (Jones, 1973), Hill reaction activity (Fry, 1970), increasing photorespiration (Lawlor, 1976), leaves may become senescent and abscise (McMichael *et al*., 1973). Other effects of prolonged stress can limit photosynthesis as a result of decreased uptake of nitrate (Shaner and Boyer, 1976) and phosphate (Greenway *et al.,* 1969); decreased nitrate reductase activity (Ackerson *et al.*, 1977); increased IAA oxidase activity (Darbyshire, 1971); decreased cytokinin content (Vaadia, 1976); increased ethylene production (McMichael *et al.,* 1972); increased ribonuclease activity (Arad *et al.*, 1973); decreased polyribsome content and decreased protein synthesis (Boyer, 1973). Drought may also decrease translocation of assimilates, but photosynthesis is affected more than translocation in cotton (Ackerson and Herbert, 1981). Translocation in adapted plants was not decreased when plants were stressed to leaf water potential of -24 bars (Ackerson and Hebert, 1981). Water deficit can alter the hormonal balance in bolls. Loss of water causes bolls to produce increasing amounts of ethylene, both when plants are stressed and when detached bolls are subjected to partial desiccation (Guinn, 1998). Further, the ABA content of young bolls on field-grown plants increases as stress develops between irrigations, and the increase in ABA content parallels an increase in rate of boll shedding (Guinn, 1998). Thus, both abscission-promoting hormones (ethylene and ABA) increase with increasing stress. Water deficit may also affect boll abscission through an effect on IAA transport to the abscission zone.

Regardless of whether the osmotic solutes are sugars, organic acids, or other organic compounds. Photosynthesis is the ultimate source. To the extent that developing bolls compete with roots for assimilates, the ability of roots to grow in a drying soil will be decreased. This relationship may explain the results that caused (Quisenberry and Roark, 1976). Copper is involved in pollen formation and has an important role in maintaining its viability, mediates pollination, biosynthesis of lignin, quinones and carotenoids (Hajiboland, 2012). Addicott and Lyon (1973) listed calcium (Ca) deficiency as a cause of abscission due to the role of Ca in the middle lamella (Ca pectates) as a possible reason, where adequate Ca inhibit abscission because it is a component of the middle lamella, promotes translocation of sugars and auxin, and helps prevent senescence. Joham (1957) found that a severe Ca deficiency caused complete failure of cotton set bolls because of starvation. A deficiency of boron (B) causes abscission of squares and bolls because of its effect on translocation of sugars and maintain phloem in a healthy condition (Eaton, 1955). Zinc (Zn) deficiency may increase abscission because Zn is required for IAA synthesis (Tsui, 1948) and photosynthesis (Ohki, 1976). Skoog (1940) indicated that Zn-deficient tissue destroyed IAA. Excessively high temperatures can increase boll shedding by causing pollen sterility and by increasing respiration and photo respiration.

3.4.2. Effect of anti-transpirants used

The tested treatments gave a significant effect on number of total flowers/ plant in the second season, in favor of the control. However, the control gave the lowest number of total bolls set/plant in both seasons. The tested treatments gave a significant effect on boll setting and earliness percentages in both seasons (Tables, 10 and 11). The highest boll setting percentage (61.80 and 63.05%) was recorded from the combination between 8 g/L liquorice root powder plus 8 g/L fenugreek powder and fenugreek powder at the high level (8 g/L) in the first and second seasons, respectively. The highest earliness percentage (64.87 and 72.29%) was recorded from the combination between 8 g/L liquorice root powder plus 8 g/L fenugreek powder during the first and second seasons, respectively. The control treatment gave the lowest boll setting percentage (55.56 and 52.82 %) and earliness percentage (53.80 and 60.15%) in the first and second seasons, respectively. The increase in setting% of the plant may be due to the similarity of licorice root extract in its behavior with GA in stimulating flowering (Table, 2). IAA normally delays or prevents abscission, possibly because it prevents the synthesis and secretion of the specific cellulase involved in abscission. Gibberellins promote abscission of explants (isolated portions of plants) but inhibit abscission when applied to cotton flowers or young bolls. Cytokinins have variable effects and may either promote or retard abscission, depending upon time and site of application. The effects of gibberellins and cytokinins may be due mainly to their ability to mobilize nutrients to the site of their application or natural distribution (Guinn, 1998).

3.4.3. Interaction effect

The interaction gave a significant effect on number of total flowers/ plant in the second season (Tables, 10 and 11). The untreated plants with anti-transpiration materials which irrigated every 21 days gave the highest number of total flowers/ plant (31.83). The lowest number of total flowers/ plant (25.29) was recorded from the plants irrigated every 14 days and received 8 g/L liquorice root powder plus 8 g/L fenugreek powder. Regarding number of total bolls set/ plant, boll setting% and earliness% in both seasons (Tables, 10 and 11), data indicated that plants irrigated every 14 days and received 8 g/L fenugreek powder gave the highest number of total bolls set/ plant (18.57) in the second season and earliness percentage (69.24 and 76.71%) in both seasons. The highest boll setting percentage (62.47 and 70.58%) was obtained from the plants irrigated every 14 days and received 8 g/L liquorice root powder plus 8 g/L fenugreek powder in both seasons. In the first season, the plants irrigated every 14 days and received 8 g/L liquorice root powder plus 8 g/L fenugreek powder gave the highest number of total bolls set/ plant (17.53). The lowest number of total bolls set/ plant (14.98) and boll setting percentage (53.52%) were recorded from the plants irrigated every 28 days and received 4 g/L liquorice root powder in the first season. Moreover, the lowest number of total bolls set/ plant (14.92), boll setting percentage (48.50%) and earliness percentage (56.47%) were recorded from the plants irrigated every 28 days and untreated with anti-transpiration materials in the second season. The plants irrigated every 28 days and untreated with anti-transpiration materials recorded the lowest earliness% (50.75%) in the first season.

Table 10: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on earliness attributes in 2018 season.

Treatments (Traits)		No. of total flowers plant^{-1}	No. of total bolls plant^{-1}	Boll setting %	Boll shedding %	Earliness %
A-Irrigation intervals:						
a_1- 14 day		28.05	16.58	59.10	40.91	61.62
a_2- 21 day		28.05	16.32	58.17	41.83	58.97
a_3- 28 day		28.04	15.92	56.76	43.24	55.66
LSD at 5%		**NS**	**0.33**	**1.15**	**1.15**	**0.23**
B-Levels of anti-transpiration materials:						
b_1- Without application (control)		28.04	15.58	55.56	44.44	53.80
b_2- 4 g Licorice roots powder/L		28.06	15.73	56.08	43.92	56.67
b_3- 8 g Licorice roots powder /L		28.13	16.15	57.44	42.56	59.85
b_4- 4 g Fenugreek powder /L		28.05	15.96	56.88	43.12	55.68
b_5- 8 g Fenugreek powder /L		28.00	16.44	58.68	41.32	58.50
b_6- ($b_2 + b_4$)		28.07	16.74	59.64	40.36	61.88
b_7- ($b_3 + b_5$)		27.98	17.29	61.80	38.20	64.87
LSD at 5%		**NS**	**0.29**	**0.94**	**0.94**	**0.39**
AXB Interaction:						
a_1	b_1	27.99	15.55	55.56	44.44	56.51
	b_2	28.22	16.08	57.00	43.00	59.43
	b_3	28.12	16.53	58.80	41.20	61.86
	b_4	28.06	16.77	59.76	40.24	58.73
	b_5	27.91	16.82	60.24	39.76	60.11
	b_6	28.01	16.77	59.87	40.13	65.45
	b_7	28.06	17.53	62.47	37.58	69.24
a_2	b_1	28.07	15.83	56.40	43.60	54.14
	b_2	27.95	16.13	57.72	42.28	57.46
	b_3	28.19	16.13	57.24	42.76	59.94
	b_4	28.01	16.00	57.12	42.88	56.81
	b_5	28.07	16.17	57.60	42.40	58.60
	b_6	28.13	16.93	60.18	39.82	61.53
	b_7	27.92	17.02	60.96	39.04	64.29
a_3	b_1	28.05	15.35	54.72	45.28	50.75
	b_2	28.00	14.98	53.52	46.48	53.11
	b_3	28.07	15.80	56.28	43.72	57.75
	b_4	28.09	15.10	53.76	46.24	51.50
	b_5	28.03	16.32	58.20	41.80	56.79
	b_6	28.08	16.53	58.87	41.13	58.65
	b_7	27.96	17.33	61.98	38.02	61.07
LSD at 5%		**NS**	**0.41**	**1.45**	**1.45**	**0.89**

Table 11: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on earliness attributes in 2019 season.

Treatments	Traits	No. of total flowers plant^{-1}	No. of total bolls plant^{-1}	Boll setting %	Boll shedding %	Earliness %
A-Irrigation intervals:						
a_1- 14 day		28.71	18.17	63.52	36.48	68.82
a_2- 21 day		29.76	16.46	55.45	44.55	65.88
a_3- 28 day		29.02	15.54	53.66	46.34	62.63
LSD at 5%		**0.37**	**0.19**	**0.36**	**0.36**	**0.43**
B-Levels of anti-transpiration materials:						
b_1- Without application (control)		30.90	16.30	52.82	47.18	60.15
b_2- 4 g Licorice roots powder/L		29.60	16.46	55.63	44.37	63.52
b_3- 8 g Licorice roots powder /L		29.17	16.99	58.24	41.76	66.63
b_4- 4 g Fenugreek powder /L		30.30	16.69	55.11	44.89	62.90
b_5- 8 g Fenugreek powder /L		29.45	16.98	57.61	42.39	65.86
b_6- ($b_2 + b_4$)		27.82	16.76	60.33	39.67	69.09
b_7- ($b_3 + b_5$)		26.89	16.89	63.05	36.95	72.29
LSD at 5%		**0.31**	**0.28**	**0.68**	**0.68**	**0.81**
AXB Interactions						
a_1	b_1	30.11	17.77	59.02	40.98	63.65
	b_2	29.30	18.02	61.51	38.49	66.52
	b_3	29.28	18.45	63.01	36.99	68.33
	b_4	29.96	18.23	60.84	39.16	65.82
	b_5	29.75	18.57	62.40	37.60	67.66
	b_6	27.25	18.33	67.25	32.75	73.08
	b_7	25.29	17.85	70.58	29.42	76.71
a_2	b_1	31.83	16.21	50.94	49.06	60.32
	b_2	29.96	16.24	54.21	45.79	64.37
	b_3	29.60	16.58	56.02	43.98	66.58
	b_4	30.74	16.55	53.85	46.15	63.89
	b_5	30.35	16.88	55.61	44.39	66.04
	b_6	28.47	16.29	57.22	42.78	68.10
	b_7	27.34	16.48	60.28	39.72	71.87
a_3	b_1	30.76	14.92	48.50	51.50	56.47
	b_2	29.54	15.11	51.16	48.84	59.68
	b_3	28.63	15.95	55.69	44.31	64.99
	b_4	30.20	15.30	50.65	49.35	58.98
	b_5	28.25	15.49	54.83	45.17	63.89
	b_6	27.73	15.67	56.51	43.49	66.10
	b_7	28.04	16.34	58.29	41.71	68.30
LSD at 5%		**0.65**	**0.46**	**0.93**	**0.93**	**1.10**

3.5. Seed cotton yield and its contributory characters

3.5.1. Effect of irrigation intervals

Interval of irrigation exhibited significant differences in number of open bolls per plant, boll weight and seed cotton yield per plant in both seasons (Tables, 12 and 13). The highest seed cotton yield per plant (45.71 and 49.44 g) with the higher number of open bolls/plant (16.42 and 17.64) and heavier bolls (2.78 and 2.80 g) resulted from irrigated cotton plants every 14 days, while plants irrigated every 28 days had the lightest bolls (2.61 g) in the first season, the lowest number of open bolls/plant (15.66 and 15.09) and the lowest seed cotton yield per plant (40.86 and 41.18 g) in both seasons. The significant increase of boll weight due to irrigate every 14 days may be due mainly to the increase in seed index and lint percentage as compared with the two other intervals. The significant increase of open bolls/plant which resulted from irrigated every 14 days may be due mainly to the increasing boll setting percentage as compared with the other two intervals. The significant increase in seed cotton yield is mainly due to the significant increase in number of open bolls/plant and heavier bolls. Similar results were obtained by other researchers (Emara *et al.*, 2015; El-Ashmouny, 2014 and Ibrahim *et al.*, 2014). However, El-Gabiery (2016) reported that the higher number of open bolls/plant was obtained from plants which irrigated every 30 days as compared with plants irrigated every 15 and 45 days. El-Shazly (2017) reported that prolonging irrigation interval from 14 days to 21 days significantly increased number of open bolls per plant, seed cotton yield per plant and boll weight.

Seed index and lint percentage were significantly affected by irrigation intervals in both seasons (Tables, 12 and 13), in favor of irrigated cotton plants every 14 days followed in ranking by irrigated every 21 days and at last irrigated every 28 days. The respective values due to these intervals were 10.43 g and 39.86%; 9.93 g and 39.59%, 9.49 g and 39.04% in the first season; 11.50 g and 42.62%, 11.11 g and 42.21%, 10.39 g and 41.54% in the second. This result agrees with those obtained by El-Ashmouny (2014) and Ibrahim *et al.,* (2014), who reported that the highest value of lint % and seed index was resulted from irrigated the plants every 14 days.

Emara *et al.* (2015) pointed out that irrigation intervals gave insignificant effect on lint % and seed index, El-Gabiery (2016) found that the highest value of lint % was resulted from irrigated plants every 45 days and El-Shazly (2017) reported that lint percentage was significantly affected by irrigation intervals, in favor of irrigated every 28 days. Also, seed index significantly responded to irrigation intervals, in favor of irrigated cotton plants every 21 days followed by irrigated every 28 days.

Results in Tables, 12 and 13 showed that irrigation every 14 day significantly increased seed cotton yield per feddan by 4.50 and 10.72%; 14.57 and 18.46% than irrigation every 21 or 28 days in the first and second seasons, respectively. The significant increase in seed cotton yield per feddan of 14 days interval may be due to the promoting effect of irrigated every 14 days on mineral nutrients (Tables, 4 and 5), photosynthetic pigments contents (Table, 6), leaves total carbohydrates and sugars contents (Table, 7), leaf area and total dry weight at 116 days old (Tables, 8 and 9), boll setting percentage (Tables, 10 and 11) and number of open bolls and heaviest bolls (Tables, 12 and 13). It was found that increasing or reducing water above or less the optimal requirement, levels of photosynthesis was limited by low CO_2 availability due to reduced stomatal and mesophyll conductance and thereby with decreased CO_2 fixation. Photosynthesis is the most essential process in plant for growth and basis of dry matter production, thus the driving force for final yield (Pettigrew and Gerik, 2007). Similar results were obtained by El-Ashmouny, (2014) and Ibrahim *et al.,* (2014), who found that irrigation cotton plants every 14 days significantly increased seed cotton yield per feddan as compared to 21 or 28 days. Balkcom *et al.,* (2006) found that irrigation improves ginning percentage and increased yield. Basal *et al.,* (2009) found that seed cotton yield increased as the irrigation levels increased. Hassan *et al.* (2016) found that superiority of irrigation at two weeks of seed cotton yield, number of open bolls per plant, number of sympodium per plant, ginning percentage and water use efficiency. On the contrary, El-Gabiery (2016) found that under El-Gemmeiza location, irrigating intervals (15, 30 and 45 days) gave significant effect on seed cotton yield/fed in favor of plants which irrigated every 30 days. El-Shazly (2017) reported that intervals of irrigation exhibited significant differences in seed cotton yield per feddan, where the highest seed cotton yield per feddan was obtained from plants irrigated every 21 days.

3.5.2. Effect of anti-transpirants used

Data in Tables, 12 and 13 showed that foliar spraying with the anti-transpirants used increased seed cotton yield per plant (49.62 and 48.96 g) with the higher numbers of open bolls (16.91 and 16.40 bolls) and heavier bolls (2.93 and 2.98 g), in favor of the combination between 8 g/L liquorice root powder plus 8 g/L fenugreek powder. The control (untreated plants) gave the lowest seed cotton yield per plant (38.53 and 41.07 g) with the lower numbers of open bolls (15.43 and 15.83) and lighter bolls (2.50 and 2.59 g) in the first and second seasons, respectively. Lint percentage and seed index were significantly affected by foliar spraying with the anti-transpirants used in both seasons (Tables, 12 and 13), in favor of the combination between 8 g/L liquorice root powder plus 8 g/L fenugreek powder. This combination significantly increased seed index by 10.40 and 18.75% than control in the first and second seasons, respectively. The same tables showed that foliar spraying with the combination between 8 g/L liquorice root powder plus 8 g/L fenugreek powder significantly increased seed cotton yield per feddan by 20.53 and 19.31% than control in the first and second seasons, respectively.

Table 12: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on seed cotton yield and its contributory characters in 2018 season.

Treatments (Traits)		No. of open bolls/plant	Boll weight (g)	Seed cotton yield/plant (g)	Lint %	Seed index (g)	Seed cotton yield/feddan (kentar)
A-Irrigation intervals:							
a_1- 14 day		16.42	2.78	45.71	39.86	10.43	11.15
a_2-21 day		16.16	2.67	43.19	39.59	9.93	10.67
a_3-28 day		15.66	2.61	40.86	39.04	9.49	10.07
LSD at 5%		**0.32**	**0.05**	**0.92**	**0.54**	**0.05**	**0.04**
B-Levels of anti-transpiration materials:							
b_1-Without application (control)		15.43	2.50	38.53	38.27	9.42	9.74
b_2- 4 g Licorice roots powder/L		15.58	2.64	41.19	39.09	9.77	10.25
b_3- 8 g Licorice roots powder /L		15.95	2.69	42.94	39.60	9.98	10.83
b_4- 4 g Fenugreek powder /L		15.80	2.58	40.75	39.16	9.89	10.08
b_5- 8 g Fenugreek powder /L		16.30	2.62	42.80	39.85	10.06	10.59
b_6- (b_2 + b_4)		16.58	2.83	46.97	39.90	10.15	11.19
b_7- (b_3 + b_5)		16.91	2.93	49.62	40.61	10.40	11.74
LSD at 5%		**0.28**	**0.03**	**0.55**	**0.35**	**0.10**	**0.07**
AXB Interaction:							
a_1	b_1	15.43	2.63	40.53	38.89	9.86	10.23
	b_2	15.83	2.75	43.60	39.37	10.15	10.75
	b_3	16.33	2.72	44.42	39.84	10.43	11.19
	b_4	16.60	2.68	44.49	39.27	10.30	10.63
	b_5	16.73	2.72	45.57	40.07	10.54	10.88
	b_6	16.63	2.94	48.89	40.45	10.66	11.84
	b_7	17.37	3.02	52.46	41.16	11.08	12.53
a_2	b_1	15.67	2.47	38.68	38.29	9.49	9.80
	b_2	16.03	2.62	41.96	39.27	9.86	10.40
	b_3	15.90	2.70	42.98	39.53	9.97	10.85
	b_4	15.87	2.57	40.77	39.16	9.90	10.28
	b_5	16.00	2.63	42.03	39.98	10.00	10.60
	b_6	16.73	2.80	46.84	40.20	10.02	11.13
	b_7	16.93	2.90	49.10	40.68	10.29	11.63
a_3	b_1	15.20	2.39	36.37	37.64	8.92	9.18
	b_2	14.87	2.56	38.00	38.64	9.29	9.61
	b_3	15.63	2.65	41.42	39.43	9.55	10.45
	b_4	14.93	2.48	36.98	39.06	9.46	9.32
	b_5	16.17	2.52	40.79	39.49	9.63	10.28
	b_6	16.37	2.76	45.18	39.05	9.76	10.61
	b_7	16.42	2.88	47.29	39.99	9.82	11.05
LSD at 5%		**0.40**	**0.05**	**1.11**	**NS**	**0.10**	**0.18**

Table 13: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on seed cotton yield and its contributory characters in 2019 season.

Traits / Treatments		No. of open bolls/plant	Boll weight (g)	Seed cotton yield/plant (g)	Lint %	Seed index (g)	Seed cotton yield/feddan (kentar)
A-Irrigation intervals:							
a_1- 14 day		17.64	2.80	49.44	42.62	11.50	12.58
a_2-21 day		15.98	2.70	43.12	42.21	11.11	10.98
a_3-28 day		15.09	2.73	41.18	41.54	10.39	10.62
LSD at 5%		**0.18**	**0.03**	**0.38**	**0.20**	**0.21**	**0.07**
B-Levels of anti-transpiration materials:							
b_1- Without application (control)		15.83	2.59	41.07	41.02	9.92	10.46
b_2- 4 g Licorice roots powder/L		15.98	2.70	43.23	42.04	10.51	11.01
b_3- 8 g Licorice roots powder /L		16.50	2.75	45.31	42.25	11.21	11.53
b_4- 4 g Fenugreek powder /L		16.21	2.64	42.75	42.03	11.15	10.91
b_5- 8 g Fenugreek powder /L		16.48	2.69	44.25	42.32	11.05	11.40
b_6- ($b_2 + b_4$)		16.27	2.85	46.50	42.42	11.38	11.95
b_7- ($b_3 + b_5$)		16.40	2.98	48.96	42.76	11.78	12.48
LSD at 5%		**0.27**	**0.05**	**0.38**	**0.11**	**0.53**	**0.14**
AXB Interaction:							
a_1	b_1	17.26	2.66	45.94	41.23	10.70	11.69
	b_2	17.50	2.73	47.80	42.53	11.14	12.18
	b_3	17.91	2.74	49.07	42.65	12.54	12.48
	b_4	17.70	2.68	47.37	42.60	11.48	12.05
	b_5	18.02	2.70	48.60	42.76	11.54	12.35
	b_6	17.79	2.94	52.37	42.86	11.23	13.32
	b_7	17.33	3.17	54.94	43.69	11.85	13.98
a_2	b_1	15.74	2.52	39.61	41.15	10.08	10.09
	b_2	15.77	2.67	42.15	42.14	10.81	10.73
	b_3	16.10	2.71	43.57	42.43	10.54	11.09
	b_4	16.07	2.61	41.88	42.18	11.13	10.66
	b_5	16.39	2.64	43.26	42.38	11.31	11.01
	b_6	15.82	2.81	44.49	42.51	11.93	11.33
	b_7	16.00	2.93	46.88	42.65	11.94	11.93
a_3	b_1	14.49	2.60	37.67	40.69	8.98	9.60
	b_2	14.67	2.71	39.74	41.46	9.57	10.13
	b_3	15.48	2.80	43.29	41.68	10.54	11.02
	b_4	14.85	2.63	38.99	41.30	10.83	10.03
	b_5	15.04	2.72	40.89	41.83	10.30	10.85
	b_6	15.21	2.80	42.65	41.89	10.98	11.19
	b_7	15.87	2.84	45.06	41.93	11.56	11.54
LSD at 5%		**0.44**	**0.05**	**0.79**	**0.17**	**0.80**	**0.18**

The significant increase may be due to the constituents of licorice root powder and ring seeds powder from phenolic compounds, mevalonic acid, triterpene saponins, protein amino acid (asparagin), lignins, vitamins (B1, B2, B3, B6, E and C), biotin, folic acid, pantothenic acid, and polysaccharide (Tables, 1 and 2). All these components play an important role in improving plant growth and thus increasing production. Moreover, licorice root powder and ring seeds powder contain many mineral compounds (P, K, Al, Ca, Fe, Mn, Co, Zn and Na), where the beneficial effects of these nutrients on plant growth. It was found that aluminum (Al) delayed lignification and ageing as well as increased membrane integrity through increased antioxidant enzymes activities such as super oxide dismutase (SOD), catalase (CAT) and ascorbate peroxidase (APX), thus enhancing the growth (Ghanati *et al*., 2005). Al^{3+} at low concentrations ameliorates toxicity of H^+ ion (Kinraide *et al*., 1992). Root length increased under increasing aluminum concentrations (Rufty *et al*., 1995). Cobalt (Co) helps to delay senescence (Bulantseva *et al*., 2001). Sodium assists in maintaining osmotic balance in plants by synthesizing large amounts of nitrogen-containing compatible solutes like glycine betaine and proline (to some extent) that leads to the accumulation of amides and polyamines (Pilon-Smits *et al*., 2009). Nitrogen is the limiting nutrient for rapid growth. It is an essential constituent of chlorophyll. N compounds comprise 40% to 50% of the dry matter of protoplasm, and it is a constituent of amino acids, the building blocks of proteins (Mengel *et al*., 2001). In photosynthesis and respiration, P plays a major role in energy storage and transfer as ADP and ATP (adenosine di- and triphosphate) and DPN and TPN (di- and tri-phosphopyridine nucleotide). P is part of the RNA and DNA structures, which are the major components of genetic information (Ahmad *et al*., 2020). Sulfur is a structural component of some amino acids (including cystein and methionine) and vitamins, and is essential for chloroplast growth and function; it is found in the iron-sulfur complexes of the electron transport chains in photosynthesis. It is essential in forming plant proteins because it is a constituent of certain amino acids (Uchida, 2000). It is actively involved in metabolism of the B vitamins biotin and thiamine and co-enzyme A. Sulfur aids in seed production, chlorophyll formation and stabilizing protein structure (Uchida, 2000). Zinc (Zn) enhances the activity of tryptophan synthesis, which is involved in the synthesis of the growth control compound IAA, the major hormone that inhibits abscission of squares and bolls (Skoog, 1940). The application of Zn increased the number of retained bolls plant^{-1}. Calcium (Ca) is involvement in the process of photosynthesis and the translocation of carbohydrates to young bolls. Calcium deficiency depressed the rate of photosynthesis (rate of CO_2 fixation). Calcium deficiency would cause carbohydrates to accumulate in leaves and not in young bolls (Guinn, 1998). Potassium plays a vital role in maintaining plant water status, increases cell membrane stability, leaf water potential, turgor potential and reduces stomatal resistance, stomatal movements, enzyme activity, osmoregulation, and membrane stability (Erel *et al*., 2015). Also, K had pronounced effects on carbohydrate partitioning by affecting either the phloem export of photosynthates (sucrose) or growth rate of sink and/or source organs (Cakmak *et al.,* 1994 a, b). Magnesium (Mg) has major physiological and molecular roles in plants; it is a component of the chlorophyll molecule, a co-factor for many enzyme processes associated with phosphorylation and the hydrolysis of various compounds, as well as a structural stabilizer for various nucleotides (Merhaut, 2007). Manganese (Mn) is involved in many biochemical functions. It primarily acts as an activator of enzymes, involved in respiration, amino acid and lignin synthesis and hormone concentrations (Humphries *et al*., 2007). Manganese activates decarboxylase and dehydrogenase and is a constituent of complex PSII- protein, SOD, and phosphatase. Deficiency of Mn induces inhibition of growth chlorosis and necrosis, early leaf fall and low reutilization (Sajedi *et al*., 2009). Zinc (Zn) can be readily transported from vegetative tissue into reproductive tissue according to a plant's capacity. However, the transformation from vegetative tissue into reproductive tissue decreases when a zinc supply is inadequate (Welch, 1995). Fe plays a key role in chlorophyll synthesis. In addition, iron enters in many plant enzymes that play dominant roles in oxidoredox reactions of photosynthesis and respiration (Curie and Briat, 2003).

3.5.3. Interaction effect

Data in Tables, 12 and 13 showed that cotton plants irrigated every 14 days and received (8 g/L liquorice root powder plus 8 g/L fenugreek powder) gave the highest seed cotton yield per plant (52.46 and 54.94 g) with high numbers of open bolls (17.37 and 17.33 boll) and heavier bolls (3.02 and 3.17 g). Also, this interaction treatment significantly increased seed cotton yield/feddan by 36.94 and 45.62% than irrigated every 28 days and untreated with anti-transpiration materials used in both seasons. However, cotton plants irrigated every 14 days and received foliar feeding with the high level (8 g/L) of fenugreek powder gave highest number of open bolls (18.02 boll) in the second season. The lowest seed cotton yield per plant (36.37 and 37.67 g) accompanied with the low numbers of open bolls (15.20 and 14.49 boll) and light bolls (2.39 and 2.60 g), in the first and second seasons, respectively were recorded in the plants irrigated every 28 days and untreated with anti-transpiration materials used. However, with one exception, where plants irrigated every 28 days and received foliar feeding at the low level (4 g/L) of liquorice root powder gave lowest number of open bolls (14.87 boll) in the first season. Lint% was significantly affected by the interaction in the second season, in favor of cotton plants irrigated every 14 days and received (8 g/L liquorice root powder plus 8 g/L fenugreek powder). Seed index was significantly increased due to irrigate every 14 days and received (8 g/L liquorice root powder plus 8 g/L fenugreek powder) in the first season and due to irrigate every 14 days and received 8 g liquorice root powder /L in the second season.

3.6. Fiber quality traits

3.6.1. Effect of irrigation intervals

Results in Tables, 14 and 15 showed that micronaire reading and fiber strength were significantly affected by the tested irrigation intervals in the first season. The highest fiber strength (10.74 Pressley units) and the lowest micronaire reading (4.37) resulted from irrigation every 14 days. However, the lowest fiber strength (10.15 Pressley units) and the highest micronaire reading (4.57) resulted from irrigated every 28 days. Length uniformity index was insignificantly affected by the tested irrigation intervals in both seasons. Significant differences were obtained in fiber length due to irrigation intervals in the second season, where the longest fibers (33.69 mm) were obtained from irrigation every 14 days and the shortest fibers (33.37 mm) resulted from irrigation every 28 days.

In this concern, Balkcom *et al.* (2006) found that fiber quality parameters such as the length, micronaire, and uniformity were affected by the irrigation regimes. Basal *et al.* (2009) found that fiber quality was influenced significantly by irrigation levels. Moisture stress negatively impacts the formation of the actin cytoskeleton that triggers the secondary cell wall synthesis, a key component in determining the fiber strength (Wang *et al*., 2010). El-Ashmouny (2014) found that the highest values of fineness and strength were resulted from irrigated the plants every 14 days as compared to 21 or 28 days. The maturity ratio, a key (Feng *et al*., 2014). Emara *et al.* (2015) pointed out that irrigation intervals gave insignificant effect on fiber properties. El-Gabiery (2016) reported that Pressley index and micronaire reading did not affected by irrigation intervals. El-Shazly (2017) found that fiber length significantly increased due to irrigated cotton plants every 21 days followed by those irrigated every 28 days and 14 days. Irrigation improved cotton yield and fiber length (Sui *et al.*, 2017). Pinnamaneni *et al.,* (2021) found that full irrigation, half irrigation, and rain-fed had a significant effect on micronaire, strength, and upper half mean length (UHML). They added that irrigation has a significant positive impact on UHML The higher lint yield in the half irrigation treatments is probably due to optimum water availability in the active root zone. In the full irrigation treatments, there was likely excess water around the root zone, owing to heavy precipitation events following the irrigation coinciding boll formation and developmental stages in July and August, which caused increased vegetative growth, boll drop, and immature boll formation.

3.6.2. Effect of anti-transpirants used

The tested treatments gave a significant effect on micronaire reading and fiber strength in the first season (Table, 14). The highest fiber strength (10.62 Pressley units) and the lowest micronaire reading (4.42) resulted from the combination between 8 g/L liquorice root powder plus 8 g/L fenugreek powder. The control (untreated plants) gave the lowest fiber strength (10.13 Pressley units) and higher micronaire reading (4.51). Significant differences were obtained in fiber length due to foliar spraying with anti-transpiration materials in the second season, where the longest fibers (33.78 and 33.79 mm) were obtained from the combination between liquorice root extract plus fenugreek extract at the two examined levels. However, the shortest fibers (33.23 mm) resulted from foliar spraying with fenugreek extract at the low level. Length uniformity index was insignificantly affected by the tested treatments in both seasons.

3.6.3. Interaction effect

The interaction gave a significant effect on fiber strength in both seasons (Tables, 14 and 15). In the first season, the plants irrigated every 14 days and received (8 g/L liquorice root powder plus 8 g/L fenugreek powder) gave the highest fiber strength (10.97 Pressley units). However, the lowest fiber strength (10.00 Pressley units) was recorded from the plants irrigated every 28 days and untreated with anti-transpirant materials. In the second season, the plants irrigated every 21 days and received foliar feeding with the high level (8 g/L) of liquorice root powder and the plants irrigated every 28 days and received foliar feeding with the high level (8 g/L) of fenugreek powder gave highest value of fiber strength (10.47 Pressley units). The lowest fiber strength (9.77 Pressley units) was recorded from the plants irrigated every 28 days and untreated with anti-transpiration materials. Significant differences were obtained in fiber length due to the interaction in the second season, where the longest fibers (34.07 mm) were obtained from the plants irrigated every 14 days and received (8 g/L liquorice root powder plus 8 g/L fenugreek powder). However, the shortest fibers (32.93 mm) resulted from the plants irrigated every 28 days and received 4 g fenugreek powder/L. Length uniformity index and micronaire reading were insignificantly affected by the interaction in both seasons.

Table 14: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on fiber quality in 2018 season.

Treatments	Traits	Micronaire reading	Pressley index	Upper half mean length (mm)	Length uniformity index (%)
A-Irrigation intervals:					
a_1- 14 day		4.37	10.74	33.20	85.25
a_2-21 day		4.49	10.38	33.24	85.57
a_3-28 day		4.57	10.15	33.20	85.06
LSD at 5%		**0.03**	**0.04**	**NS**	**NS**
B-Levels of anti-transpiration materials:					
b_1-Without application (control)		4.51	10.13	33.08	85.24
b_2- 4 g Licorice roots powder/L		4.50	10.36	33.14	85.27
b_3- 8 g Licorice roots powder /L		4.50	10.47	33.37	85.20
b_4- 4 g Fenugreek powder /L		4.50	10.36	33.33	85.17
b_5- 8 g Fenugreek powder /L		4.43	10.49	33.26	85.36
b_6- ($b_2 + b_4$)		4.47	10.54	33.24	85.74
b_7- ($b_3 + b_5$)		4.42	10.62	33.08	85.08
LSD at 5%		**0.06**	**0.03**	**NS**	**NS**
AXB Interaction:					
a_1	b_1	4.40	10.40	32.43	84.47
	b_2	4.40	10.67	33.57	85.40
	b_3	4.40	10.73	33.73	85.70
	b_4	4.37	10.70	33.00	84.87
	b_5	4.30	10.83	33.23	85.53
	b_6	4.40	10.90	32.87	85.27
	b_7	4.30	10.97	33.57	85.53
a_2	b_1	4.57	10.00	34.03	86.30
	b_2	4.53	10.30	32.80	85.73
	b_3	4.53	10.47	33.13	85.33
	b_4	4.50	10.30	33.30	85.33
	b_5	4.43	10.43	33.37	85.63
	b_6	4.43	10.53	33.13	85.70
	b_7	4.43	10.60	32.93	84.97
a_3	b_1	4.57	10.00	32.77	84.97
	b_2	4.57	10.10	33.07	84.67
	b_3	4.57	10.20	33.23	84.57
	b_4	4.63	10.07	33.70	85.30
	b_5	4.57	10.20	33.17	84.90
	b_6	4.57	10.20	33.73	86.27
	b_7	4.53	10.30	32.73	84.73
LSD at 5%		**NS**	**0.05**	**NS**	**NS**

Table 15: Effect of irrigation intervals, anti-transpirants levels as well as their interactions on fiber quality in 2019 season.

Treatments	Traits	Micronaire reading	Pressley index	Upper half mean length (mm)	Length uniformity index (%)
A-Irrigation intervals:					
a_1- 14 day		4.64	10.19	33.69	85.92
a_2-21 day		4.69	10.22	33.46	86.06
a_3-28 day		4.75	10.11	33.37	85.83
LSD at 5%		**NS**	**NS**	**0.18**	**NS**
B-Levels of anti-transpiration materials					
b_1- Without		4.76	10.07	33.58	85.81
b_2- 4 g Licorice roots powder/L		4.81	10.04	33.29	85.71
b_3- 8 g Licorice roots powder /L		4.72	10.24	33.30	86.59
b_4- 4 g Fenugreek powder /L		4.58	10.18	33.23	85.26
b_5- 8 g Fenugreek powder /L		4.63	10.24	33.57	85.94
b_6- ($b_2 + b_4$)		4.63	10.24	33.79	86.16
b_7- ($b_3 + b_5$)		4.72	10.18	33.78	86.08
LSD at 5%		**NS**	**NS**	**0.26**	**NS**
AXB Interaction					
	b_1	4.60	10.43	33.50	86.18
	b_2	4.60	10.13	33.60	85.97
	b_3	4.63	10.17	33.50	86.07
a_1	b_4	4.63	10.07	33.63	85.47
	b_5	4.83	10.07	33.47	86.23
	b_6	4.50	10.30	34.03	85.83
	b_7	4.70	10.13	34.07	85.67
	b_1	4.83	10.00	33.50	85.93
	b_2	4.83	10.00	33.07	85.10
	b_3	4.53	10.47	33.40	86.73
a_2	b_4	4.53	10.33	33.13	86.13
	b_5	4.60	10.20	33.77	85.67
	b_6	4.70	10.27	33.60	86.40
	b_7	4.77	10.27	33.77	86.43
	b_1	4.83	9.77	33.73	85.30
	b_2	5.00	10.00	33.20	86.07
	b_3	5.00	10.10	33.00	86.97
a_3	b_4	4.57	10.13	32.93	84.17
	b_5	4.47	10.47	33.47	85.93
	b_6	4.70	10.17	33.73	86.23
	b_7	4.70	10.13	33.50	86.13
LSD at 5%		NS	0.34	0.29	NS

4. Conclusion

It could be concluded that combined addition treatments of licorice root extract and ring seeds extract as foliar spraying at the two levels examined gave best results under different irrigation intervals used on productivity and quality of cotton plants. These natural compounds can be used safely to reduce the negative impact of drought and recommended to use when water scarcity becomes widespread under conditions like El-Gemmeiza location.

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