American-Eurasian J. Agric. & Environ. Sci., 19 (3): 153-163, 2019
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2019.153.163

Soybean Growth and Seed Yield as Affected by the Prevailing Climate Factors in Giza, Egypt

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Abstract: To investigate the effect of prevailing climate factors during the growing season on soybean growth, seed yield and its components, two field experiments were conducted at the Agric. Exp. Research Station at Giza, Fac. of Agric., Cairo Univ., Egypt, during 2014 and 2015 seasons. Soybean variety Giza 111 was seeded at five sowing dates (April, May, June, July and August) to obtain varied climate parameters, using a randomized complete block design in five replications. Delaying sowing date from April to August decreased the duration from emergence to flowering stage (E-FL) and flowering to physiological maturity stage (FL-PM). Thus the whole growing season (E-PM) decreased by about two weeks. This was related to high values of maximum temperature (T_{max}.), minimum temperature (T_{min}), actual sunshine hours (ASSH), accumulated growing degree days (AGDD) and accumulated photo-thermal units (APTU) more than other climate factors according to coefficient of determination R^2 values in both seasons. Delay in sowing date after June caused significant decrease in leaf area per plant and top dry weight per plant at 60-days plant age in both seasons. This was related to ASSH and solar radiation energy (SRE) during the period from emergence until 60 days later which their values were the lowest at the last sowing date in both seasons. Seed yield and its components were gradually decreased as sowing date was delayed from April until August in both seasons. This was accompanied with decrease in the duration of FL.-PM, leaf area per plant and top dry weight. The value of "R^2" for seed yield and its components cleared that the variation in these characters were more related to change in diurnal temperature range (DTR), ASSH and SRE prevailed during the reproductive growth stage.

Key words: Soybean · Glycine max · Sowing date · Climate parameters · Solar radiation energy · Growing degree day Photo-thermal units · Coefficient of determination · Regression

INTRODUCTION

Soybean is the most important oilseed crop in the world. It ranked the first with regard to harvested area (123.5 million ha) and seed production (352.6 million tons) [1].

Soybean is grown in different growing zones all over the world under different climates, which may affect its performance and seed constituents [2, 3]. United States, Brazil, Argentina and China produce more than 80% of the world production of the soybeans [1]. In Egypt, it is grown on area of 15.000 ha. which produce 45000 tons [1]. Climate change has many impacts on crop productivity, but the extent of these impacts is not yet certainly known and quantified at the global scale. The expected change in the global climate during this century will cause negative impacts on main crops, including soybean in temperate and tropical zones [4]. The performance of soybean may become different due to change in sowing date when the prevailing climate factors become different. Changes in climate factors during the growing season may affect growth parameters and yield components as well as stand at harvest which could produce different seed yield per unit land area.

Thus, the researchers in agriculture sector should work hard in the area of adaptation options to mitigate these negative effects and to face the increased food requirements of the increasing world population, in Africa and Asia in Particular. This is more necessary in the nations with the high rate of population increase such as Egypt. In this study, soybean was chosen because Egypt imports more than 95% of edible oil (1.7 million tons). In 2016, Egypt imported 0.9 million tons of soybean oil and 1.8 million tons of soybean meal [5]. Thus, Egypt

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needs to increase the area of soybean and its productivity and/or avoid the yield decrease due to expected climate change, through adaptation options. This needs more information about the performance of soybean in relation to the different prevailing climates during the growing season under Egyptian conditions. For that, this study aimed to get some information that could be used to create an adaptation options to mitigate the negative effects of the expected climate change on soybean under Egyptian conditions.

The objectives of this investigation were to study the growth, development, yield and yield components in relation to some climate factors such as temperature parameters, sunshine hours, solar radiation energy and agro-climate indices such as growing degree-days and photo thermal units.

MATERIALS AND METHODS

To obtain variable climate factors under field conditions two field experiments were carried out during 2014 and 2015 summer seasons at the Agricultural Experiment and Research Station, Faculty of Agriculture, Cairo University Giza, Egypt (latitude 30.0°N, longitude 31.3°E and elevation of 24 m above sea level). Soybean variety Giza-111 seeds were seeded at five seeding dates in each season, *i.e.* last week of April, last week of May, last week of June, second week of July and first week of August in 2014 and 2015 seasons. A randomized complete block design in five replications was used. Plot size was 3x3.5 m (10.5 m^2). Each plot contained 5 ridges (60.0 cm apart, 3.5 m long). Soybean seeds were manually drilled in a wit soil (soil contains about 50-60% moisture). Seeding rate was 15 g per ridge (72 kg/ha). The soil of the experimental site was clay loam in texture; it contained 9.5 ppm available N and 3.0 ppm available P and 580 ppm available K, with PH 7.8 and EC 0.57 ds/m (1:2.25). Calcium super phosphate (15.5% P_2O_5) was added before ridging at 35.7 kg P_2O_5/ ha (15 kg/faad.). Nitrogen fertilizer as ammonium nitrate (33% N) was added at 142.8 kg N/ha (60 kg/fadd.) in two equal doses at 15 and 30 days after sowing. Irrigation was practiced at 15-day interval until physiological maturity. Harvesting was done 10 days after physiological maturity of each sowing date.

Collected Data

Climate Data: Daily maximum temperature ($T_{max.}$), daily minimum temperature (T_{min}.), daily average temperature ($T_{av.}$), sunshine hours (SSH) and solar radiation energy (SRE) were obtained from Meteorological Station of Central Lap of Agricultural Climate, Agric. Res. Cent., which located 500 meters far from the experimental site. Average of $T_{max.}$, $T_{min.}$, $T_{av.}$, diurnal temperature range DTR (T_{max} - T_{min}), SSH and SRE of each sowing date were calculated during the following periods:

- Emergence (E) to flowering (FL).
- Flowering to physiological maturity (PM).
- Emergence to physiological maturity.

Agro-Climate Indices: Growing degree-days (GDD) and photo-thermal units (PTU), during these periods of each sowing date was computed according to Kumar *et al*. [6] as follows:

- Daily GDD (C°/day) = [(Tmax. +Tmin.)/2-Tb] where Tb = soybean base temperature(10°C), then the accumulated GDD for the periods was calculated.
- Daily PTU (°C /day) = GDD×SSH, then the accumulated PTU for the periods was calculated.

Phenological Parameters: Date of emergence of each plot was recorded when the most of plants of the inner three ridges were appeared on soil surface. At 25 days after seeding, 5 plants in each ridge were labeled to record the flowering date (1st flower) and the date of physiological maturity, *i.e.*, one normal pod on the main stem has reached mature pod color (normally brown or tan depending on variety) according to Febr *et al*. [7]. The average number of days from emergence to flowering, flowering to physiological maturity and from emergence to physiological maturity was calculated (average of 15 plants).

Growth Parameters: Each ridge from the inner 3 rows were divided into 3 parts; 50 cm from each end of the row were excluded to avoid border effect, 200 cm were left for estimation of the seed yield and the rest 50 cm were devoted to take a random sample of 5 plants at 60-day plant age to estimate the number of leaves per plant, leaf area per plant (dm^2) and top dry weight of leaves, stem and pod per plant (g).Plants were uprooted, translocated to the lab, then the roots (the part below cotyledon node) were excluded, leaves were separated and counted. Leaf area per plant (dm^2) was measured using digital electronic leaf area meter (model 3100 area meter). Then leaves and stems were dried at 70°C until constant weight and then average of dry weight of tops per plant was calculated.

Seed Yield and its Components: At harvest, 10 guarded plants from each plot were randomly taken and then pods per plant were counted, separated, put in paper bags. Thereafter, 20 pods from each plot were hand threshed, seeds were counted. The following characteristics were measured:

- Number of pods /plant: as an average of ten plants.
- Number of seeds /pod: number of seeds of 20 pods divided by 20.
- Number of seeds /plant: seeds per pod multiplied by pods per plant.
- Seed weight/ plant: average of seed weight of 10 plants (plus the seeds of the 20 pods).
- Seed yield (t/ha.): the plants of 2 meter of the three inner rows were dried and hand threshed, seeds were weighted, then seed weight per ha. were calculated.
- 100-seed weight (g): a random 100 seeds were taken from each plot and weighted.
- Stand at harvest (plants/m^2): plants in one meter long (0.6m^2) of one row of each plot were counted and converted to plants per square meter.

Statistical Analysis: A regular analysis of variance of randomized complete block design was performed for each season. The simple regression coefficient, simple linear equation and coefficient of determination between each of climate parameters as independent factor and each of studied characters as dependent factors were computed according to Gomez and Gomez [8].

RESULTS AND DISCUSSION

Climate Data: Results in Table 1 show the bi-weekly average of temperature, solar radiation energy and actual sunshine hours during the period from April to November, the time range of the growing season of the five sowing dates in 2014 and 2015.

Data in Table 1 cleared that average temperature tended to increase from April until mid-September, then returned to decrease. However, the actual sunshine hours tended to increase from start of April until mid-June and then returned to decrease slowly until end of August and with a higher rate after that. Therefore, the solar radiation energy was highest during July and August and lowest during October and November.

Table 2 shows the average of climate parameters during emergence to flowering (E-FL), flowering to physiological maturity (FL-PM) and from emergence to physiological maturity (E-PM) periods, respectively. The temperature parameters ($T_{max.}$, $T_{min,}$ T_{av}) during E-Fl period tended to increase as sowing date was delayed. Data also cleared that the temperature parameters tended to increase during the FL-PM period by delay in sowing date from April to June and returned to decrease in July and August. A similar trend was observed during Emergence to physiological maturity (E-PM) *i.e.*, the whole growing season.

From the results in Table 2, it cloud be concluded that, the range of the temperature parameters (calculated as an average of the two seasons) was different during E-FL, FL-PM and the whole growing season (E-PM). Maximum temperature range was 3.9, 2.6 and 2.05°C, however, the minimum temperature range was 8.6, 2.05 and 2.8°C, thus average temperature range was 6.2, 2.1 and 2.4°C during E-FL, FL-PM and E-PM, respectively. With regard to actual sunshine hours (ASSH) and solar radiation energy (SRE) during E-FL period, they tended to increase by delay in sowing date from April to June and returned to decrease after that. However, both parameters during FL-PM period were gradually decreased as sowing date was delayed in both seasons. This was also true during E-PM period.

Results presented in Table 3 show the accumulated growing degree days (AGDD) and the accumulated photo-thermal units (APTU) during E-Fl, Fl-PM and E-PM in 2014 and 2015 seasons. Results cleared that AGDD gradually increased during E-FL and Fl-PM periods as sowing date was delayed from April until July, with a small decrease for the August sowing date. However, the APTU during both growth periods showed a similar increase as sowing date was delayed from April until June and tended to decrease for July and August sowing dates. Regarding to the whole growing season (E-PM), results in Table 3 indicated that both indices increased as sowing was delayed from April until June and returned to decrease for the July and August sowing dates.

Growth and Development

Phenological Periods: Results in Table 4 indicate that delaying in sowing date of soybean after April reduced the three Phenological periods in both seasons. This reduction was more pronounced when soybean was seeded in August but with lesser value when seeded in July. As an average of the two seasons, the reduction in (E-FL), (FL-PM) and (E-PM) periods estimated by 3.80, 12.10 and 15.90 days, respectively, when sowing date delayed from April to August. This was attributed to an increase in $T_{Max,}$ T_{min}. and $T_{av.}$ and decrease in DTR during the E-FL. period in both seasons (Table 2).

Table 1: Bi-weekly average climate parameters during April-November in 2014 and 2015 seasons

		Average temperature (°C)		Solar radiation (MJ/m^2)		Actual sunshine hours(h)	
Month	Period	2014	2015	2014	2015	2014	2015
April	1-15	19.2	21.3	20.2	20.8	12.59	12.59
	16-30	21.7	24.5	20.6	22.5	13.00	13.00
May	1-15	23.8	25.4	23.0	20.8	13.31	13.31
	16-31	27.3	26.7	22.7	21.5	13.34	13.33
June	1-15	25.9	27.5	21.4	23.4	12.55	12.50
	16-30	27.4	29.6	21.8	23.8	12.54	12.52
July	1-15	27.5	29.7	21.3	23.2	12.45	12.44
	16-31	30.4	27.8	24.3	21.5	12.40	12.40
August	1-15	32.6	29.6	23.2	21.1	12.20	12.22
	16-31	32.2	28.3	22.4	22.6	12.18	12.12
September	1-15	30.1	30.1	19.1	20.5	11.18	11.15
	16-30	29.5	30.6	19.3	18.9	11.16	11.16
October	1-15	26.8	25.3	12.6	16.0	11.05	11.00
	16-31	23.7	23.6	12.5	12.3	11.00	11.00
November	1-15	21.1	25.0	10.2	9.7	10.26	10.26
	16-30	19.5	18.3	9.5	9.5	10.25	10.25

Table 2: Mean of climate parameters prevailed during three growth periods of the five sowing dates in 2014 and 2015 seasons

	April	May	June	July	August	April	May	June	July	August
Parameters	2014					2015				
Emergence to flowering (E-FL) period										
$T_{max.}$ (°C)	33.2	35.3	36.1	36.3	36.5	32.6	34.0	35.3	36.6	37.1
$T_{min.}$ (°C)	16.0	19.6	23.7	25.0	25.6	18.6	21.9	24.2	25.6	26.3
$T_{av.}$ (°C)	24.6	27.5	29.9	30.6	31.1	25.8	27.9	29.7	31.1	31.7
DTR (°C)	17.2	15.7	12.4	11.3	10.9	14.0	12.1	11.1	11.0	10.8
ASSH (h)	12.4	13.3	13.3	12.5	12.2	12.5	13.3	13.2	12.5	12.2
SRE(Mj/m^2)	22.8	23.00	24.1	23.1	22.5	23.5	24.0	24.6	23.2	22.8
Flowering to physiological maturity (FL-PM) period										
$T_{max.}$ (°C)	34.5	35.6	35.8	34.2	33.6	35.8	36.2	36.4	34.8	33.4
$T_{min.}$ (°C)	22.4	24.5	24.4	23.4	23.0	23.1	25.0	25.1	24.4	23.7
$T_{av.}$ (°C)	28.5	30.1	30.1	28.8	28.3	29.5	30.6	30.8	29.6	28.4
DTR (°C)	12.01	11.1	11.4	10.8	10.6	12.7	11.2	11.3	10.4	10.1
ASSH (h)	13.4	13.2	12.2	11.4	10.3	13.4	13.3	12.2	11.4	10.3
SRE (Mj/m^2)	24.0	23.1	21.6	20.6	17.2	25.2	24.3	21.3	18.9	17.1
Emergence to physiological maturity (E-PM) period										
$T_{max.}$ (°C)	34.7	35.3	35.9	34.7	33.5	33.7	34.7	35.4	34.3	33.8
$T_{min.}$ (°C)	24.3	24.6	24.8	22.3	21.0	22.5	22.7	23.1	21.8	21.2
$T_{av.}$ (°C)	29.5	30.0	30.3	28.5	27.2	29.1	28.7	29.25	28.1	27.5
DTR (°C)	10.4	10.8	11.1	12.4	12.5	11.2	12.0	12.3	12.5	12.6
ASSH (h)	13.3	12.2	12.2	11.4	10.2	13.3	13.2	11.5	11.4	10.3
SRE (Mj/m^2)	23.4	223.1	22.9	21.9	19.9	23.3	23.3	22.4	21.8	20.2

Tmax. =maximum temp., Tmin. =minimum temp., Tav= average temp.
DTR=diurnal temp. range, ASSH=Actual sunshine hours, SRE= Solar radiation energy.

Table 3: Accumulated growing degree-day (AGDD) and accumulated photo-thermal units (APTU) during three growth periods of the five sowing dates in 2014 and 2015 seasons

	April		May		June		July		August	
Parameter	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Emergence to flowering (E-FL) period										
AGDD (°C)	342	420	459	481	513	536	520	546	504	525
APTU (°C)	4860	5250	6104	6131	6772	7075	6500	6825	6148	6405
Flowering to physiological maturity (FL-PM) period										
AGDD (°C)	1278	1707	1420	1834	1400	1640	1224	1700	1062	1673
APTU (°C)	16614	22839	18460	24346	16800	20057	13464	19414	11682	17169
Emergence to physiological maturity (E-PM) period										
AGDD (°C)	1900	1636	1980	1818	1940	1881	1692	1746	1428	1462
APTU (°C)	24700	23868	25740	24090	23280	22572	18612	19904	14280	14620

Table 4: Mean number of days of Phenological periods as affected by sowing date in 2014 and 2015 seasons.

	Sowing date				
Phenological periods	April	May	June	July	August
	2014				
E-FL(day)	28.7 a	27.5 a	27.0 a	26.1 b	24.5 c
FL-PM(day)	71.6 a	71.4 a	70.2 a	68.2 ab	59.6 c
E-PM(day)	100.3 a	98.9 a	97.2 a	94.3 b	84.1 c
	2015				
E-FL(day)	28.8 a	28.2 ab	27.5 bc	25.8 c	25.4 d
FL-PM(day)	73.3 a	72.8 a	71.9 b	70.8 c	61.1 d
E-PM(day)	102.1 a	101.0 a	99.4 ab	97.4 b	86.5 c

Means followed by the same letter (s) are not significantly different at 5% probability

E =emergence, FL = flowering, PM = physiological maturity

Results in Table 5 show significant differences and recoded high value of coefficient of determination (R^2) value of T_{av}. and DTR in both seasons and T_{max}.andT_{min}. in 2nd season in relation to days from E to FL. This means that the temperature parameters in general and T_{av}. and DTR in particular could explain the high percentage of the total variation in E-Fl period regardless of the others in both seasons. This is because the ratio of variation was high in the second season, it was 90.61, 95.52, 98.40 and 67.60 % for the T_{max}, T_{min}, T_{av} and DTR, respectively, while it was 55.22, 48.01, 88.70 and 77.72% on the same order in the first season (Table 5). This means that simple regression equation could be used to expect the change in E-FL. duration using T_{av}. or DTR as independent factor.

With regard to FL-PM period, the R^2 value indicates a strong relation between all climate parameters, except T_{min}. and DTR in both seasons and T_{Max} and T_{av} in first season (Table 5). The R^2 value of ASSH, SRE, AGDD or APTU, regardless of the others, could explain at least 66.26% of total variation in days from flowering to physiological maturity stage. With regard to the whole season of soybean (E-PM), results in Table (5) indicate that, it was attributed closely to all climate parameters in both seasons, except T_{av} and DTR in the 2nd season. The R^2 value was high for most of these parameters, which means that the simple linear equation of each parameter, regardless of the others, is fit to expect the change in the duration of soybean growing season under the conditions of this experiment. This could be clearer for AGDD and APTU, which showed the highest R^2 values in both seasons (Table 5).

Many researchers reported a marked variation in Phenological stages as well as rate of soybean development in relation to climate parameters such as temperature and day length [2, 9, 10]. While George *et al.* [11] stated that low temperature delayed flowering in soybean. In that context, Thomas *et al*. [12] and Seddigh *et al.* [13] reported that night temperature had a significant effect on the development of early mature soybean cultivars. However, Kumar *et al.* [14] and Zhang *et al.* [15] in USA reported that days to flowering and to maturity decreased as sowing date was delayed The early flowering at late sowing date was attributed to accumulated growing degree days and accumulated photo-thermal units. Similar findings were reported by Gibson and Mullen [16] and Egli *et al*. [17].

Growth Parameters: Table 6 shows the mean climate parameters prevailed during the period from emergence to 60 days after emergence for the five sowing dates in 2014 and 2015 seasons. Leaf area (LA) per plant and top dry weight (TDW) per plant were determined at 60-days plant age as indicators to soybean growth in relation to climate parameters prevailing during this period in different sowing dates.

Results in Table 7 show that, LA and TDW per plant as affected by sowing date in 2014 and 2015 seasons. Leaf area at 60-days may become important for light interception during the subsequent stage, *i.e.* seed formation. In addition, top dry weight at mid-season may be an indicator to the dry matter accumulation during the 60-day period in relation to prevailed climate factors. LA and TDW per plant were significantly reduced with delaying sowing date after June, i.e. on July and August in both seasons. This was attributed to high $T_{max.}T_{min.}$ and $T_{av.}$ during the first 60 days of growing for (May, June and July sowing) and continuous reduction in DTR from April to August in both seasons. An increase in ASSH and SRE was noticed by delaying sowing date from April to May, but both tended to reduce after May with each delay is sowing up to August. On the other hand, AGDD and APTU increased by delaying sowing from April to May or June before they started to reduce as sowing date was delayed to July or August in both seasons.

Table 5: Coefficient of determination (R^2) and simple linear regression equation between climate parameter and Phenological periods in 2014 and 2015 seasons

	2014		2015	
Parameter	R^2	Linear equation	R^2	Linear equation
		E- FL Period		
$T_{max.}$ (°C)	0.55	Y= 45.8-0.54 X	0.91	Y= 51.1-0.68 X**
$T_{min.}$ (°C)	0.48	Y= 31.68-0.23 X	0.96	Y = -18.42-0.38 X**
$T_{av.}$ (°C)	0.89	Y= 15.02-0.41 X**	0.98	Y= 39.8-0.44 X**
DTR (°C)	0.73	Y=21.09-0.41 X*	0.68	Y= 17.76 – 0.81 X*
ASSH(h)	0.34	Y = -6.86-1.56 X	0.26	Y= 10.34 + 1.33X
SRE (Mj/m^2)/day	0.32	Y=18.87+3.39X	0.34	Y=1.55+1.09 X
A GDD. (°C)	0.36	Y=19.56 +0.02 X	0.58	Y=15.35- 0.01 X
A PTU (°C)	0.53	Y=19.22+0.00X	0.30	Y= 26.65+0.00 X
		FL-PM Period		
$T_{max.}$ (°C)	0.57	Y= 72.20+4.05 X	0.83	Y=62.02+3.74 X**
$T_{min.}$ (°C)	0.10	Y = 27.80+1.72 X	0.08	Y =28.26+1.72X
$T_{av.}$ (°C)	0.33	Y= 26.98 +3.26 X	0.64	Y= -55.22+1.20X
DTR (°C)	0.49	Y= 1.80+5.93 X	0.49	Y=31.33+4.48 X
ASSH(h)	0.84	Y= 25.16+3.53X**	0.77	Y=28.87+3.39 X*
SRE (Mj/m^2)/day	0.98	Y= 29.44+2.23 X**	0.66	Y= 44.53+1.19 X
A GDD. (°C)	0.77	Y= 29.63+0.03 X*	0.98	Y=23.80+0.03 X**
A PTU (°C)	0.78	Y=316.3 -0.00X*	0.90	Y=45.80+0.00X**
		E-PM Period		
$T_{max.}$ (°C)	0.63	Y= -101.79 +5.65 X	0.84	Y= -185.91+8.24 X*
$T_{min.}$ (°C)	0.86	Y= 12.37+3.53 X*	0.66	Y= 57.58+6.96 X
$T_{av.}$ (°C)	0.83	Y= 39.51+4.62 X*	0.42	Y= 80.19+6.26 X
DTR (°C)	0.72	Y= 157.59-5.46X	0.43	Y= 189.30-7.59 X
ASSH (h)	0.94	Y= 37.52+4.74 X**	0.72	Y= 40.91+4.76 X*
SRE (Mj/m^2)/day	0.59	Y= -5.65+4.53 X	0.69	Y= 25.86+3.20 X*
AGDD (°C)	0.94	Y= 47.00+0.03 X**	0.81	Y= 36.40+0.04 X*
APTU (°C)	0.94	Y= 67.50+0.00 X**	0.88	Y= 64.88+0.00 X**

*, ** = significant at 0.05 and 0.01 probability levels, respectively.

Table 6: Average of climate parameters during the period from emergence to 60 day after emergence in 2014 and 2015 seasons

	April	May	June	July	August
Parameter			2014 season		
$T_{max.}$(°C)	34.04	36.7	36.60	36.10	35.40
$T_{min.}$ (°C)	20.20	22.3	25.40	24.80	23.70
$T_{av.}$ (°C)	27.10	29.5	31.00	30.45	29.55
DTR (°C)	13.80	14.40	11.20	11.30	12.00
ASSH (h	13.10	12.56	12. 34	11.15	10.25
SRE (Mj/m^2)/day	22.70	24.30	23.10	21.8	20.90
AGDD (°C)	1084.2	938.40	1469.5	1141.5	1179.6
APTU (°C)	14203	11786	18133	12727	12090
			2015 season		
$T_{max.}$(°C)	35.00	36.50	36.30	36.00	35.60
$T_{min.}$ (°C)	23.60	22.50	25.20	26.20	25.40
$T_{av.}$ (°C)	29.30	29.50	30.70	31.10	30.50
DTR (°C)	11.40	14.00	11.10	9.80	10.20
ASSH (h	13.00	12.54	12.31	11.17	10.26
SRE (Mj/m^2)/day	22.40	24.10	23.00	21.00	20.20
AGDD (°C)	1075.2	1054.8	1240	1290	1234

Table 7: Mean leaf area (LA) and top dry weight (TDW) per plant at 60-days plant age as affected by sowing date in 2014 and 2015 seasons

	April		May		June		July		August	
Character	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
LA/pl.(dm^2)	54.29a	56.4a	56.7 a	58.8 a	53.6 a	52.2 a	38.3b	32.1b	18.3c	16.4c
TDW/pl.(g)	13.63a	12.08a	13.76a	12.86a	12.89a	12.16a	10.29	8.72b	4.08c	4.51c

Means in the same column followed by the same letter (s) are not significantly different at 1% of probability level

Table 8: Coefficient of determination (R^2) and simple linear regression equation between climate factors and leaf area (LA) and top dry weight (TDW) per plant at 60 days plant old in 2014 and 2015 seasons

	Parameter	2014	2015	
	R^2	Linear equation	R^2	Linear equation
	LA / plant			
$T_{max.}$(°C)	0.00	Y= 46.12+0.130 x	0.00	Y=38.5+0.07 x
$T_{min.}$ (°C)	0.14	Y=69.2-0.79 x	0.55	Y=263.02-9.02
$T_{av.}$ (°C)	0.66	Y=72.8-0.74 x	0.51	Y=544.5-16.65 x
DTR (°C)	0.23	Y= 32.9 +1.42x	0.46	Y= -43.5 +7.50 x
ASSH (h)	0.83	$Y=58.8+2.51x^{*}$	0.99	$Y=-151.42+16.24\ x^{**}$
SRE(Mj/m^2)/day	0.83	$Y=-4.34+2.46\ x^{*}$	0.75	$Y= -183.27+10\ x^{*}$
AGDD (°C)	0.01	Y=51.51-0.0x	0.56	Y=192.8-0.13x
APTU (°C)	0.23	Y=39.76+0.0x	0.13	Y= 49.79+0.0x
	Top DW/plant			
$T_{max.}$(°C)	0.11	Y=19.60-0.16 x	0.35	Y= -29.3 +1.09 x
$T_{min.}$ (°C)	0.03	Y=14.76-0.04 x	0.50	Y= 50.34-1.64 x
$T_{av.}$ (°C)	0.60	Y=16.32-0.08 x	0.37	Y= 91.9 -2.71 x
DTR (°C)	0.01	Y=13.59+0.02 x	0.51	Y= -7.11 +1.50 x
ASSH (h)	0.78	$Y= -13.34+2.3\ x^{*}$	0.93	$Y= -25.6 +3\ x^{**}$
SRE (Mj/m^2)/day	0.76	$Y=17.95+0.19\ x^{*}$	0.82	$Y= -34.8+2.02\ x^{*}$
AGDD (°C)	0.34	Y=15.60-0.0 x	0.47	Y= 36.4+0.02x
APTU (°C)	0.69	Y=16.08 -0.0 x	0.61	Y= -9.16 + 0.0 x

*, ** = significant at 0.05 and 0.01 probability levels, respectively.

Table 9: Seed yield and its component as affected by sowing date in 2014 and 2015 seasons

	April	May	June	July	August
Character			2014 Season		
1-No of pods/ plant	33.70a	29.50b	28.50c	23.00d	18.60e
2- No of seeds/pod	1.75a	1.71b	1.58c	1.47d	1.39e
3- No of seeds / plant	59.20a	49.20b	45.00c	34.0d	26.0e
4-100 –seed weight(g)	17.54a	17.08b	15.68b	14.98c	11.69d
5- Seed yield/ plant (g)	10.38a	8.29b	6.99b	5.08c	3.10d
6- Stand of harvest/m^2	33.14a	31.38b	29.26c	26.70d	21.20e
7- Seed yield/h (ton)	3.43a	2.60b	2.05c	1.357d	0.675e
			2015 Season		
1-No of pods/ plant	32.90a	28.80b	26.70c	22.70d	18.10e
2- No of seeds/pod	1.73a	1.66b	1.62c	1.46d	1.31e
3- No of seeds / plant	56.90a	47.70b	43.40c	33.10	33.20d
4-100 –seed weight(g)	17.66a	17.43a	15.83b	15.03d	13.65d
5- Seed yield/ plant (g)	9.88a	8.09b	6.74 b	4.74 c	3.06e
6- Stand of harvest/m^2	34.54a	32.44a	30.52c	26.28c	20.40c
7- Seed yield/h (ton)	3.33a	2.65b	2.042c	1.327d	0.640e

Means in the same row followed by the same letter(s) were not significantly different at 0.01 probabilities.

Results in Table 8 indicate that, high value of R^2 for LA and TDW in relation to ASSH and SRE compared to the other climate parameters. This means that, the simple linear relationship between ASSH and each of LA and TDW as well as between SRE and each of both characters, could explain most of the variation in LA and TDW 60-day plant age under the conditions of this experiment.

Yield and Yield Components: Table (9) shows means of seed yield and its components as affected by sowing date in 2014 and 2015 seasons. Results indicated that seed yield/ ha gradually decreased as seeding date was delayed from April to August in both seasons. However, the reduction was more pronounced in August. As an average of the two seasons the reduction rate was estimated by 22.3, 39.46, 60.29 and 80.55 % when sowing delayed from April to May, June, July and August, respectively. Such reduction was associated with reduction in its two major components, i.e., seed yield per plant and number of plants /m^2 at harvest (Table 9). Seed yield per plant decreased by 19.13, 32.22, .51.54 and 69.58 % as sowing date was delayed from April to May, June, July and August, respectively (as an average of the two seasons). This reduction in yield per plant was associated with a reduction in pods per plant, seeds per

Table 10: Coefficient of determination (R^2) and simple linear regression of yield and its components in relation to climate parameters in 2014 season

	R^2	Linear equation	R^2	Linear equation
Parameter	No of pods per plant		No of seeds/pod	
$T_{max.}$(°C)	0.39	Y= -110.52+3.94 x	0.36	Y= -1.85+0.10 x
$T_{min.}$ (°C)	0.00	Y= 28.93-0.069 x	0.00	Y=1.54+0.02 x
$T_{av.}$ (°C)	0.75	Y= - 142.4+5.72 x*	0.77	Y= -2.87+0.15 x*
DTR (°C)	0.79	Y= -59.6+7.75 x*	0.68	Y= 0.5004+0.19 x
ASSH (h)	0.95	Y= -26.29+4.37x**	0.98	Y= 0.18+0.16 x**
SRE(Mj/m^2)/day	0.93	Y = -19.32 + 2.15 x**	0.91	Y= 0.39 + 0.06** x
AGDD (°C)	0.05	Y= 15.91 + 0.0087 x	0.10	Y=1.45+0.00 x
APTU (°C)	0.52	Y = 1.39 + 0.0017 x	0.43	Y= 0.98+0.00 x
	No of seeds / plant		100 –seed weight	
$T_{max.}$(°C)	0.33	Y= -232.35+7.91 x	0.42	Y= -37.7+1.53x
$T_{min.}$ (°C)	0.01	Y=70.17-1.16x	0.02	Y= 7.23 +0.34 x
$T_{av.}$ (°C)	0.70	Y= -317.34 – 1.16 x*	0.75	Y= -49.6+2.20 x*
DTR (°C)	0.81	Y= -149.74 + 17.30 x*	0.50	Y= -10.30 + 2.31 x
ASSH (h)	0.94	Y= -73.7+9.62 x**	0.96	Y= -4.53 + 1.65 x**
SRE(Mj/m^2)/day	0.92	Y= -57.64 + 4.70** x	0.97	Y= -2.32+ 0.83 x**
AGDD (°C)	0.17	Y=28.4 + 0.0116 x	0.13	Y= 8.84+ 0.00x
APTU (°C)	0.44	Y= -8.32 + 0.0034 x	0.67	Y= 4.7+0.00 x
	Seed yield per plant (g)		Seed yield (t/ha)	
$T_{max.}$(°C)	0.30	Y= -50.31 + 1.64 x	0.27	Y= -2592 + 79.79 x
$T_{min.}$ (°C)	0.01	Y= 13.40-0.28x	0.01	Y= 501.45- 12.43 x
$T_{av.}$ (°C)	0.69	Y= -70.51 +2.61 x	0.66	Y= -184.5 +69.07 x
DTR (°C)	0.77	Y= -33.95 +.66 x*	0.80	Y= -471.52 + 87.7 x*
ASSH (h)	0.96	Y= -18.6+ 2.09 x**	0.95	Y= -250.32 +20.31 x**
SRE(Mj/m^2)/day	0.94	Y= -15.18 + 1.030 x**	0.92	Y= -757.7 + 79.05 x**
AGDD (°C)	0.01	Y= 3.90 +.003 x	0.01	Y= -250.32+20.31 x
APTU (°C)	0.43	Y= -4.21 + 0.007 x	0.40	Y= 256.91 -0.00 x

*, ** = significant at 0.05 and 0.01 probability levels, respectively.

Table 11: Coefficient of determination (R^2) and simple linear regression of yield and its components in relation to climate parameters in 2015 season

	R^2	Linear equation	R^2	Linear equation
Parameter	No of Pods per plant		No of Seeds/pod	
$T_{max.}$(°C)	0.77	Y= -125.4+4.32 X*	0.88	Y= -3.29 +0.14 X*
$T_{min.}$ (°C)	0.01	Y= 37.2-0.47 X	0.01	Y=1.115+0.02 X
$T_{av.}$ (°C)	0.32	Y= -88.20+3.84 X	0.48	Y= -2.61 +0.14 X
DTR (°C)	0.88	Y= -23.9 +4.64 X*	0.77	Y= 0.159 +0.13 X*
ASSH (h)	0.95	Y= -25.2+4.21 X**	0.96	Y=0.0214+0.13 X**
SRE(Mj/m^2)/day	0.72	Y= 2.57+ 1049 X*	0.74	Y= 0.0214 +0.12 X*
AGDD (°C)	0.58	Y= 28.8 -0.01X	0.66	Y= 1.56-0.00 X
APTU (°C)	0.56	Y= 29.10 -0.00 X	0.64	Y=1.66-0.00 X
	No of Seeds / plant		100 –Seed weight	
$T_{max.}$(°C)	0.79	Y= -311.03+10.57 X*	0.79	Y= -29.4 +1.29 X*
$T_{min.}$ (°C)	0.00	Y= 62.4 -0.889 X	0.00	Y= 14.51+0.058 X
$T_{av.}$ (°C)	0.34	Y= -227.6 +9.06X	0.39	Y= -21.32 +1.25 X
DTR (°C)	0.88	Y= -73.7 +10.68X*	0.76	Y= 2.18+1.280 X*
ASSH (h)	0.95	Y=-76.5+9.69 X**	0.57	Y=0.47+1.27 X
SRE(Mj/m^2)/day	0.72	Y= -12.7+2.41 X*	0.90	Y=8.26+0.345 X**
AGDD (°C)	0.57	Y= 47.7-0.00 X	0.99	Y=16.8080.00X **
APTU (°C)	0.55	Y= 48.312 -0.00X	0.54	Y=16.87-0.00 X
	Seed yield per plant (g)		Seed yield (t/ha)	
$T_{max.}$(°C)	0.76	Y= -64.8+2.03 X*	0.75	Y= -2592+79.7 X*
$T_{min.}$ (°C)	0.01	Y= 13.36-0.29X	0.01	Y= 501.45-12.4 X
$T_{av.}$ (°C)	0.31	Y= -46.14 +2.2X	0.30	Y= -184.5+69.0X
DTR (°C)	0.90	Y= -17.40+2.00X**	0.90	Y -741 .5+ 87.7X**
ASSH (h)	0.95	Y= -17.72+2.00X**	0.95	Y= -757.7+79.0X**
SRE(Mj/m^2)/day	0.76	Y= -4.82+0.51 X*	0.77	Y= -250.3+20.3X*
AGDD (°C)	0.51	Y= 7.85+0.00 X	0.51	Y= 253.08 -0.01X
APTU (°C)	0.49	Y= 7.94-0.00X	0.49	Y= 256.910.00X

*, ** = significant at 0.05 and 0.01 probability levels, respectively

pod and 100- seed weight in both seasons. The negative effects of delaying sowing date on yield and its components were also reported by Beatty *et al*. [18] and Debruim and Pedersen [19] when seeding delayed from mid-April to mid-July. A similar trend was observed by Yassari *et al*. [21]; Baratiet *et al*, [21] and Sadeghi and Niyaki, [22] when soybean was delayed from May to July in Iran.

Reduction in soybean yield per plant was attributed to a gradual decrease in DTR during flowering to physiological maturity period, which means that the high night temperature may increase the respiration rate during the night. In context, the ASSH and SRE during reproductive growth period (FL-PM) were decreased as sowing date was delayed. Thus, high temperature during flowering, reduction in ASSH and SRE during (FL-PM) period may result in such reduction in seed yield per plant and per ha.

Results in Tables 10 and 11 indicate that R^2 values of seed yield in relation to climate factors show a strong association between seed yield /ha and each of DTR, ASSH and SRE in both seasons. Concerning plant yield components, Tables 10 and 11 showed high values of R^2 for pods per plant and seeds per pod, seeds per plant and 100- seed weight in relation to each of DTR, ASSH and SRE in both seasons. Moreover, ASSH and SRE showed higher values of R^2 in relation to yield and its components compared to the other climate parameters. This means that the R^2 value of either ASSH or SRE could explain more than 90% of variation in yield and its components. For that the ASSH or SRE as independent factors could be used through the linear simple regression equations to expect the yield or any of its components under the condition of this experiment. These results are in general agreement with the results of Dronbos and Mullen [23] who stated that raising temperature from 29/20°C to 34/20°C (day/night) during seed filling period decreased soybean seed yield. Mann and Jaworski [24] stated that temperature over 40°C severely affected pod formation. However, Huxley *et al*. [25] observed that increase in day temperature from 27 to 33°C and night temperature from 19 to 24°C decreased seed number per plant. Also Thomas and Raper [26] reported that temperature over 25/20°C (day/night) decreased number of pods per plant. Moreover, Dornbos and Mullen [27] stated that seeds per m^2 were decreased when temperature above 29/20°C was prevailed during seeds fill, however, number of seeds per pod was less affected .Therefore, Board and Harville [28] concluded that exposing soybean plant to stress conditions that reduce crop growth rate during start of flowering to seed formation stage induced the greatest decrease in seed yield. Seed number per pod and per plant as well as per m^2 were reduced due to high temperature during flowering stage .This may be due to its effect on pollen formation, pollen viability and pollen function as well as ovary and seed abortion [29]. In this context, Kumar *et al*. [15] reported that climate parameters T_{max}., T_{min}. and T_{av}. during the start of branching and start of flowering was positively correlated with seed yield. However, seed yield showed a negative correlation with T_{min}. and T_{av}. during flowering to end-dough stage. With regard to stand at harvest (harvested plants/m^2), the second major yield component of yield per unit area, it reduced by 5.70 11.67, 21.71 and 38.53 % as an average of both seasons, when sowing date delayed from April to May, June, July and August, respectively. This may be due to the increase in all climate parameters at sowing time which reached maximum at August sowing date. The high value of T_{max}, ASSH and SRE during the day at late sowing dates may increase soil temperature which accelerated soil dryness due to increase in evaporation rate. Thus, this may decrease germination percentage and/or increase mortality rate of soybean seedling. Such reduction in stand at harvest in addition to the reduction in yield per plant of late sowing dates (July and August) explains the great reduction in yield per ha. Consequently, the reasons of the reduction in stand at harvest at late sowing dates need more investigation to overcome its negative effect on land productivity.

CONCLUSION

From the results of this study it could be concluded that the prevailed climate factors during the different growth stages of soybean affected the period of growing season. The variation in growing season duration could be explained by the change in ASSH, AGDD and APTU. However, the variation in seed yield and its components was related to the change in DTR, ASSH and SRE more than the other climate parameters. Thus, under the conditions of the expected climate change during this century, it could be suggested that soybean could be grown and produce high seed yield when (sowing date) and where (location) revealed the suitable climate factors (high daily average temperature, long sunshine hours and high solar radiation energy) that could be prevailed during the reproductive growth stage.

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