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Statistical Study: Nature Relationship between Climatic Variables Prevailing Prior to Flowering or Subsequent to Boll Setting and Cotton Production

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Abstract

This study investigates the statistical relationship between climatic variables and aspects of cotton production (*G. barbadense*), and the effects of climatic factors prevailing prior to flowering or subsequent to boll setting on flower and boll production and retention in cotton. The effects of specific climatic factors during both pre- and post-anthesis periods on boll production and retention are mostly unknown. Thus, an understanding of these relationships may help physiologists to determine control mechanisms of production in cotton plants. Evaporation, sunshine duration, relative humidity, surface soil temperature at 1800 h, and maximum air temperature, are the important climatic factors that significantly affect flower and boll production. The least important variables were found to be surface soil temperature at 0600 h and minimum temperature. There was a negative correlation between flower and boll production and either evaporation or sunshine duration, while that correlation with minimum relative humidity was positive. Higher minimum relative humidity, short period of sunshine duration, and low temperatures enhanced flower and boll formation.

Keywords

Cotton Flower and Boll Production, Boll Retention, Evaporation, Relative Humidity, Sunshine Duration, Temperature

1. Introduction

Climate affects crop growth interactively, sometimes resulting in unexpected responses to prevailing conditions.

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Many factors, such as length of the growing season, climate (including solar radiation, temperature, light, wind, rainfall, and dew), cultivar, availability of nutrients and soil moisture, pests and cultural practices affect cotton growth [1]. The balance between vegetative and reproductive development can be influenced by soil fertility, soil moisture, cloudy weather, spacing and perhaps other factors such as temperature and relative humidity [2]. Weather, soil, cultivars, and cultural practices affect crop growth interactively, sometimes resulting in plants responding in unexpected ways to their conditions [3].

Water is a primary factor controlling plant growth. Xiao *et al*. [4] stated that, when water was applied at 0.85, 0.70, 0.55 or 0.40 ET (evapotranspiration) to cotton plants grown in pots, there was a close relationship between plant development and water supply. The fruit-bearing branches, square and boll numbers and boll size were increased with increased water supply. Barbour and Farquhar [5] reported on greenhouse pot trials where cotton cv. CS50 plants were grown at 43% or 76% relative humidity (RH) and sprayed daily with abscisic acid (ABA) or distilled water. Plants grown at lower RH had higher transpiration rates, lower leaf temperatures and lower stomatal conductance. Plant biomass was also reduced at the lower RH. Within each RH environment, increasing ABA concentration generally reduced stomatal conductance, evaporation rates, superficial leaf density and plant biomass, and increased leaf temperature and specific leaf area.

Temperature is also a primary factor controlling rates of plant growth and development. Eddy *et al*. [6] in growth chamber experiments found that Pima cotton cv. S-6 produced lower total biomass at 35.5˚C than at 26.9˚C and no bolls were produced at the higher temperature of 40˚C. Schrader *et al*. [7] stated that high temperatures that plants are likely to experience inhibit photosynthesis. Zhou *et al.* [8] indicated that light duration is the key meteorological factor influencing the wheat-cotton cropping pattern and position of the bolls, while temperature had an important function on upper (node 7 to 9) and top (node 10) bolls, especially for double cropping patterns with early maturing varieties. Fisher [9] found that high temperatures can cause male sterility in cotton flowers, and could have caused increased boll shedding in the late fruiting season. Zhao [10] indicated that temperature was the main climatic factor affecting cotton production and 20˚C - 30˚C was the optimum temperature for cotton growth. Reddy *et al*. [11] found that when Upland cotton (*G. hirsutum*) cv. DPL-51 was grown in naturally lit plant growth chambers at 30˚C/22˚C day/night temperatures from sowing until flower bud production, and at 20˚C/12˚C, 25˚C/17˚C, 30˚C/22˚C, 35˚C/27˚C and 40˚C/32˚C for 42 days after flower bud production, fruit retention was severely curtailed at the two higher temperatures compared with 30˚C/22˚C. Species/cultivars that retain fruits at high temperatures would be more productive both in the present-day cotton production environments and even more in future warmer world.

The objectives of this investigation: collects information about the nature of the relationship between various climatic factors and cotton boll development and the 15-day period both prior to and after initiation of individual boll of field grown cotton plants in Egypt. This could pave the way for formulating advanced predictions as for the effect of certain climatic conditions on production of Egyptian cotton. It would be useful to minimize the deleterious effects of the factors through utilizing proper cultural practices which would limit and control their negative effects, and this would lead to an improvement in cotton yield [12].

2. Data and Methods

Two uniform field trials were conducted at the experimental farm of the Agricultural Research Center, Ministry of Agriculture, Giza, Egypt (30˚N, 31˚:28'E at an altitude of 19 m), using the cotton cultivar Giza 75 (*Gossypium barbadense* L.) in 2 successive seasons (I and II). The soil texture was a clay loam, with an alluvial substratum (pH = 8.07, 42.13% clay, 27.35% silt, 22.54% fine sand, 3.22% coarse sand, 2.94% calcium carbonate and 1.70% organic matter) [13].

In Egypt, there are no rain-fed areas for cultivating cotton. Water for the field trials was applied using surface irrigation. Total water consumed during each of two growing seasons supplied by surface irrigation was about 6000 $m^3 \cdot h^{-1}$. The criteria used to determine amount of water applied to the crop depended on soil water status. Irrigation was applied when soil water content reached about 35% of field capacity (0 - 60 cm). In season I, the field was irrigated on 15 March (at planting), 8 April (first irrigation), 29 April, 17 May, 31 May, 14 June, 1 July, 16 July, and 12 August. In season II, the field was irrigated on 23 March (planting date), 20 April (first irrigation), 8 May, 22 May, 1 June, 18 June, 3 July, 20 July, 7 August and 28 August. Techniques normally used for growing cotton in Egypt were followed. Each experimental plot contained 13 to 15 ridges to facilitate proper surface irrigation. Ridge width was 60 cm and length was 4 m. Seeds were sown on 15 and 23 March in seasons I and II, respectively, in hills 20 cm apart on one side of the ridge. Seedlings were thinned to 2 plants per hill 6 weeks after planting, resulting in a plant density of about 166,000 $plants \cdot ha^{-1}$. Phosphorus fertilizer was applied at a rate of 54 $kg \cdot P_2O_5 \cdot ha^{-1}$ as calcium super phosphate during land preparation. Potassium fertilizer was applied at a rate of 57 $kg \cdot K_2O \cdot ha^{-1}$ as potassium sulfate before the first irrigation (as a concentrated band close to the seed ridge). Nitrogen fertilizer was applied at a rate of 144 $kg \cdot N \cdot ha^{-1}$ as ammonium nitrate in two equal doses: the first was applied after thinning just before the second irrigation and the second was applied before the third irrigation. Rates of phosphorus, potassium, and nitrogen fertilizer were the same in both seasons. These amounts were determined based on the use of soil tests [13].

After thinning, 261 and 358 plants were randomly selected (precaution of border effect was taken into consideration by discarding the cotton plants in the first and last two hills of each ridge) from 9 and 11 inner ridges of the plot in seasons I, and II respectively. Pest control management was carried out on an-as-needed basis, according to the local practices performed at the experimental. Flowers on all selected plants were tagged in order to count and record the number of open flowers, and set bolls on a daily basis. The flowering season commenced on the date of the first flower appearance and continued until the end of flowering season (31 August). The period of whole September (30 days) until the 20th of October (harvest date) allowed a minimum of 50 days to develop mature bolls. In season I, the flowering period extended from 17 June to 31 August, whereas in season II, the flowering period was from 21 June to 31 August. Flowers produced after 31 August were not expected to form sound harvestable bolls, and therefore were not taken into account [13].

For statistical analysis, the following data of the dependent variables were collected: number of tagged flowers separately counted each day on all selected plants (Y_1), number of retained bolls obtained from the total daily tagged flowers on all selected plants at harvest (Y_2), and (Y_3) percentage of boll retention ([number of retained bolls obtained from the total number of daily tagged flowers in all selected plants at harvest]/[daily number of tagged flowers on each day in all selected plants] × 100). As a rule, observations were recorded when the number of flowers on a given day was at least 5 flowers found in a population of 100 plants and this continued for at least five consecutive days. This rule omitted eight observations in the first season and ten observations in the second season. The number of observations (n) was 68 (23 June through 29 August) and 62 (29 June through 29 August) for the two seasons, respectively. Variables of the soil moisture status considered were, the day prior to irrigation, the day of irrigation, and the first and second days after the day of irrigation [13].

The climatic factors (independent variables) considered were daily data of: maximum air temperature (˚C, X_1); minimum air temperature (˚C, X_2); maximum-minimum air temperature (diurnal temperature range) (˚C, X_3); evaporation (expressed as Piche evaporation) ($mm \cdot day^{-1}$, X_4); surface soil temperature, grass temperature or green cover temperature at 0600 h (˚C, X_5) and 1800 h (˚C, X_6); sunshine duration ($h \cdot day^{-1}$, X_7); maximum relative humidity (maxRH) (%, X_8), minimum relative humidity (minRH) (%, X_9) and wind speed ($m \cdot s^{-1}$, X_{10}) in season II only. The source of the climatic data was the Agricultural Meteorological Station of the Agricultural Research Station, Agricultural Research Center, Giza, Egypt. No rainfall occurred during the two growing seasons [12].

Daily records of the climatic factors (independent variables) were taken for each day during production stage in any season including two additional periods of 15 days preceding and after the production stage. Range and mean values of the climatic parameters recorded during the production stage for both seasons and overall data are listed in **Table 1**. Daily number of flowers and number of bolls per plant which survived till maturity (dependent variables) during the production stage in the two seasons are graphically illustrated in **Figure 1** and **Figure 2** [13].

In each season, the data of the dependent and independent variables (68 and 62 days) were regarded as the original file (a file which contains the daily recorded data for any variable during a specific period). Fifteen other files before and another 15 after the production stage were obtained by fixing the dependent variable data, while moving the independent variable data at steps each of 1 day (either before or after production stage) in a matter similar to a sliding role [12]. The following is an example (in the first season):

File	Data of any dependent variable (for each flowers and bolls)		Any independent variable (for each climatic factors)			
	Production stage		In case of original file and files before production stage		In case of original file and files after production stage	
	Date	Days	Date	Days	Date	Days
Original file	23 Jun - 29 Aug	68	23 Jun - 29 Aug	68	23 Jun - 29 Aug	68
1st new file	23 Jun - 29 Aug	68	22 Jun - 28 Aug	68	24 Jun - 30 Aug	68
2nd new file	23 Jun - 29 Aug	68	21 Jun - 27 Aug	68	25 Jun - 31 Aug	68
15th new file	23 Jun - 29 Aug	68	8 Jun - 14 Aug	68	8 Jul - 13 Sept	68

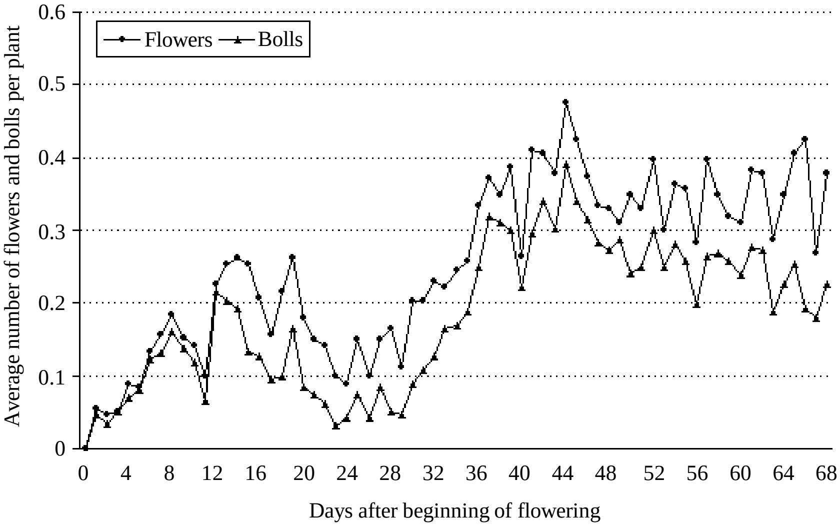

Figure 1. Daily number of flowers and bolls during the production stage (68 days) in the first season (I) for the Egyptian cotton cultivar Giza 75 (*Gossypium barbadense* L.) grown in uniform field trial at the experimental farm of the Agricultural Research Centre, Giza (30˚N, 31˚:28'E), Egypt. The soil texture was a clay loam, with an alluvial substratum, (pH = 8.07). Total water consumptive use during the growing season supplied by surface irrigation was about 6000 $m^3 \cdot ha^{-1}$. No rainfall occurred during the growing season. The sampling size was 261 plants [13].

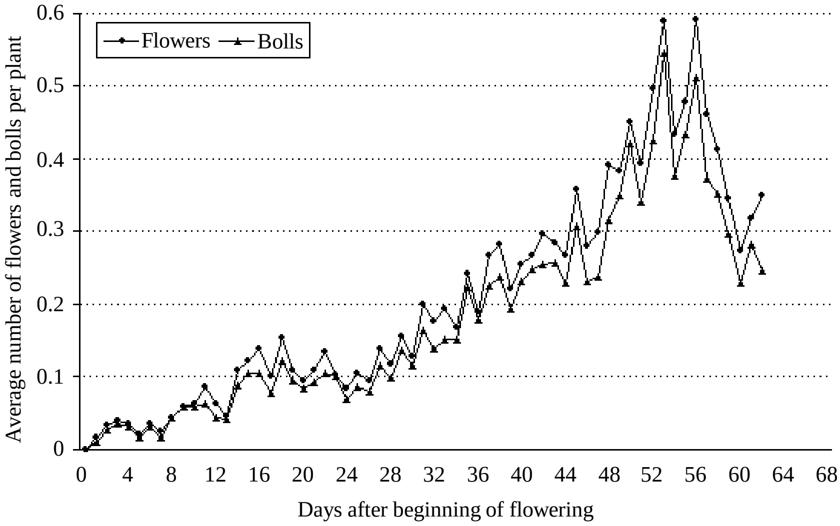

Figure 2. Daily number of flowers and bolls during the production stage (62 days) in the second season (II) for the Egyptian cotton cultivar Giza 75 (*Gossypium barbadense* L.) grown in uniform field trial at the experimental farm of the Agricultural Research Centre, Giza (30˚N, 31˚:28'E), Egypt. The soil texture was a clay loam, with an alluvial substratum, (pH = 8.07). Total water consumptive use during the growing season supplied by surface irrigation was about 6000 $m^3 \cdot ha^{-1}$. No rainfall occurred during the growing season. The sampling size was 358 plants [13].

Thus, the climate data were organized into records according to the complete production stage (68 days the first year and 62 days the second year) and 15 day, 14 day, 13 day,… and 1 day periods both before and after the production stage. This produced 31 climate periods per year that were analyzed for their relationships with cotton flowering and boll production [12].

Simple correlation coefficients were computed between the original dependent variable (boll setting and boll

Table 1. Mean, standard deviation, maximum and minimum values of the climatic factors during the flower and boll stage (initial time) and the 15 days prior to flowering or subsequent to boll setting for I and II season at Giza, Egypt.

Climatic factors	First season*				Second season**			
	Mean	S.D.	Max.	Min.	Mean	S.D.	Max.	Min.
Max temp [˚C] (X_1)	34.1	1.2	44.0	31.0	33.8	1.2	38.8	30.6
Min temp [˚C] (X_2)	21.5	1.0	24.5	18.6	21.4	0.9	24.3	18.4
Max-Min temp [˚C] (X_3)♦	12.6	1.1	20.9	9.4	12.4	1.3	17.6	8.5
Evapor [$mm \cdot d^{-1}$] (X_4)	10.6	1.6	16.4	7.6	6.0	0.7	9.8	4.1
0600 h temp [˚C] (X_5)	17.5	1.1	21.5	13.9	17.6	1.2	22.4	13.3
1800 h temp [˚C] (X_6)	24.2	1.9	32.3	19.6	23.7	1.1	27.4	20.6
Sunshine [$h \cdot d^{-1}$] (X_7)	11.7	0.8	12.9	9.9	11.7	0.4	13.0	10.3
Max hum [%] (X_8)	85.6	3.3	96.0	62.0	72.9	3.8	84.0	51.0
Min hum [%] (X_9)	30.2	5.2	45.0	11.0	39.1	5.0	52.0	23.0
Wind speed [$m \cdot s^{-1}$] (X_{10})	ND	ND	ND	ND	4.6	0.9	7.8	2.2

*Flower and boll stage (68 days, from 23 June through 29 August); **Flower and boll stage (62 days, from 29 June through 29 August); ♦Diurnal temperature range. ND not determined [12].

retention) and the independent variables for each of the original file and the 15 new files just before or after flowering in each season. The significance of the simple correlation at a probability level not exceeding 5% was tested to determine the factors affecting the dependent variables. The relationship between the most effective and consistent climatic factors affecting flower and boll production and retention was computed using the step-wise regression analysis method. Linear regression equations comprising selected predictive variables were computed and coefficients of determination (r^2 for simple or R^2 for multiple linear regression equations) were calculated to measure the efficiency of the regression models in explaining the variation in the data. The statistical analysis was carried out according to Draper and Smith [14], by means of the computer program SAS package using the procedures outlined in the general linear model (GLM) [15].

3. Results and Discussion

3.1. Correlation Estimates

Results of the correlation between climatic factors and each of flower and boll production during the 15 day periods before flowering day (**Table 2**, **Table 3**) revealed the following [12]:

3.1.1. First Season

Daily evaporation and sunshine duration showed consistent negative and statistically significant correlations with both flower and boll production for each of the 15 moving window periods before anthesis (**Table 2**). Evaporation appeared to be the most important climate factor affecting flower and boll production. Daily maximum and minimum humidity showed consistent positive and statistically significant correlations with both flower and boll production in most of the 15 moving window periods before anthesis. Maximum daily temperature showed low but significant negative correlation with flower production during the 2 - 5, 8, and 10 day periods before anthesis. Minimum daily temperatures generally showed insignificant correlation with both production variables. The diurnal temperature range showed few correlations with flower and boll production. Daily soil surface temperature at 0600 h showed a significant positive correlation with boll production during the period extending from the 11 - 15 day period before anthesis, while its effect on flowering was confined only to the 12 and the 15 day periods prior anthesis. Daily soil surface temperature at 1800 h showed a significant negative correlation with flower production during the 2 - 10 day periods before anthesis [12].

3.1.2. Second Season

Daily Evaporation, the diurnal temperature range, and sunshine duration were negatively and significantly correlated with both flower and boll production in all the 15 day periods, while maximum daily temperature was negatively and significantly related to flower and boll formation during the 2 - 5 day periods before anthesis (**Table 3**) [12].

Table 2. Simple correlation coefficients (r) between climatic factors and number of flower and harvested bolls in initial time (0) and each of the 15-day periods before flowering in the first season (I).

Climate period		Air temp. (˚C)			Evap. (mm·d^{-1})	Surface soil temp. (˚C)		Sunshine duration (h·d^{-1})	Humidity (%)	
		Max.	Min.	Max-Min♦		0600 h	1800 h		Max.	Min.
		(X$_1$)	(X$_2$)	(X$_3$)	(X$_4$)	(X$_5$)	(X$_6$)	(X$_7$)	(X$_8$)	(X$_9$)
0#	Flower	−0.07	−0.06	−0.03	−0.56**	−0.01	−0.20	−0.25*	0.40**	0.14
	Boll	−0.03	−0.07	−0.01	−0.53**	−0.06	−0.16	−0.14	0.37**	0.10
1	Flower	−0.15	−0.08	−0.11	−0.64**	−0.01	−0.17	−0.30*	0.39**	0.20
	Boll	−0.07	−0.08	−0.02	−0.58**	−0.06	−0.10	−0.23*	0.36**	0.13
2	Flower	−0.26*	−0.10	−0.22	−0.69**	−0.07	−0.30*	−0.35**	0.42**	0.30*
	Boll	−0.18	−0.08	−0.14	−0.64**	−0.05	−0.21	−0.25*	0.40**	0.20
3	Flower	−0.28*	−0.02	−0.31**	−0.72**	0.15	−0.29*	−0.37**	0.46**	0.35**
	Boll	−0.19	−0.02	−0.21	−0.65**	0.11	−0.20	−0.30*	0.37**	0.25*
4	Flower	−0.26*	−0.03	−0.26*	−0.67**	0.08	−0.24*	−0.41**	0.46**	0.35**
	Boll	−0.21	−0.04	−0.21	−0.63**	0.04	−0.18	−0.35**	0.39**	0.29*
5	Flower	−0.27*	−0.02	−0.27*	−0.68**	0.16	−0.29*	−0.45**	0.49**	0.38**
	Boll	−0.22	0.00	−0.24*	−0.63**	0.16	−0.21	−0.39**	0.44**	0.32**
6	Flower	−0.21	0.05	−0.25*	−0.73**	0.16	−0.28*	−0.46**	0.47**	0.42**
	Boll	−0.15	0.08	−0.21	−0.67**	0.19	−0.19	−0.46**	0.43**	0.35**
7	Flower	−0.17	−0.01	−0.17	−0.69**	0.10	−0.27*	−0.43**	0.46**	0.35**
	Boll	−0.11	−0.06	−0.15	−0.64**	0.14	−0.19	−0.46**	0.43**	0.32**
8	Flower	−0.24*	−0.03	−0.24*	−0.71**	0.09	−0.30*	−0.44**	0.45**	0.45**
	Boll	−0.14	0.04	−0.17	−0.63**	0.16	−0.17	−0.48**	0.44**	0.39**
9	Flower	−0.23	−0.10	−0.19	−0.68**	0.05	−0.33**	−0.32**	0.43**	0.44**
	Boll	−0.14	0.04	−0.17	−0.61**	0.15	−0.21	−0.40**	0.42**	0.41**
10	Flower	−0.26*	0.05	−0.30*	−0.67**	0.13	−0.29*	−0.29*	0.40**	0.48**
	Boll	−0.14	0.13	−0.22	−0.58**	0.22	−0.17	−0.36**	0.46**	0.41**
11	Flower	−0.20	0.10	−0.27*	−0.62**	0.21	−0.19	−0.29*	0.42**	0.44**
	Boll	−0.04	0.22	−0.16	−0.53**	0.27*	−0.04	−0.38**	0.45**	0.36**
12	Flower	−0.17	0.16	−0.26*	−0.62**	0.29*	−0.15	−0.40**	0.44**	0.45**
	Boll	0.00	0.25*	−0.13	−0.51**	0.35**	−0.04	−0.45**	0.40**	0.30*
13	Flower	−0.13	0.16	−0.22	−0.62**	0.23	−0.12	−0.42**	0.43**	0.45**
	Boll	0.00	0.22	−0.11	−0.51**	0.30*	−0.03	−0.49**	0.41**	0.33**
14	Flower	−0.08	0.18	−0.18	−0.56**	0.21	−0.15	−0.44**	0.41**	0.46**
	Boll	0.01	0.21	−0.10	−0.47**	0.26*	−0.09	−0.49**	0.42**	0.33**
15	Flower	−0.08	0.22	−0.21	−0.51**	0.24*	−0.22	−0.42**	0.39**	0.38**
	Boll	−0.03	0.19	−0.13	−0.45**	0.24*	−0.17	−0.44**	0.43**	0.30*

*Significant at 5% level; **Significant at 1% level; #0 = Initial time; ♦Diurnal temperature range [12].

Table 3. Simple correlation coefficients (r) between climatic factors^{z} and number of flower and harvested bolls in initial time (0) and each of the 15-day periods before flowering in the second season (II).

Climate period		Air temp. (˚C)			Evap. (mm·d^{-1})	Surface soil temp. (˚C)		Sunshine duration (h·d^{-1})	Humidity (%)	
		Max.	Min.	Max-Min$^{♦}$		0600 h	1800 h		Max.	Min.
		(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)	(X_7)	(X_8)	(X_9)
0$^{\#}$	Flower	-0.42^{**}	0.00	-0.36^{**}	-0.61^{**}	−0.14	-0.37^{**}	-0.37^{**}	0.01	0.45^{**}
	Boll	-0.42^{**}	0.02	-0.37^{**}	-0.59^{**}	−0.13	-0.36^{**}	-0.36^{**}	0.01	0.46^{**}
1	Flower	-0.42^{**}	0.10	-0.42^{**}	-0.63^{**}	−0.08	-0.29^{*}	-0.41^{**}	0.05	0.48^{**}
	Boll	-0.41^{**}	0.11	-0.42^{**}	-0.62^{**}	−0.07	-0.28^{*}	-0.41^{**}	0.05	0.47^{**}
2	Flower	-0.40^{**}	0.08	-0.43^{**}	-0.65^{**}	−0.09	-0.27^{*}	-0.39^{**}	0.02	0.49^{**}
	Boll	-0.40^{**}	0.08	-0.43^{**}	-0.64^{**}	−0.08	-0.26^{*}	-0.40^{**}	0.03	0.49^{**}
3	Flower	-0.38^{**}	0.13	-0.43^{**}	-0.61^{**}	−0.06	−0.17	-0.38^{**}	0.00	0.45^{**}
	Boll	-0.37^{**}	0.15	-0.44^{**}	-0.61^{**}	−0.05	−0.15	-0.38^{**}	0.01	0.46^{**}
4	Flower	-0.36^{**}	0.17	-0.41^{**}	-0.61^{**}	−0.04	−0.18	-0.38^{**}	0.02	0.45^{**}
	Boll	-0.35^{**}	0.18	-0.41^{**}	-0.60^{**}	−0.03	−0.16	-0.36^{**}	0.03	0.44^{**}
5	Flower	-0.30^{*}	0.13	-0.36^{**}	-0.60^{**}	−0.07	−0.23	-0.32^{**}	−0.05	0.43^{**}
	Boll	-0.28^{*}	0.15	-0.35^{**}	-0.58^{**}	−0.05	−0.21	-0.31^{**}	−0.05	0.41^{**}
6	Flower	−0.24	0.21	-0.38^{**}	-0.61^{**}	−0.02	−0.12	-0.28^{*}	0.02	0.40^{**}
	Boll	−0.22	0.24	-0.38^{**}	-0.59^{**}	0.00	−0.07	-0.29^{*}	0.02	0.40^{**}
7	Flower	−0.19	0.23	-0.29^{*}	-0.54^{**}	−0.03	−0.05	-0.26^{*}	−0.04	0.32^{**}
	Boll	−0.18	0.23	-0.27^{*}	-0.53^{**}	−0.02	−0.03	-0.27^{*}	−0.04	0.30^{*}
8	Flower	−0.15	0.24	-0.25^{*}	-0.52^{**}	−0.03	−0.07	-0.24^{*}	−0.05	0.28^{*}
	Boll	−0.14	0.22	−0.22	-0.51^{**}	−0.03	−0.06	-0.22^{*}	−0.05	0.26^{*}
9	Flower	−0.16	0.34^{**}	-0.32^{**}	-0.56^{**}	0.08	−0.02	-0.25^{*}	0.05	0.30^{*}
	Boll	−0.14	0.34^{**}	-0.31^{**}	-0.56^{**}	0.09	−0.01	-0.23^{*}	0.07	0.29^{*}
10	Flower	−0.16	0.31^{**}	-0.30^{*}	-0.56^{**}	0.11	−0.06	-0.27^{*}	0.11	0.33^{**}
	Boll	−0.14	0.28^{*}	-0.27^{*}	-0.55^{**}	0.09	−0.07	-0.25^{*}	0.09	0.31^{**}
11	Flower	−0.16	0.31^{**}	-0.27^{*}	-0.55^{**}	0.10	−0.02	-0.31^{**}	0.08	0.32^{**}
	Boll	−0.15	0.29^{*}	-0.26^{*}	-0.53^{**}	0.10	0.00	-0.29^{*}	0.08	0.29^{*}
12	Flower	−0.17	0.44^{**}	-0.37^{**}	-0.57^{**}	0.26^{*}	0.02	-0.36^{**}	0.17	0.34^{**}
	Boll	−0.17	0.42^{**}	-0.36^{**}	-0.55^{**}	0.25^{*}	0.01	-0.34^{**}	0.16	0.32^{**}
13	Flower	−0.14	0.40^{**}	-0.33^{**}	-0.56^{**}	0.21	0.03	-0.28^{*}	0.10	0.34^{**}
	Boll	−0.15	0.38^{**}	-0.34^{**}	-0.56^{**}	0.21	0.01	-0.27^{*}	0.09	0.33^{**}
14	Flower	−0.19	0.39^{**}	-0.38^{**}	-0.59^{**}	0.25^{*}	0.04	-0.34^{**}	0.16	0.35^{**}
	Boll	−0.20	0.39^{**}	-0.40^{**}	-0.59^{**}	0.26^{*}	0.03	-0.36^{**}	0.17	0.36^{**}
15	Flower	−0.24	0.49^{**}	-0.45^{**}	-0.62^{**}	0.37^{**}	0.16	-0.38^{**}	0.27^{*}	0.42^{**}
	Boll	−0.24	0.51^{**}	-0.48^{**}	-0.63^{**}	0.40^{**}	0.15	-0.40^{**}	0.26^{*}	0.43^{**}

*Significant at 5% level; **Significant at 1% level; $^{\#}$0 = Initial time; $^{♦}$Diurnal temperature range; ^{z}Wind speed did not show significant effect upon the studied production variables, so it is not reported [12].

Minimum daily temperature showed positive and statistically significant correlations with both production variables only during the 9 - 15 day periods before anthesis, while daily minimum humidity showed the same correlation trend in all the 15 moving window periods before anthesis. Daily soil surface temperature at 0600 h was positively and significantly correlated with flower and boll production for the 12, 14, and 15 day periods prior to anthesis only. Daily soil surface temperature at 1800 h showed negative and significant correlations with both production variables only during the first and second day periods before flowering. Daily maximum humidity showed insignificant correlation with both flower and boll production except for one day period only (the 15th day). Generally, the results in the two seasons indicated that daily evaporation, sunshine duration and minimum humidity were the most effective and consistent climatic factors, which exhibited significant relationships with the production variables for all the 15 day periods before anthesis in both seasons [12].

The factors in this study which had been found to be associated with boll development are the climatic factors that would influence water loss between plant and atmosphere (low evaporation demand, high humidity, and shorter solar duration). This can lead to direct effects on the fruiting forms themselves and inhibitory effects on mid-afternoon photosynthetic rates even under well-watered conditions. Human *et al*. [16] stated that, when sunflower plants were grown under controlled temperature regimes, water stress during budding, anthesis and seed filling, the CO_2 uptake rate per unit leaf area as well as total uptake rate per plant, significantly diminished with stress, while this effect resulted in a significant decrease in yield per plant.

The correlation between climatic factors and each of boll production and boll retention over a period of 15 day periods after flowering (boll setting) day (**Table 4**, **Table 5**) [12] revealed the following:

3.1.3. First Season

Daily evaporation showed significant negative correlation with number of bolls for all the 15 day periods after flowering (**Table 4**). Meanwhile its relationship with retention ratio was positive and significant in the 9 - 15 day periods after flowering. Daily sunshine duration was positively and significantly correlated with boll retention ratio during the 5 - 13 day periods after flowering. Daily maximum humidity had a significant positive correlation with the number of bolls during the first 8 day periods after flowering, while daily minimum humidity had the same correlation for only the 11, and 12 day periods after flowering. Daily maximum and minimum temperatures and the diurnal temperature range, as well as soil surface temperature at 1800 did not show significant relationships with both number of bolls and retention ratio. Daily soil surface temperature at 0600 h had a significant negative correlation with boll retention ratio during the 3 - 7 day periods after anthesis [12].

3.1.4. Second Season

Daily evaporation, soil surface temperature at 1800 h, and sunshine duration had a significant negative correlation with number of bolls in all the 15 day periods after anthesis (**Table 5**). Daily maximum and minimum temperatures and the diurnal temperature range, and soil surface temperature at 0600 h had a negative correlation with boll production. Their significant effects were observed during the 1, and 10 - 15 day periods for maximum temperature, and the 1 - 5, and 9 - 12 day periods for the diurnal temperatures range. Meanwhile, the daily minimum temperature and soil surface temperature at 0600 h had a significant negative correlation only during the 13 - 15 day periods. Daily minimum humidity had a significant positive correlation with number of bolls during the first 5 day periods, and the 9 - 15 day periods after anthesis. Daily maximum humidity showed no significant relation to number of bolls produced, and further no significant relation was observed between any of the studied climatic factors and boll retention ratio [12].

The results in the two seasons indicated that evaporation and humidity, followed by sunshine duration had obvious correlation with boll production. From the results obtained, it appeared that the effects of air temperature, and soil surface temperature tended to be masked in the first season, *i.e.* did not show any significant effects in the first season on the number of bolls per plant. However, these effects were found to be significant in the second season. These seasonal differences in the impacts of the previously mentioned climatic factors on the number of bolls per plant are most likely ascribed to the sensible variation in evaporation values in the two studied seasons where their means were 10.2 $mm \cdot d^{-1}$ and 5.9 $mm \cdot d^{-1}$ in the first and second seasons, respectively [12].

There is an important question here concerning, if there is a way for forecasting when evaporation values would mask the effect of the previous climatic factors. The answer would be possibly achieved through relating humidity values to evaporation values which are naturally liable to some fluctuations from one season to another

Table 4. Simple correlation coefficient (r) values between climatic factors and number of harvested bolls and retention ratio in initial time (0) and each of the 15-day periods after flowering in the first season (I).

Climate period		Air temp. (˚C)			Evap. (mm·d^{-1})	Surface soil temp. (˚C)		Sunshine duration (h·d^{-1})	Humidity (%)	
		Max.	Min.	Max.-Min$^{♦}$.		0600 h	1800 h		Max.	Min.
		(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)	(X_7)	(X_8)	(X_9)
0$^{\#}$	Retention ratio•	−0.05	−0.03	−0.03	−0.10	−0.11	0.10	0.20	−0.04	−0.02
	No. of bolls	−0.03	−0.07	−0.01	−0.53**	−0.06	−0.16	−0.14	0.37**	0.10
1	Retention ratio	−0.07	−0.08	−0.01	−0.10	−0.16	0.04	0.15	0.04	0.05
	No. of bolls	0.02	−0.08	0.08	−0.49**	−0.09	−0.05	−0.20	0.35**	0.09
2	Retention ratio	−0.08	−0.14	0.02	−0.08	−0.19	0.03	0.17	0.02	−0.02
	No. of bolls	0.02	−0.04	0.07	−0.46**	−0.06	−0.01	−0.19	0.33**	0.09
3	Retention ratio	−0.09	−0.21	0.06	−0.08	−0.24*	0.02	0.19	0.01	−0.10
	No. of bolls	0.03	−0.03	0.06	−0.44**	−0.04	0.05	−0.18	0.32**	0.08
4	Retention ratio	−0.05	−0.20	0.09	−0.01	−0.24*	0.01	0.22	0.00	−0.15
	No. of bolls	0.01	−0.05	0.05	−0.40**	−0.03	0.04	−0.16	0.31*	0.08
5	Retention ratio	−0.03	−0.21	0.13	0.07	−0.25*	0.00	0.26*	−0.02	−0.22
	No. of bolls	0.00	−0.07	0.05	−0.37**	−0.02	0.03	−0.13	0.29*	0.07
6	Retention ratio	0.01	−0.19	0.15	0.12	−0.24*	0.02	0.27*	−0.03	−0.20
	No. of bolls	−0.01	−0.08	0.04	−0.38**	−0.02	0.04	−0.15	0.31*	0.13
7	Retention ratio	0.05	−0.17	0.17	0.18	−0.25*	0.05	0.29*	−0.02	−0.21
	No. of bolls	−0.03	−0.09	0.03	−0.39**	−0.04	0.06	−0.14	0.34**	0.18
8	Retention ratio	0.06	−0.08	0.13	0.21	−0.20	0.07	0.28*	−0.06	−0.19
	No. of bolls	−0.05	−0.07	−0.01	−0.35**	−0.02	0.02	−0.17	0.28*	0.17
9	Retention ratio	0.08	0.00	0.08	0.26*	−0.14	0.08	0.29*	−0.12	−0.20
	No. of bolls	−0.08	−0.06	−0.05	−0.33**	−0.01	0.00	−0.23	0.20	0.16
10	Retention ratio	0.06	−0.02	0.05	0.27*	−0.13	0.09	0.27*	−0.10	−0.08
	No. of bolls	−0.11	−0.10	−0.07	−0.34**	−0.03	−0.03	−0.19	0.18	0.21
11	Retention ratio	0.04	−0.04	0.08	0.28*	−0.12	0.08	0.26*	−0.09	−0.05
	No. of bolls	−0.18	−0.18	−0.06	−0.37**	−0.10	−0.04	−0.14	0.15	0.28*
12	Retention ratio	0.02	0.01	−0.08	0.32**	−0.05	0.05	0.25*	−0.08	−0.03
	No. of bolls	−0.17	−0.13	−0.08	−0.32**	−0.06	−0.07	−0.11	0.16	0.24*
13	Retention ratio	−0.04	0.04	−0.09	0.38**	0.00	0.01	0.27*	−0.09	−0.02
	No. of bolls	−0.15	−0.09	−0.09	−0.29*	−0.03	−0.10	−0.08	0.18	0.20
14	Retention ratio	−0.07	0.04	−0.13	0.34**	0.06	−0.02	0.18	−0.08	−0.01
	No. of bolls	−0.15	−0.10	−0.10	−0.28*	−0.01	−0.1	−0.15	0.17	0.17
15	Retention ratio	−0.13	0.03	−0.18	0.33**	0.09	−0.04	0.06	−0.07	0.00
	No. of bolls	−0.16	−0.1	−0.11	−0.28*	0.00	−0.11	−0.13	0.17	0.15

*,**Significant at 5% and 1% levels of significance, respectively; $^{\#}$0 = Initial time; •Retention ratio: (the number of retained bolls obtained from the total number of each daily tagged flowers in all selected plants at harvest/each daily number of tagged flowers in all selected plants) × 100; $^{♦}$Diurnal temperature range [12].

Table 5. Simple correlation coefficient (r) values between climatic factors[z] and number of harvested bolls and retention ratio in initial time (0) and each of the 15-day periods after flowering in the second season (II).

Climate period		Air temp. (˚C)			Evap. (mm·d^{-1})	Surface soil temp. (˚C)		Sunshine duration (h·d^{-1})	Humidity (%)	
		Max.	Min.	Max.-Min♦		0600 h	1800 h		Max.	Min.
		(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)	(X_7)	(X_8)	(X_9)
0#	Retention ratio•	−0.04	0.20	−0.31*	−0.14	0.12	−0.20	0.01	−0.04	0.17
	No. of bolls	−0.42**	0.02	−0.37**	−0.59**	−0.13	−0.36**	−0.36**	0.01	0.46**
1	Retention ratio	−0.10	−0.03	−0.22	−0.21	−0.15	−0.05	−0.04	−0.02	0.23
	No. of bolls	−0.25*	−0.01	−0.36**	−0.63**	−0.15	−0.30*	−0.25*	0.06	0.44**
2	Retention ratio	−0.15	−0.06	−0.10	−0.15	−0.08	−0.21	−0.01	−0.04	0.12
	No. of bolls	−0.18	−0.01	−0.34**	−0.65**	−0.11	−0.25*	−0.32*	0.13	0.43**
3	Retention ratio	−0.03	−0.01	−0.02	−0.21	−0.01	−0.17	−0.08	0.09	0.12
	No. of bolls	−0.15	−0.06	−0.30*	−0.62**	−0.05	−0.28*	−0.31*	0.14	0.33**
4	Retention ratio	0.08	−0.02	0.07	−0.09	−0.03	−0.09	−0.10	0.05	−0.04
	No. of bolls	−0.15	−0.05	−0.28*	−0.63**	−0.06	−0.25*	−0.33**	0.15	0.32*
5	Retention ratio	0.23	−0.03	0.12	−0.06	−0.06	−0.01	−0.11	0.01	−0.16
	No. of bolls	−0.14	−0.05	−0.25*	−0.62**	−0.06	−0.24*	−0.35**	0.15	0.31*
6	Retention ratio	0.09	−0.08	0.12	−0.09	−0.07	−0.01	−0.09	0.00	−0.05
	No. of bolls	−0.15	−0.04	−0.22	−0.61**	−0.08	−0.25*	−0.34**	0.13	0.22
7	Retention ratio	−0.03	−0.12	0.12	−0.10	−0.11	−0.01	−0.04	−0.03	0.02
	No. of bolls	−0.15	−0.02	−0.19	−0.60**	−0.10	−0.29*	−0.32*	0.10	0.18
8	Retention ratio	−0.02	0.05	0.03	−0.10	−0.04	−0.03	−0.02	−0.01	0.01
	No. of bolls	−0.20	−0.03	−0.23	−0.61**	−0.10	−0.28*	−0.32*	0.19	0.22
9	Retention ratio	−0.02	0.13	−0.05	−0.10	0.08	−0.05	−0.01	0.03	0.00
	No. of bolls	−0.24	−0.04	−0.29*	−0.62**	−0.11	−0.30*	−0.33**	0.13	0.27*
10	Retention ratio	−0.04	0.12	−0.08	−0.09	0.05	0.11	−0.02	0.04	0.02
	No. of bolls	−0.27*	−0.07	−0.30*	−0.60**	−0.16	−0.34**	−0.34**	0.11	0.26*
11	Retention ratio	−0.07	0.10	−0.10	−0.08	0.03	0.20	−0.03	0.05	0.04
	No. of bolls	−0.30*	−0.12	−0.30*	−0.61**	−0.18	−0.39**	−0.36**	0.10	0.27*
12	Retention ratio	−0.11	0.09	−0.14	−0.11	0.04	0.13	−0.08	0.11	0.09
	No. of bolls	−0.32*	−0.19	−0.26*	−0.60**	−0.22	−0.42**	−0.37**	0.09	0.27*
13	Retention ratio	−0.14	0.09	−0.17	−0.18	0.06	−0.06	−0.14	0.16	0.12
	No. of bolls	−0.33**	−0.26*	−0.23	−0.59**	−0.28*	−0.48**	−0.39**	0.08	0.27*
14	Retention ratio	−0.11	−0.04	−0.10	−0.13	−0.15	−0.05	−0.09	0.01	0.12
	No. of bolls	−0.34**	−0.32*	−0.21	−0.61**	−0.32*	−0.48**	−0.38**	0.06	0.27*
15	Retention ratio	−0.08	−0.11	0.02	−0.08	−0.22	−0.05	−0.02	−0.03	0.12
	No. of bolls	−0.35**	−0.37**	−0.18	−0.61**	−0.38**	−0.48**	−0.37**	0.03	0.27*

*, **Significant at 5% and 1% levels of significance, respectively; #0 = Initial time; •Retention ratio: (the number of retained bolls obtained from the total number of each daily tagged flowers in all selected plants at harvest/each daily number of tagged flowers in all selected plants) × 100; ♦Diurnal temperature range; zWind speed did not show significant effect upon the studied production variables, so it is not reported [12].

[12]. It was found that the ratio between the mean of maximum humidity and the mean of evaporation in the first season was 85.8/10.2 = 8.37, while in the second season this ratio was 12.4. On the other hand, the ratio between the mean minimum humidity and the mean of evaporation in the first season was 30.8/10.2 = 3.02, while in the second season this ratio was 6.75 (**Table 4**) [12]. From these ratios it seems that minimum humidity which is closely related to evaporation is more sensitive than the ratio between maximum humidity and evaporation. It can be seen from the results and formulas that when the ratio between minimum humidity and evaporation is small (3:1), the effects of air temperature, and soil surface temperature were hindered by the effect of evaporation, *i.e.* the effect of these climatic factors were not significant. However, when this ratio is high (6:1), the effects of these factors were found to be significant. Accordingly, it could be generally stated that the effects of air, and soil surface temperatures could be masked by evaporation when the ratio between minimum humidity and evaporation is less than 4:1 [12].

Evaporation appeared to be the most important climatic factor (in each of the 15-day periods both prior to and after initiation of individual bolls) affecting number of flowers or harvested bolls in Egyptian cotton. High daily evaporation rates could result in water stress that would slow growth and increase shedding rate of flowers and bolls. The second most important climatic factor in our study was humidity. Effect of maximum humidity varied markedly from the first season to the second one, where it was significantly correlated with the dependent variables in the first season, while the inverse pattern was true in the second season. This diverse effect may be due to the differences in the values of this factor in the two seasons; where it was on average 87% in the first season, and only 73% in the second season (**Table 1**). Also, was found that, when the average value of minimum humidity exceeded the half average value of maximum humidity, the minimum humidity can substitute the maximum humidity on affecting number of flowers or harvested bolls. In the first season (**Table 4**) the average value of minimum humidity was less than half of the value of maximum humidity (30.2/85.6 = 0.35), while in the second season it was higher than half of maximum humidity (39.1/72.9 = 0.54) [12].

The third most important climatic factor in our study was sunshine duration, which showed a significant negative relationship with boll production. The r values of (**Tables 2-5**) indicated that the relationship between the dependent and independent variables preceding flowering (production stage) generally exceeded in value the relationship between them during the entire and late periods of production stage. In fact, understanding the effects of climatic factors on cotton production during the previously mentioned periods would have marked consequences on the overall level of cotton production, which could be predictable depending on those relationships [12].

3.2. Regression Models

An attempt was carried out to investigate the effect of climatic factors on cotton production via prediction equations including the important climatic factors responsible for the majority of total variability in cotton flower and boll production. Hence, regression models were established using the stepwise multiple regression technique to express the relationship between each of the number of flowers and bolls/plant and boll retention ratio (Y), with the climatic factors, for each of the a) 5, b) 10, and c) 15 day periods either prior to or after initiation of individual bolls (**Table 6**, **Table 7**) [12].

1) Concerning the effect of prior days the results indicated that evaporation, sunshine duration, and the diurnal temperature range were the most effective and consistent climatic factors affecting cotton flower and boll production (**Table 6**). The fourth effective climatic factor in this respect was minimum humidity. On the other hand, for the periods after flower the results obtained from the equations (**Table 7**) indicated that evaporation was the most effective and consistent climatic factor affecting number of harvested bolls [12].

Regression models obtained demonstrate of each independent variable under study as an efficient and important factor. Meanwhile, they explained a sensible proportion of the variation in flower and boll production, as indicated by their R^2, which ranged between 0.14 - 0.62, where most of R^2 prior to flower opening were about 0.50 and after flowering all but one are less than 0.50 [12]. These results agree with Miller *et al*. [17] in their regression study of the relation of yield with rainfall and temperature. They suggested that the other 0.50 of variation related to management practices, which can be the same in this study.

2) Also, the regression models indicated that the relationships between the number of flowers and bolls per plant and the studied climatic factors for the 15 day period before or after flowering (Y_3) in each season explained the highly significant magnitude of variation ($P < 0.05$). The R^2 values for the 15 day periods before and

Table 6. The models obtained for the number of flowers and bolls per plant as functions of the climatic data derived from the 5, 10, and 15 day periods prior to flower opening in the two seasons (I, II).

Season	Model^z	R^2	Significance
First			
Flower	$Y_1 = 55.75 + 0.86X_3 - 2.09X_4 - 2.23X_7$	0.51	**
	$Y_2 = 26.76 - 5.45X_4 + 1.76X_9$	0.42	**
	$Y_3 = 43.37 - 1.02X_4 - 2.61X_7 + 0.20X_8$	0.52	**
Boll	$Y_1 = 43.69 + 0.34X_3 - 1.71X_4 - 1.44X_7$	0.43	**
	$Y_2 = 40.11 - 1.82X_4 - 1.36X_7 + 0.10X_8$	0.48	**
	$Y_3 = 31.00 - 0.60X_4 - 2.62X_7 + 0.23X_8$	0.47	**
Second			
Flower	$Y_1 = 18.58 + 0.39X_3 - 0.22X_4 - 1.19X_7 + 0.17X_9$	0.54	**
	$Y_2 = 16.21 + 0.63X_3 - 0.20X_4 - 1.24X_7 + 0.16X_9$	0.61	**
	$Y_3 = 14.72 + 0.51X_3 - 0.20X_4 - 0.85X_7 + 0.17X_9$	0.58	**
Boll	$Y_1 = 25.83 + 0.50X_3 - 0.26X_4 - 1.95X_7 + 0.15X_9$	0.61	**
	$Y_2 = 19.65 + 0.62X_3 - 0.25X_4 - 1.44X_7 + 0.12X_9$	0.60	**
	$Y_3 = 15.83 + 0.60X_3 - 0.22X_4 - 1.26X_7 + 0.14X_9$	0.59	**

^{z}Where Y_1, Y_2, Y_3 = number of flowers or bolls per plant at the 5, 10 and 15 day periods before flowering, respectively, X_2 = minimum temperature (˚C), X_3 = diurnal temperature range (˚C), X_4 = evaporation (mm·day^{-1}), X_7 = sunshine duration (h·day^{-1}), X_8 = maximum humidity (%) and X_9 = minimum humidity (%) [12].

Table 7. The models obtained for the number of bolls per plant as functions of the climatic data derived from the 5, 10, and 15 day periods after flower opening in the two seasons (I, II).

Season	Model^z	R^2	Significance
First	$Y_1 = 16.38 - 0.41X_4$	0.14	**
	$Y_2 = 16.43 - 0.41X_4$	0.14	**
	$Y_3 = 27.83 - 0.60X_4 - 0.88X_9$	0.15	**
Second	$Y_1 = 23.96 - 0.47X_4 - 0.77X_8$	0.44	**
	$Y_2 = 18.72 - 0.58X_4$	0.34	**
	$Y_3 = 56.09 - 2.51X_4 - 0.49X_6 - 1.67X_7$	0.56	**

^{z}Where Y_1, Y_2, Y_3 = number of bolls per plant at the 5, 10, and 15 day periods after flowering, respectively, X_4 = evaporation (mm·day^{-1}), X_6 = soil surface temperature (˚C) at 1800, X_7 = sunshine duration (h·day^{-1}), X_8 = maximum humidity (%) and X_9 = minimum humidity (%) [12].

after flowering were higher than most of those obtained for each of the 5 and the 10 day periods before or after flowering. This clarifies that the effects of the climatic factors during the 15 day periods before or after flowering are very important for Egyptian cotton boll production and retention. Thus, an accurate climatic forecast for the effect of these 15 day periods provides an opportunity to avoid any possible adverse effects of unusual climatic conditions before flowering or after boll formation by utilizing additional treatments and/or adopting proper precautions to avoid flower and boll reduction [12].

The main climatic factors from this study affecting the number of flowers and bolls, and by implication yield, is evaporation, sunshine duration and minimum humidity, with evaporation (water stress) being by far the most important factor. Various activities have been suggested to partially overcome water stress. Temperature conditions during the reproduction growth stage of cotton in Egypt do not appear to limit growth even though they are above the optimum for cotton growth [12]. This is contradictory to the finding of Holaday *et al*. [18]. A possible reason for that contradiction is that the effects of evaporation rate and humidity were not taken into consideration in the research studies conducted by other researchers in other countries. The matter of fact is that temperature and evaporation are closely related to each other to such an extent that the higher evaporation rate could possible mask the effect of temperature. Sunshine duration and minimum humidity appeared to have secondary effects, yet they are in fact important players [12]. The importance of sunshine duration has been alluded to by Oosterhuis [19]. Also, Mergeai and Demol [20] found that cotton yield was assisted by intermediate relative humidity.

4. Conclusions

It could be concluded that during the 15-day periods both prior to and after initiation of individual boll, evaporation, minimum relative humidity and sunshine duration, were the most significant climatic factors affecting cotton flower and boll production and retention in Egyptian cotton. The negative correlation between each of evaporation and sunshine duration with flower and boll formation along with the positive correlation between minimum relative humidity value and flower and boll production, indicated that low evaporation rate, short period of sunshine duration and high value of minimum humidity would enhance flower and boll formation. Temperature appeared to be less important in the reproduction growth stage of cotton in Egypt than evaporation (water stress), sunshine duration and minimum humidity. These findings concur with those of other researchers except for the importance of temperature. A possible reason for that contradiction is that the effects of evaporation rate and relative humidity were not taken into consideration in the research studies conducted by other researchers in other countries. The matter of fact is that temperature and evaporation are closely related to each other to such an extent that the higher evaporation rate could possibly mask the effect of temperature. Water stress is in fact the main player and other authors have suggested means for overcoming its adverse effect which could be utilized in the Egyptian cotton. It must be kept in mind that although the reliable prediction of the effects of the aforementioned climatic factors could lead to higher yields of cotton, yet only 50% of the variation in yield could be statistically explained by these factors and hence consideration should also be given to the management practices presently in use [12].

Finally, the early prediction of possible adverse effects of climatic factors might modify their effect on production of Egyptian cotton. Minimizing deleterious effects through the application of proper management practices, such as, adequate irrigation regime, and utilization of specific plant growth regulators could limit the negative effects of some climatic factors [13].

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