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Original Research Article

CORRELATION COEFFICIENT ANALYSIS AMONG MORPHOLOGICAL CHARACTERS UNDER NORMAL AND TEMPERATURE STRESS IN SOYBEAN (*Glycine max* L.)

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Abstract: *The world is facing severe climate change today, mainly due to global warming, a continuous rise in earth's temperature. Its most striking effect is being felt on agriculture, especially in the yield and quality of crop that ultimately threatens the ever-growing population's food security. Like many other crops, soybean, a climate-sensitive crop, is greatly affected by rising temperatures. So, it is the dire need of the hour to develop climate-ready genotype of soybean. That is why research was conducted to check the effect of high temperatures on soybean genotypes and to determine the correlation among morphological traits. After the germplasm collection, two experiments were conducted, one in the laboratory and the other in the wirehouse of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, in 2019-2020. Split plot arrangement was made with a Completely Randomized Design and a Randomized Complete Block Design for lab and field experiments, respectively. Three temperature treatments namely To =30ºC (Control), T1 =35ºC and T3 =40ºC were replicated thrice. Data of different morphological traits were recorded and subjected to ANOVA and correlation coefficient analysis. Results of ANOVA for varieties and their interaction with high temperature were significant for most of the traits. The correlation coefficient analysis explained that the No. of leaves/plant, pods/plant, days to 50% flowering and pod setting positively associated with high temperature. On the other hand, seeds/pod and 100-seed weight had a negative correlation with the rise of temperature. The number of leaves and seeds/pod had a positive and significant correlation with 100-seed weight, which means that an increase in these traits would benefit in terms of yield. So, the plant with a higher No. leaves and seeds/pod would be a good criterion for selecting the high-yielding and climate-ready genotype that would benefit in the future against elevated temperature.*

Keywords: Climate change, Correlation, Morphological traits, Soybean (*Glycine max* L.), Temperature

Introduction

The world is facing severe climate change today; however, the earth's climate has been changing throughout history. Earth acts like a greenhouse that traps the sun's heat and helps maintain its warmth. There is a suitable combination of various gases that makes the atmosphere and helps to maintain its warmth. Global warming is the main cause of climate change, which is the continuous increase in earth's temperature. Due to human activities, the concentration of gases in the atmosphere is disturbed and this disturbance causes global warming, which is the major driving factor behind climate change. Carbon dioxide is the most prominent in this scenario among various greenhouse gases. Its concentration had never been above 300 ppm before 1950, and now it has increased to about 410 ppm due to human activities since mid-20th century. In mid-19th century it became clear that CO_2 has heat-trapping nature. So, an increase in greenhouse gases will increase the earth's temperature (NASA, 2019). Greenhouse gases, aerosols and other precursors collectively called anthropogenic emissions will

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cause a 0.5ºC increase in temperature. Human activities will increase the earth's temperature by about 1ºC. It would increase the earth's temperature at 1.5ºC by the end of 2052 (Anonymous, 2019).

The world population is increasing rapidly, and it is estimated to be 9 billion by 2050 (Anonymous, 2019). So, to feed such a large population, we need enough food reserves that are directly connected to crop production. Climate change threatens food security by reducing crop production in many ways. It is associated with plant's growth, development, accumulation of protein and other nutrients in the seed and ultimately, the crop yield that is greatly affected by the rise in temperature (Zewdie, 2014).

Among various crops being used for oil extraction and as a protein source, *Glycine max* L. obtains the primary position. *Glycine max* L. contains 40% good quality protein and 20% oil content (Zong et al., 2017a). Various dried, fermented, and fresh food have been prepared for centuries from the seeds of the soybean. Soy oil could be used as biodiesel; this discovery had opened up another possibility for industries to use it as a renewable energy source. Being a leguminous crop, soybean can utilize the nitrogen in the atmosphere. It is a climate sensitive crop and the photoperiod and temperature are also defining its adaptation. The yield of *Glycine max* L. is influenced by different morphological traits and their interaction directly or indirectly due to change in climatic conditions (Varnica et al., 2018)).

Climate change is extremely influencing soybean grain crop productivity (Battisti and Naylor 2009). The suitable temperature for soybean was reported to be about 25-37°C for the vegetative and 22-26°C for reproductive stages (Hasanuzzaman *et al.*, 2016). Temperature greatly affects all the growth stages except flower initiation. Only 1ºC change in temperature affects the growth of the crop (Varnica et al., 2018). Rise in temperature till 30°C positively affects crop production and is said to be optimum for the soybean crop. While a temperature higher than the optimum temperature would lead to a decline in crop yield. Raising temperatures above 30°C during seed filling decreased soybean seed yield (Dornbos and Mullen, 1991). Reproduction is the most critical stage for the survival and succession of a seed crop. From flowering to seed maturity, crop's duration, quality and quantity of reproductive products are regulated by abiotic factors. As temperature increase negatively correlates with days to germination, flower initiation (Thuzar, 2010), pod set, No. of seed per pod (Allen Jr et al., 2018) (Hoque et al., 2015) ; (Varnica et al., 2018); internodal distance (Zong et al., 2017a) (Hoque et al., 2015), seed per plant (Tacarindua, 2013) ; (Onat et al., 2017), dry matter accumulation, harvest index (Tacarindua, 2013), seed weight (Onat et al., 2017) (Puteh et al., 2013a) (Zheng et al., 2009), growth rate and root growth (F. Alsajri et al., 2019). While vegetative growth, No. of nodes (Allen Jr et al., 2018), delay in reproductive process (Tacarindua, 2013), flower abortion (Onat et al., 2017), percentage of aborted pods (Puteh et al., 2013a) (Zhang & Singh, 2018) are positively correlated with the temperature rise.

So, if the suitable combination of these climatic factors prevails in a region, the crop will be adapted to that region and performs at its full potential as it becomes clear that the yield of *Glycine max* L. is influenced by different morphological traits and their interaction directly or indirectly due to rise in temperature (Varnica et al., 2018)). So, there is a need to select a genotype that would have better adaptability in future climates. One attempt to improve the crop and its adaptability in future climates by genetically improving plants through a plant breeding program. Setting the selection criteria is useful in guiding a plant breeder to select the -performing line and predict the genetic gains. Information on genetic parameters such as correlation is needed to plan a more efficient selection program. Soybean varieties that would better adapt to the changing climate and have high quality and yield are of main concern. It could be achieved through various traditional and modern breeding techniques. An advancement in selection efficiency can be expected through empirical and theoretical research and using powerful genetic technologies. The present study was focused on the effect of high temperature on germination, the correlation between temperature and yield-related traits of soybean and identifying the yield components that could be effective selection criteria for yield involving climatic variables.

Materials and methods

The research consisted of two experiments i.e., laboratory and field experiments. These experiments were conducted in the growth chambers of the Seed Science and Technology department and in the research area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad (UAF), respectively. Soybean germplasm was collected from the Oilseed Department of Ayub Agriculture Research Institute, Faisalabad, Pakistan. It consisted of the three approved varieties of soybean (*Glycine max* L.) which were Faisal soybean (V1), Rawal(V2) and NARC-II (V3). The maximum and minimum temperature during the field experiment is represented in figure 1.

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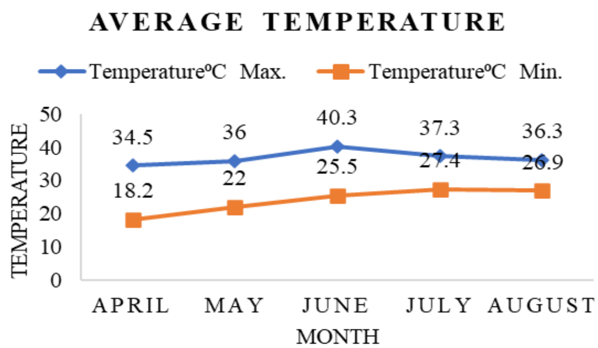

Figure 1. Max. and min. temperature during field experiment

A laboratory experiment was conducted to check the germination under controlled conditions. Total 45 pots (5pots×3genotypes×3replication) per treatment were filled with equal proportions (50% each) of soil and sand and placed in growth chambers. An experiment was conducted using a split-plot arrangement with a Completely Randomized Design. Three different temperature treatments (TTs) were used i.e., T_o=30°C (Control), T_1 =35°C and T_2=40°C. Pots were observed daily to check the germination. After one week of germination, Hoagland solution was given to plants to avoid nutrient deficiency stress. Data on the various traits were recorded after 21 days.

The field experiment was conducted in the wirehouse of the Plant Breeding and Genetics Department. These pots were filled with soil and two handfuls of sand were added above the soil to facilitate soybean germination. A split plot arrangement with a completely randomized block design with three replications was used. Five seeds of each accession per replication were grown in three different sowing with a gap of 15 days to maintain the temperature treatments (T_o=30°C (Control), T_1 =35°C and T_2=40°C) from 15th April to 15th May 2020. The temperature of the wirehouse was recorded with a thermometer daily. All agronomic practices were made. Plants were observed till harvesting, and data on the different morphological traits were observed. Recorded data from both experiments were analyzed using statistical software STATISTIX 10 for ANOVA (Steel *et al.*, 1997) and Tukey HSD as a mean comparison test while R-Software for correlation coefficient analysis (Kwon and Torrie, 1964). The significance of ANOVA results was reported at 0.05 while that of Tukey HSD and correlation at $p<0.05$.

Results and discussion

The analysis of variance for days to germination, first true leaf emergence, number of leaves, fresh and dry seedling weight and other morphological traits, including harvest index and 100 seed weight among soybean genotypes under control (30°C) and the other two treatment 35°C and 40°C were performed. Treatment, genotypes and their interaction showed significant differences except for shoot length, root length and dry seedling weight, which showed non-significant differences among genotypes in a laboratory experiment. Mean values for all the traits observed in lab experiments are presented in figure 2. Thuzar, 2010 also reported significant results between temperature and genotypes for days to germination. Results of ANOVA showed that varieties were similar in the above-mentioned traits but their interaction with temperature showed significant differences, meaning that temperature rise significantly influences the crop. Traits observed in field experiments were also subjected to analysis of variance. Genotypes and their interaction with temperature showed significant differences that were studied for all the traits.

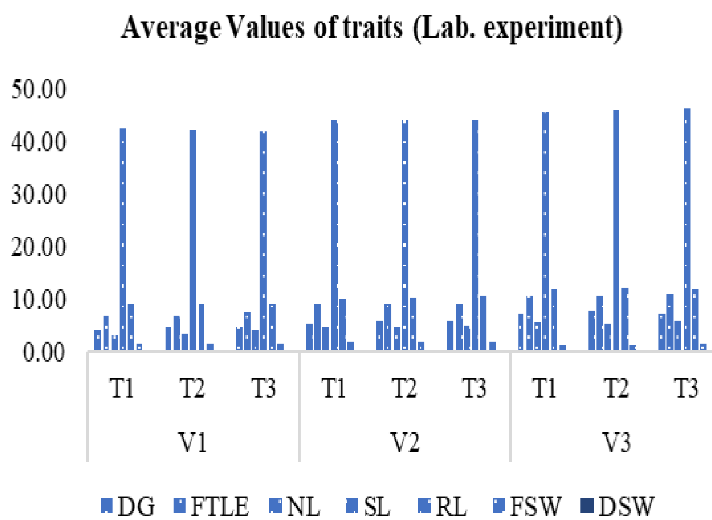

Figure 2. Average values for days to germination (DG), First true lead emergence (FTLE), No. of leaves (NL), Shoot length (SL), Root length (RL), Fresh seedling weight (FSW) and dry seedling weight (DSW) observed in lab experiment

Germination % was the highest (90%) at 30°C in all three genotypes in both experiments. At 40°C, germination % was minimum (73%) in a field experiment. It shows that a temperature rise reduces germination. In both experiments, days to germination and first true leaf emergence were delayed by maximum of upto 3 and 5 days, respectively, at 40° compared with the optimum temperature. Hence, an increase in temperature caused a delay in the reproductive phase. So, the higher the temperature will be the days taken to germination, the first true leaf emergence, flowering and other traits observed, as shown in figure 3. On the other hand, the number of leaves, shoot length, root length, and fresh and dry seedling weight increases, which means the vegetative growth

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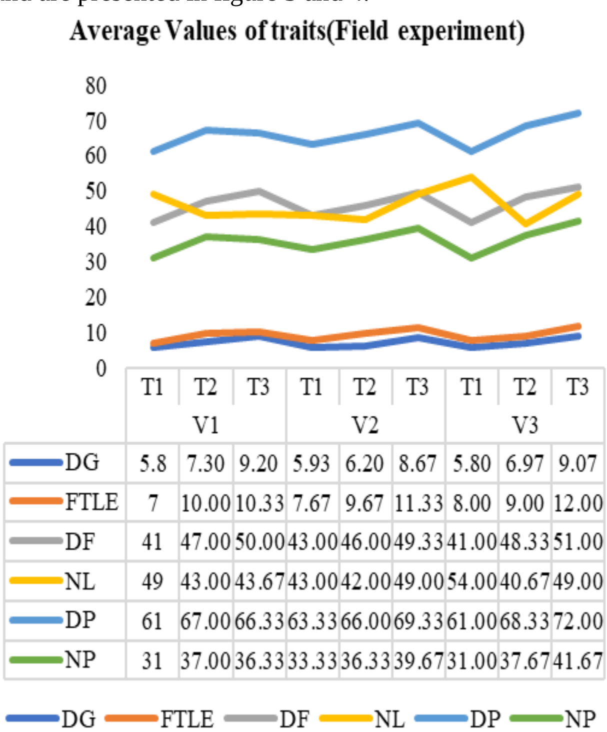
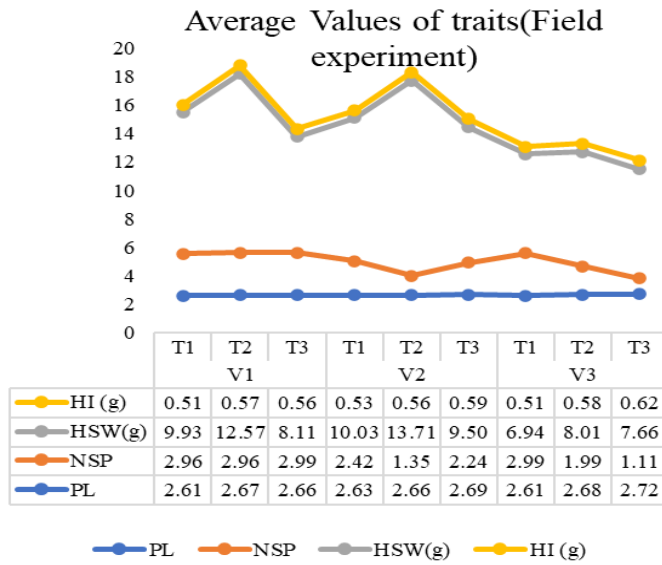
increases with a rise in temperature (Figure 2) (Thuzar, 2010; Zong *et al.*, 2017; Allen *et al.*, 2018; Alsajri *et al.*, 2019). The number of pods, seeds/pod, 100-seed weight, and harvest index were maximum at 30ºC while the minimum at 40ºC (Figure 4), which means that temperature rise reduces the production of the crop. (Egli *et al.*, 2005; Aditya *et al.*, 2011; Khan *et al.*, 2011; Allen *et al.*, 2017; Singh *et al.*, 2018; Alsajri *et al.*, 2019). varieties performed almost similarly under one treatment; however, the number of seeds per plant was the highest in Faisal soybean, about 103 under controlled temperature. Number of pods per plant were higher at 35ºC (Figure 3) compared with the other two treatments however, seed setting was affected by the rise of temperature and a lower number of seeds were found in pods at higher temperatures due to which more seed production at 30ºC (Figure 4). However, seed size was reduced at elevated temperatures, which was obvious in 100-seed weight (Allen *et al.*, 2017). However, seed weight and other observed traits were almost similar in all three varieties. Still, lowest values for most of the traits were observed in Rawal (V2) under all treatments and highest in Faisal soybean (V1) while the average in NARC II (V3) and are presented in figure 3 and 4.



	T1 (V1)	T2 (V1)	T3 (V1)	T1 (V2)	T2 (V2)	T3 (V2)	T1 (V3)	T2 (V3)	T3 (V3)
DG	5.8	7.30	9.20	5.93	6.20	8.67	5.80	6.97	9.07
FTLE	7	10.00	10.33	7.67	9.67	11.33	8.00	9.00	12.00
DF	41	47.00	50.00	43.00	46.00	49.33	41.00	48.33	51.00
NL	49	43.00	43.67	43.00	42.00	49.00	54.00	40.67	49.00
DP	61	67.00	66.33	63.33	66.00	69.33	61.00	68.33	72.00
NP	31	37.00	36.33	33.33	36.33	39.67	31.00	37.67	41.67

Figure 3Average values of Days to germination (DG), First true lead emergence (FTLE), Days to 50% flowering (DF), No. of leaves (NL), Days to 50% pod setting (DP) and No. of pods/plant(NP) for field experiment



	T1 (V1)	T2 (V1)	T3 (V1)	T1 (V2)	T2 (V2)	T3 (V2)	T1 (V3)	T2 (V3)	T3 (V3)
HI (g)	0.51	0.57	0.56	0.53	0.56	0.59	0.51	0.58	0.62
HSW(g)	9.93	12.57	8.11	10.03	13.71	9.50	6.94	8.01	7.66
NSP	2.96	2.96	2.99	2.42	1.35	2.24	2.99	1.99	1.11
PL	2.61	2.67	2.66	2.63	2.66	2.69	2.61	2.68	2.72

Figure 4 Average values of Pod length (PL), No. of seed/pod (NSP) and Harvest index (HI) for field experiment

Correlation coefficient analysis of different morphological traits with dry seedling weight and 100-seed weight in lab and field experiments respectively were measured in soybean genotypes. In the lab experiment, root length showed non-significant, while the Number of leaves, shoot length and fresh seedling weight showed a positive and significant correlation with the rise in temperature (Table 1). Onat *et al.*, (2017) found that -temperature favors vegetative growth; hence, by increasing it, seedling parameters would also increase, resulting in more fresh weight and, ultimately, dry seedling weight. So, these parameters had a positive correlation with high temperature. A positive but non-significant correlation was observed in days to germination and first true leaf emergence. It shows that dry seedling weight is not affected by these two traits. Sing *et al.* (1976); Arshad *et al.* (2005); Malik *et al.* (2007) and Thuzar (2010) reported that days to germination had a non-significant effect with other traits during all growth stages for biomass.

Table 1. Correlation coefficient analysis of all traits with dry seedling weight observed in the lab experiment

TTs	DG	FTLE	NL	SL	RL	FSW
T1	1.02	0.46	0.59	0.92	-0.41	0.51
T2	1.00	0.69	0.72	0.46	-1.04	0.26
T3	1.04	1.35	0.30	1.17	-0.41	1.09

Significance at $p<0.05$, DG= Days to germination, FTLE= First true lead emergence, NL= No. of leaves, SL= Shoot length, RL= Root length, FSW= Fresh seedling weight

High temperature negatively affects seed germination, and it delayed as temperature increased from 30ºC to 40ºC (Farias, 1994). The rise in temperature had a

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negative correlation with seed germination observed by Khalil et al. (2010b) while studying the effect of high temperature on soybean germination and osmotic stress. He found 25ºC as the optimum temperature for the emergence of *G. max* under osmotic stress. Reduction in standard germination was observed at 38ºC, and this temperature also affected the seed vigor that Egli et al. (2005) reported. A strong linear correlation was found between temperature and node initiation and appearance, and node appearance was taken as first true leaf emergence. The photoperiod primarily influences initiation of flowering, but significant interaction is often found between temperature and blooming (Summerfield and Wein, 1980). High temperature (38/28ºC) had a negative correlation with flowering stage (Djanaguiraman et al. (2011). An increased temperature above optimum delayed the days taken to anthesis from 8 to 14 days and rise above 30ºC delayed the pod setting and reproductive growth (Singh *et al.,* 2018). Puteh et al. (2013a) exposed the two reproductive stages R1-R2 of soybean for 5 days to high temperatures. Longer exposure to high temperatures of more than 30ºC had a negative and significant effect on both reproductive stages. The temperature of 38ºC caused a reduction in standard germination (SG) and seed vigor, while 33ºC only affected the seed vigor. In the field experiment, days to germination, 50% flowering, 50% pod setting, and first true leaf emergence had a negative and significant correlation with 100-seed weight, as presented in table 2. It was observed in the experiment that by increasing the temperature, days taken to above-mentioned traits were also increased, which shows that temperature rise would delay the reproductive phase. The high temperature was harmful to the soybean crop growth. It was estimated that there would be 5% to 10% yield loss under the slowest warming and an 8% to 22% loss under rapid warming in soybean (Chen *et al.,* 2013). The number of leaves and seeds/pod had a positive and significant correlation with 100-seed weight (Table 2), which means that an increase in these traits would benefit in terms of yield. Jagtap and Choudary, (1993) and Malik *et al.,* (2007) also reported similar results. Pod length showed no relationship with yield. So, the plant with the maximum no. of leaves and seed/pod would be a good criterion for selecting the high-yielding crop.

Table 2. Correlation coefficient analysis of all traits with 100-seed weight observed in field experiment

TTs	T1	T2	T3
DG	-0.95	-0.85	-0.96
FTLE	-0.99	-1.04	-0.92
DF	-1.007	-1.013	-0.99
NL	0.95	0.72	0.503
DP	-0.98	-0.13	-0.47
NP	0.83	0.97	0.77
PL	-0.98	-1.00	-1.00
NSP	0.96	0.28	0.14
HI (g)	-0.98	-1.01	-1.00

Significance at $p<0.05$, DG= Days to germination, FTLE= First true lead emergence, DF= Days to 50% flowering, NL= No. of leaves, DP= Days to 50% pod setting, NP= No. of pods/plant, PL= Pod length, NSP= No. of seed/pod, HI= Harvest index

Conclusion

It was concluded from the above discussion that a soybean crop would face severe extremes of temperature and other climatic conditions in the future. So, to minimize the effects of climate change on the quality and yield of the crop, it is dire need of the hour to focus on developing climate-ready genotypes. Mutual efforts of plant breeders, biotechnologists, and experts in other related fields could achieve it.

Conflict of interest: None

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