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Exploring the impact of heat stress on inheritance patterns of key agronomic traits in upland cotton (*Gossypium Hirsutum* L.) through generation mean analysis

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Abstract

The goal of this study is to study the influence of heat stress on the hereditary patterns of different agronomic traits in upland cotton (*Gossypium hirsutum* L.) by utilizing generation mean analysis. A total of six parental varieties were cultivated in a controlled greenhouse environment, consisting of three heat-tolerant cultivars (CIM-600, Cyto-178, and FH-142) and three heat-susceptible cultivars (Aleppo-1, Marvi and AMSI-38). Following the development of six primary generations resulting from three crosses (CIM-600 × Aleppo-1, Cyto-178 × AMSI-38 and FH-142 × Marvi), the seeds were subsequently planted at the farm of the Central Cotton Research Institute, Multan. The dominant component significantly influenced plant height more than the additive component in all crosses under normal conditions. The inheritance of traits in both situations was influenced by epistatic components (i, j, and l), except cross 1 under heat stress. It is worth noting that negative values for component [i] suggest the absence of any fixable additive genetic effect in some crosses. The presence of negative component values [j] in some crosses has led to the proposal of a digenic interaction. Diverse prior investigations have documented both similarities and differences in their respective conclusions.

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Introduction

The cotton production in Pakistan is adversely affected by insect pest complex, weeds and diseases (Razzaq et al., 2023; Mubeen et al., 2022; Tariq et al., 2020; 2018; 2017; Ayman et al., 2020). In addition to these biotic stresses, heat and drought are other contributors of low cotton productivity (Zafar et al., 2023; Rahman et al., 2020; Tariq et al., 2022). The cotton belt in Pakistan is situated in an area characterized by high temperatures and arid conditions, with summer temperatures reaching up to 50 degrees Celsius (Khan et al., 2008). Additional challenges associated with elevated temperatures include drought and increased light intensity. These factors intensify the impact of heat, resulting in a drop in the number of plants per unit area. Consequently, this reduction in plant density leads to decreased crop yields and compromised quality (Rahman, 2006). According to Boyer's (1982) study, it was observed that elevated temperatures led to a decrease in crop output by around 25 percent. Heat stress can do a lot of damage to cotton plants, which affects many important agronomic traits, including yield, fibre quality, growth, tolerance to drought, and resistance to pests and diseases. Based on Boyer's research in 1982, it has been seen that high temperatures can lower cotton yield because they hurt important parts of the plant's reproductive cycle, like flowering, boll development, and maturity. Heat stress can have a considerable impact on the microstructure, length, and strength of fibers. Furthermore, it is worth noting that this can potentially have a negative effect on the quality of the fiber. The growth of cotton plants might be impeded, leading to a decrease in their overall size. Moreover, the occurrence of heat stress exacerbates drought stress, hence diminishing the plant's capacity to cope with water scarcity. In order to mitigate the adverse effects of heat stress, it is imperative to implement cultural approaches such as proper irrigation and crop management. The adjustment in sowing times is most widely used strategy to compensate the negative impacts of heat stress (Afzal et al., 2020; Tariq et al., 2021). Managing the use of nitrogen and potassium fertilizer is another approach to improve yield in various stress conditions (Afzal et al., 2019; Tariq et al., 2018). Furthermore, it is imperative to employ heat-tolerant cotton varieties that have been developed through selective breeding initiatives. Reddy et al. (1991) have indicated that the optimal temperature range for the optimal growth and development of a cotton plant falls within the interval of 20 to 30 degrees Celsius. In the regions of India and Pakistan, cotton is commercially cultivated under conditions of elevated temperatures, reaching up to 40 degrees Celsius. The best temperature settings for cotton crops remain a subject of ongoing debate and lack a definitive consensus. This is primarily attributed to the significant variability in plant response, which is contingent upon the developmental phase of the plant and the specific plant organ under consideration (Burke and Wanjura, 2009). Extensive research has been conducted and documented on the impact of elevated heat stress on several aspects of plant growth and development, including germination percentage of seed, seedling growth, vegetative component growth, and crop development (Hodges et al., 1993; Reddy et al., 1996). These studies have contributed to a substantial body of knowledge that is easily accessible to interested readers. According to Oosterhuis (2002), it has been observed that high or low temperatures can impact several stages of development. Hussain et al. (2022) observed the reduction in excise leaf water loss under stress condition in cotton. However, it is noteworthy that the reproductive development of the crop is particularly vulnerable to temperature extremes. The implications of this

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susceptibility are of considerable importance. The present trial was planned to study the inheritance pattern of heat tolerant traits to select the appropriate breeding method for the development of future heat tolerant varieties.

Material and Methods

A total of six parental varieties were cultivated in a controlled greenhouse environment, consisting of three heat-tolerant cultivars (CIM-600, Cyto-178, and FH-142) and three heat-susceptible cultivars (Aleppo-1, Marvi and AMSI-38). The CIM-600, Cyto-178, and FH-142 are transgenic cultivars containing Cry1AC gene and susceptible group belongs to non-transgenic. The objective of this cultivation was to facilitate the process of hybridization. A concerted effort was made to maximize the number of crossings conducted in order to obtain a greater quantity of F₁ cotton seeds. In the next season, three hybrid combinations (CIM-600 × Aleppo-1, Cyto-178 × AMSI-38, and FH-142 × Marvi) were cultivated in the field alongside their respective parental varieties at the Central Cotton Research Institute, Multan. In order to generate BC₁ and BC₂ generations, crossings were conducted during the pre-flowering stage, while a portion of the F₁ seeds from each of the three hybrids were set aside for future sowing. Similarly, a limited number of F₁ plants were subjected to self-fertilization in order to generate F₂ progeny for all three crosses. The seeds were effectively collected at reaching maturity.

Following the development of six primary generations resulting from three crosses (CIM-600 × Aleppo-1, Cyto-178 × AMSI-38 and FH-142 × Marvi), the seeds were subsequently planted at the farm of the Central Cotton Research Institute, Multan. The objective was to assess the inherent basis of generations in relation to numerous quantitative characteristics. The initial experiment was conducted in the middle of March, while the subsequent trial took place in the middle of May. The aforementioned seeding approach involved subjecting successive generations to varying amounts of heat in order to assess the genetic responses of several physiological markers. The experiment was conducted using the RCB Design with three replications. In the process of replication, two rows were allocated for each of the parental plants and the F₁ generation. Backcrosses and F_{2s} were sown in three and four rows, respectively. The length of rows was consistently set at ten feet for parents, F₁ and back crosses, while it was extended to 40 feet for F₂. The plants were spaced 30 cm apart from each other, while the rows were spaced 75 cm apart. To gather data, random samples consisting of 30 plants were collected from each parent, F₁, and backcross population. Additionally, 150 plants were sampled from each F₂ population. The data, as given by Steel and Torrie (1980), underwent an analysis of variance. The potency ratio was determined through calculations using the methodology proposed by Griffing (1950). The quantification of inbreeding depression involved assessing the percentage decrease observed in the F₂ generation when compared to the F₁ generation. The calculation of the environmental, additive, and dominance genetic variances, using the three parameter model, was performed following the directions provided by Simmonds in 1979. To determine the presence of non-allelic gene interaction, scaling tests were conducted using the protocols outlined by Mather and Jinks (1989) and Hayman and Mather (1955). The utilization of Hayman's (1958) six parameters model was employed to estimate different genetic components. This study was conducted based on the premise that there was no

genetic linkage, a high number of alleles, lethal genes, and that both gametes and zygotes exhibited complete viability.

Results

Plant height: The range of plant height observed in all 18 generations (including P₁, P₂, F₁, F₂, BC₁, and BC₂) of each cross, under both normal and heat stress conditions, is presented in Table 1. The recorded values varied between 97.33 and 121.036 cm. The examination of generation mean data revealed that the expression of plant height was governed by many genes, as indicated in Table 1. In the normal condition, the control factors for cross-1, cross-2, and cross-3 were [mdhi], [mdhij], and [mdhj], respectively. However, under heat stress circumstances, the control factors for cross-1, cross-2, and cross-3 were [md], [mdj], and [mdhij], respectively, as indicated in Table 2. A notable degree of hybrid vigour was detected in three crosses for plant height under both conditions, with the exception of cross 2 under heat stress. This finding suggests that heterozygosity has an impact on this particular feature. The range of heterosis observed in this study varied from 3.30 to 12.12, as presented in Table 3. Table 3 demonstrates the presence of positive heterobeltosis throughout the range of 0.64 to 4.18 in cross-1 and cross-3, as observed in both situations. Abro et al. (2009) and Panni et al. (2012) reported comparable findings, while Baloch et al. (2015a) provided conflicting data.

Bolls plant⁻¹ The bolls per plant exhibited a range of 20.57 to 40.70 (Table 1) across all three crosses in both experimental sets. This observation was made over the course of 12 generations, with six generations from each cross (namely P₁, P₂, F₁, F₂, BC₁, and BC₂). The phenomenon of polygenic control over the trait of boll count per plant was investigated using generation mean analysis. The data presented in Table 2 indicates that in the progenies of cross-1, cross-2, and cross-3, the control under normal conditions was exerted by [mdhij], [mdhij], and [mdj], respectively (Table 2). Under conditions of stress, the control of [mdhi], [mdhil], and [mdhil] was observed in populations derived from cross-1, cross-2 and cross-3 under conditions of heat stress. In the second cross, a negative dominant component was observed, indicating the prevalence of genes that contribute to the reduction of this feature over genes that promote its enhancement. The results obtained from cross-2 and cross-3 conducted under stress conditions demonstrated duplicate epistasis, which was observed as a result of the presence of opposite signs on the variables [h] and [l].

The narrow sense and wide sense heritability exhibited moderate values throughout all the crossings, ranging from 0.206 to 0.741 for narrow sense heritability and 0.121 to 0.502 for broad sense heredity. The findings presented in Table 3 provide further support for the influence of both environmental factors and the interplay between genotype and environment on the reduction of heritability in the presence of heat stress. Other researchers, such as Ahmed et al. (2006) and Desalegn et al. (2009), have also reported findings on bolls per plant.

Positive heterosis was observed in all crosses under both situations, with the exception of cross 1 under stress settings. This finding suggests that heterozygosity could potentially be advantageous for enhancing the trait. The positive heterosis was found to be between 3.58 and 50.74, while heterobeltosis ranged from 0.49 to 30.16 for all three crossings under normal conditions. It is worth noting that negative heterosis was seen in these crosses, as

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indicated in Table 3. The findings reported by Abro et al. (2009), Panni et al. (2012), El-Refaey and El-Razek (2013), and Abro et al. (2014) support the conclusions of the present study. The impact of heterosis on the number of bolls per plant was shown to be significant across different generations of upland cotton.

Table 1. Means values of different generations for plant height, bolls per plant, boll weight, Fruit shedding per plant and ginning out turn in upland cotton under normal (N) and heat stress (H) conditions.

Trait	Stress Condition	Generation Means						Pop Effect
		P ₁	P ₂	F ₁	F ₂	BC ₁	BC ₂	
Plant height (cm)	N1	116.2	99.7	121.0	112.0	109.7	104.7	**
	N2	117.3	107.1	115.9	118.4	116.5	117.5	**
	N3	115.8	110.6	117.1	109.2	97.3	115.7	**
	H1	108.6	100.0	109.3	104.8	101.7	102.2	**
	H2	111.0	101.1	104.6	104.0	99.8	102.8	**
	H3	102.7	101.5	106.9	111.7	97.6	115.7	**
Bolls per plant (%)	N1	32.4	27.4	33.7	27.8	32.8	26.2	**
	N2	31.3	22.7	40.7	35.4	29.9	30.9	**
	N3	34.6	28.6	34.8	24.6	37.3	25.7	**
	H1	35.1	27.5	29.9	22.4	31.4	27.1	**
	H2	34.6	20.6	33.9	30.3	28.0	23.8	**
	H3	28.0	24.3	27.1	22.3	28.4	24.7	**
Boll weight (g)	N1	3.3	2.8	3.3	3.1	3.1	3.2	*
	N2	3.1	2.6	3.2	3.0	3.1	3.0	**
	N3	3.2	3.0	3.2	3.1	3.2	3.4	**
	H1	3.1	2.6	3.4	3.0	3.1	3.2	**
	H2	3.4	2.6	3.4	2.8	2.9	3.2	**
	H3	2.9	2.5	3.2	2.6	3.0	3.2	**
Fruit shedding per plant	N1	27.2	45.0	24.8	28.8	23.6	33.7	**
	N2	38.6	49.3	28.6	34.1	29.8	33.8	**
	N3	32.2	49.1	26.0	28.2	28.8	32.0	**
	H1	33.8	48.5	31.7	37.7	36.6	35.7	**
	H2	36.6	43.5	31.7	40.4	33.1	29.6	**
	H3	38.1	50.2	35.9	42.4	40.9	38.7	**
Ginning Out Turn (%)	N1	39.8	37.5	38.7	38.9	39.5	37.6	**
	N2	38.6	36.9	38.3	37.1	39.0	37.7	**
	N3	40.0	38.6	39.4	38.4	39.9	39.5	**
	H1	39.7	37.7	37.7	37.9	38.7	37.0	**
	H2	38.6	36.6	39.1	36.6	37.7	37.3	**
	H3	39.0	37.6	38.1	38.2	38.5	37.9	**

Boll weight: The F₁ generations resulting from the cross 1 and cross 2 exhibited the highest boll weight, ranging from 3.22 to 3.43 g. This weight surpassed that of the F₂, BC1, and BC2 populations in both experimental settings. Thus, it can be inferred that heterozygosity may have a significant role in influencing this particular characteristic, as seen in Table 1. In the current investigation, the boll weight exhibited a range of 2.51 to 3.44 g across all three crossings, both in normal and heat stress circumstances. The examination of generation means revealed that the inheritance of boll weight is influenced by many genes. Under typical circumstances, the control of [mdhj], [mdh], and [mhijl] was carried out through cross-1, cross-2, and cross-3, respectively. However, when subjected to heat stress conditions, the five parameter models [mdhij] exhibited the best fit for boll weight, as indicated by the non-significant χ^2 approximation (Table 2). The epistatic component [i] had a positive value. In all crosses, the dominant component exhibited a bigger magnitude than the additive component, both under normal settings and when subjected to stress. The only exception to this pattern was observed in cross 2 under normal temperature, where the contribution of the dominant component was not detected.

The narrow sense and broad sense heritability exhibited moderate values in both crosses, ranging from 0.214 to 0.783 for narrow sense heritability and 0.227 to 0.755 for broad sense heredity of boll weight (Table 3). The observed rise in heritability in the presence of heat stress provides further support for the diminished significance of environmental factors and the interactions between genotype and environment. Ahmed et al. (2006) and El-Refaey and El-Razek (2013) reported similar findings; however, Murtaza (2006), Desalegn et al. (2009), and Batool et al. (2010) did not agree with the results.

The calculation of positive heterosis was performed for boll weight in all crosses, considering both conditions. The results indicated that heterozygosity could be a valuable tool for enhancing the trait of boll weight. The observed range of positive heterosis extended from 1.61 to 18.96, while the range of positive heterobeltosis varied from 2.46 to 10.53. Negative heterosis was observed in cross -2 and -3 when subjected to normal and stress conditions, respectively, as indicated in Table 3. Abd-El-Haleem et al. (2010), Panni et al. (2012), and El-Refaey and El-Razek (2013) have also reported findings that support the conclusions of the present study.

Fruit Shedding Plant¹: The fruit shedding per plant exhibited a range of 23.6 to 50.17 across all crossings, as observed in both normal and heat stress conditions (refer to Table 1). The analysis of Table 2 in the study on generation mean indicated that the shedding of bolls per plant was influenced by polygenic factors. Under typical circumstances, the control of [mdhj], [mdhij], and [mdhij] was observed through cross-1, cross-2, and cross-3, respectively. Among the various models tested, the five-parameter models [mdhij] demonstrated the best fit for fruit shedding per plant in both cross-1 and cross-2, with non-significant χ^2 approximations. Conversely, in all instances of cross 3 under stress conditions, control was exerted by [mdh]. In the context of heat stress, the dominance component exhibited a higher magnitude compared to the additive component, as indicated in Table 2. The findings of this investigation demonstrate the involvement of the epistatic component [i] in regulating the percentage of fruit shedding, as indicated in Table 2. However, it is important to note that no evidence of epistasis was observed in cross 3 when subjected to heat stress conditions.

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The narrow sense heritability values ranged from 0.027 to 0.742, whereas the wide sense heritability values ranged from 0.122 to 0.544 across all crosses (Table 3). The present investigation has indicated the absence of positive heterosis for this particular trait under both experimental settings. Conversely, negative heterosis was observed, with values ranging from -18.66 to -35.97. In both experimental settings, Table 3 demonstrates the presence of negative heterobeltosis in the fruit shedding % across all crosses.

Ginning Out Turn: In the current study, the ginning out turn of six populations from three crosses was seen to range from 36.55% to 40.01% under both normal and heat stress circumstances. The examination of generation means indicated that the ginning out turn was under the control of many genes. The models that demonstrated the best fit for cross 1, cross 2, and cross 3 were denoted as [mdj], [mdhil], and [mdhil], respectively. In the presence of stress, the control was maintained by [mdh], [mdhi], and [md] for cross 1, cross 2, and cross 3, respectively, specifically under heat stress circumstances.

Table 2. Estimates of the best fit model for generation means parameters (\pm , standard error) by weighted least squares analysis in upland cotton under normal (N) and heat stress (H) conditions.

Traits	Treatment	Genetic Effects						X ² (DF)
		M \pm S.E.	[d] \pm S.E.	[h] \pm S.E.	[i] \pm S.E.	[j] \pm S.E.	[l] \pm S.E.	
Plant Height	N1	127.39 \pm 7.05	7.53 \pm 1.17	-55.39 \pm 18.49	-	-	49.04 \pm 12.16	1.23 (1)
	N2	122.02 \pm 1.56	5.12 \pm 0.43	-5.91 \pm 2.00	-9.71 \pm 1.67	-12.40 \pm 1.92	-	1.32 (1)
	N3	113.21 \pm 1.20	2.58 \pm 1.20	-24.93 \pm 5.32	-	-43.89 \pm 5.59	28.79 \pm 5.33	2.25 (1)
	H1	104.27 \pm 0.78	3.45 \pm 1.34	-	-	-	-	7.19 (4)
	H2	103.92 \pm 0.65	5.00 \pm 1.38	-	-	-17.08 \pm 6.22	-	5.98 (3)
	H3	114.45 \pm 2.15	0.60 \pm 0.93	-8.90 \pm 2.85	-13.64 \pm 2.40	-35.96 \pm 3.73	-	1.98 (1)
Boll Weight	N1	2.98 \pm 0.03	0.25 \pm 0.04	0.31 \pm 0.06	-	-0.81 \pm 0.22	-	1.43 (2)
	N2	2.85 \pm 0.17	0.21 \pm 0.04	0.34 \pm 0.06	-	-	-	3.70 (3)
	N3	2.13 \pm 0.20	-	2.66 \pm 0.55	0.98 \pm 0.20	-0.58 \pm 0.15	1.64 \pm 0.36	2.06 (1)
	H1	2.62 \pm 0.07	0.24 \pm 0.03	0.80 \pm 0.09	0.26 \pm 0.077	-0.65 \pm 0.17	-	2.00 (1)
	H2	2.11 \pm 0.10	0.42 \pm 0.03	1.33 \pm 0.14	0.91 \pm 0.11	-1.29 \pm 0.15	-	0.70 (1)
	H3	2.32 \pm 0.11	0.18 \pm 0.07	0.64 \pm 0.19	0.39 \pm 0.12	0.50 \pm 0.22	-	2.62 (1)
Fruit shedding Plant⁻¹	N1	35.23 \pm 0.79	8.91 \pm 0.92	-11.50 \pm 1.37	-	-38.85 \pm 4.47	-	3.41 (2)
	N2	43.09 \pm 1.11	5.35 \pm 1.11	-25.69 \pm 4.22	-21.44 \pm 5.72	10.40 \pm 3.80	-	2.18 (1)

	N3	30.32 ± 1.14	8.39 ± 0.84	-4.33 ± 1.53	10.24 ± 1.43	-22.83 ± 3.48	-	0.21 (1)
	H1	41.34 ± 1.07	7.37 ± 1.21	-9.26 ± 1.98	-	-12.33 ± 4.91	-	1.13 (2)
	H2	76.12 ± 5.55	3.45 ± 0.96	-98.66 ± 14.11	-36.06 ± 5.4	54.24 ± 9.13	-	0.01 (1)
	H3	44.38 ± 1.12	4.93 ± 1.12	-7.86 ± 1.95	-	-	-	6.18 (3)
Bolls plant⁻¹	N1	21.82 ± 1.78	2.50 ± 0.70	11.77 ± 2.72	8.07 ± 1.909	8.42 ± 3.49	-	0.09 (1)
	N2	10.07 ± 1.89	4.28 ± 0.79	30.96 ± 3.02	17.04 ± 2.042	-10.50 ± 3.95	-	0.50 (1)
	N3	30.66 ± 0.61	2.80 ± 0.84	-	-	17.61 ± 4.08	3.47 ± 1.48	3.31 (2)
	H1	15.10 ± 2.30	3.82 ± 1.19	15.70 ± 3.47	16.93 ± 2.678	-	-	4.18 (2)
	H2	44.77 ± 5.06	6.00 ± 0.93	-47.03 ± 12.57	-17.83 ± 4.91	-	36.13 ± 7.99	2.14 (1)
	H3	9.24 ± 2.99	2.56 ± 0.60	34.36 ± 7.64	16.82 ± 2.89	-	-16.53 ± 5.04	2.12 (1)
Ginning out turn	N1	38.67 ± 0.07	1.12 ± 0.12	-	-	1.65 ± 0.59	-	2.48 (3)
	N2	32.94 ± 0.75	0.90 ± 0.10	11.36 ± 1.86	4.80 ± 0.74	-	-6.05 ± 1.17	2.47 (1)
	N3	33.96 ± 0.90	0.64 ± 0.15	12.27 ± 2.37	5.31 ± 0.89	-	-6.83 ± 1.54	0.74 (1)
	H1	38.50 ± 0.18	1.23 ± 0.18	-1.10 ± 0.33	-	-	-	5.71 (3)
	H2	34.04 ± 0.40	0.82 ± 0.18	5.05 ± 0.55	3.62 ± 0.46	-	-	1.92 (2)
	H3	38.21 ± 0.10	0.67 ± 0.19	-	-	-	-	0.26 (4)

The observed decrease in heredity, both in the broad sense and narrow sense, under conditions of heat stress in all crossings provides evidence for the influence of environmental factors and the interplay between genotype and environment on the manifestation of the trait (Table 3). The process of selecting individuals based on their traits is facilitated in cases when a higher heritability of a trait is seen, as opposed to instances where a trait has low heritability due to the influence of environmental factors that obscure the underlying genotypic effects. The narrow sense heredity and broad sense heritability exhibited moderate values in all the crosses, with a range of 0.269 to 0.735 for narrow sense heritability and for broad sense heritability, the values were in the range of 0.008 to 0.747, for ginning out turn. The study conducted by Farooq and al. (2014) yielded similar results, however Naveed et al. (2004) reported lower heritability values for ginning out turn.

Negative heterosis was calculated regarding lint percentage under heat stress condition in cross-1 and cross-3. The positive heterosis values are ranged from 0.25 to 3.99 in three different crosses, as measured under both experimental conditions. Negative heterobeltosis was computed for all crosses in both conditions, with the exception of cross 2 under the stress condition (see Table 3). Potdukhe (2001) and Baloch et al. (2015b) reported similar results, however, the findings of Soomro et al. (2000), Abd-El-Haleem et

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al. (2010), El-Refaey and El-Razek (2013), and Baloch et al. (2015a) are not aligned with current results.

Table 3. Narrow sense heritability (h^2_{ns}), broad sense heritability (h^2_{bs}), Heterosis (Ht) and better parent heterosis (Hbt) in upland cotton under different levels of heat stress.

Traits	Cross	Condition	h^2_{ns}	h^2_{bs}	Ht	Hbt
Plant Height	1	Normal	0.52	0.48	12.12	4.18
		Heat Stress	0.35	0.25	4.78	0.64
	2	Normal	0.91	0.90	3.30	-1.19
		Heat Stress	0.16	0.14	-1.38	-5.77
	3	Normal	0.56	0.64	3.41	1.10
		Heat Stress	0.72	0.71	4.70	4.09
Boll Weight	1	Normal	0.21	0.38	11.00	2.46
		Heat Stress	0.57	0.75	18.96	9.62
	2	Normal	0.45	0.57	12.39	3.87
		Heat Stress	0.78	0.74	13.58	-0.29
	3	Normal	0.31	0.31	1.61	-0.32
		Heat Stress	0.45	0.23	17.54	10.53
Bolls plant⁻¹	1	Normal	0.38	0.47	12.60	3.916
		Heat Stress	0.30	0.12	-4.38	-14.80
	2	Normal	0.21	0.28	50.74	30.16
		Heat Stress	0.74	0.50	22.72	-2.19
	3	Normal	0.36	0.48	10.02	0.49
		Heat Stress	0.67	0.26	3.58	-3.32
Fruit shedding Plant⁻¹	1	Normal	0.11	0.41	-31.27	-44.85
		Heat Stress	0.61	0.53	-22.98	-34.66
	2	Normal	0.74	0.12	-34.81	-41.89
		Heat Stress	0.66	0.52	-20.85	-27.08
	3	Normal	0.03	0.17	-35.97	-46.95
		Heat Stress	0.68	0.54	-18.66	-28.44
Ginning out turn	1	Normal	0.64	0.71	0.01	-2.81
		Heat Stress	0.27	-0.01	-2.65	-5.16
	2	Normal	0.73	0.75	1.31	-0.83
		Heat Stress	0.66	0.46	3.99	1.30
	3	Normal	0.50	0.51	0.25	-1.52
		Heat Stress	0.56	0.48	-0.42	-2.18

Discussion

In normal conditions, the dominant component exhibited a greater magnitude than the additive component for the plant height trait in very cross. Epistatic components [i], [j], and [l] were observed to contribute under both conditions excluding cross1 during heat stress condition. A negative sign for [i] in cross one and cross two under normal conditions and cross three under heat stress situations, indicates the absence of a fixable additive genetic impact (Table 1). The presence of a negative sign for [j] in both crossword two and cross three at both temperature conditions indicates the occurrence of digenic interaction. Murtaza et al. (2006), Ahmad et al. (2009) and Batool et al. (2013) also

reported similar findings, but Nadeem and Azhar (2004), Khan and Qasim (2012) and Iqbal et al. (2013) provided contradictory data.

The negative sign of [j] indicated the absence of fixable additive components in the early segregating generations, which affected the boll weight. The results indicated that the epistatic component also had a significant influence on the inheritance of boll weight, both under normal conditions and during heat thermal stress (Table 2). Ahmad et al. (2009), Batool et al. (2013), and Iqbal et al. (2013) showed similar findings regarding gene activity. Conversely, Nadeem and Azhar (2004) and Mohamed et al. (2009) reported contrasting results.

Given the specified parameters for the number of bolls, selection may be necessary to attain homozygosity and accumulation of genes associated with a greater bolls per plant (Table 2). The combined influence of additive, dominance gene effects, and additive \times additive interaction epistasis effect on the inheritance of the bolls per plant aligns closely with the research findings of Wang and Pan (1991), Deshpande and Baig (2003), Mert et al. (2003a), McCarty et al. (2004), Meredith (2005), and Mei-Zhen et al. (2005). Esmail (2007), Ahmad et al. (2009), Hussain et al. (2009) and Batool et al. (2013) also reported similar findings, but Nadeem and Azhar (2004), Khan and Qasim (2012), Iqbal et al. (2013) presented contradictory results.

The negative sign of [h] (dominance impact) indicates a dominance towards fruit shedding. This means that the selection of plants with high boll retention may need to be delayed until future generations.

The data on ginning out turn indicated that the dominance component was greater than the additive component for cross-2 and 3 under normal condition. However, the additive component was more prominent under heat stress conditions (Table 2). The study of cross-2 and cross-3 revealed the presence of duplicate epistasis, as evidenced by the negative values of [l] and [h] under normal conditions (Table 2). Ahmad et al. (2009), Batool et al. (2013), and Iqbal et al. (2013) reported similar findings; however, Nadeem and Azhar (2004), Mohamed et al. (2009), and Abd-El-Haleem et al. (2010) reported contrasting results. It is concluded that material with reduced fruit shedding may be used for development of heat tolerant varieties.

References

- Abd-El-Haleem, S.H.M., Metwali, E.M.R. & Al-Felaly, A.M.M. (2010). Genetic analysis of yield and its components of some Egyptian cotton (*Gossypium barbadense* L.) varieties. *World Journal of Agricultural Sciences*, 6, 615–621.
- Abro, S., Kandhro, M.M., Laghari, S., Arain, M.A. & Deho, Z.A. (2009). Combining ability and heterosis for yield contributing traits in upland cotton (*Gossypium hirsutum* L.). *Pakistan Journal of Botany*, 41, 1769–1774.
- Abro, S., laghari, S., Deho, Z. & Manjh, M.A. (2014). To estimates heterosis and heterobeltosis of yield and quality traits in upland cotton. *Journal of Biology, Agriculture and Healthcare*, 4, 19–22.
- Afzal M.N., Tariq, M., Ahmed, M., Abbas, G. & Mehmood, Z. (2020). Managing planting time for cotton production. In: Ahmad S., Hasanuzzaman M. (eds) Cotton Production and Uses. Springer, Singapore. https://doi.org/10.1007/978-981-15-1472-2_3

Genetic analysis of agronomic traits under Impact of heat stress

- Afzal, M.N., Tariq, M., Ahmad, M., Mubeen, K., Khan, M.A., Afzal, M.U., & Ahmad, S. (2019). Dry matter, lint mass and fiber properties of cotton in response to nitrogen application and planting densities. *Pakistan Journal of Agricultural Research*, 30, 32(2), 229–240.
- Ahmad, R.T., Malik, T.A., Khan, I.A. & Jaskani, M.J. (2009). Genetic analysis of some morpho-physiological traits related to drought stress in cotton (*Gossypium hirsutum* L.). *International Journal of Agriculture and Biology*, 11, 235–240.
- Ahmed, H.M., Kandhro, M.M., Laghari, S. & Abro, S.. (2006). Heritability and Genetic Advance as Selection Indicators for Improvement in Cotton (*Gossypium hirsutum* L.). *Journal of Biological Sciences*, 1, 96–99.
- Ayman, E.S., Hossain, A., Islam, M.S., Barutcular, C., Ratnasekera, D., Gormus, O., Amanet, K., Mubeen, M., Nasim, W., Fahad, S., Tariq, M., Llanes, A., Meena, R.S., Ueda, A., Saneoka, H., Erman, M. & Hasanuzzaman, M. (2020). Drought and heat stress in cotton (*Gossypium hirsutum* L.): Consequences and their possible mitigation strategies. In: Hasanuzzaman M. (eds) *Agronomic Crops*. Springer, Singapore. https://doi.org/10.1007/978-981-15-0025-1_30.
- Baloch, A.W., Solangi, A.M., Baloch, M., Baloch, G.M. and Abro, S. (2015a). Estimation of heterosis and heterobeltiosis for yield and fiber traits in F₁ hybrids of upland cotton (*Gossypium hirsutum* L.) genotypes. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, 31, 221–228.
- Baloch, M.J., Sial, P., Qurat-ul-Ain, B.T. & Arain, M.A. (2015b). Assessment of heterotic effects in F₁ hybrids of cotton (*Gossypium hirsutum* L.). *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*. 31, 193–202.
- Batool, S., Khan, N.U., Gul, S., Baloch, M.J., Turi, N.A., Taran, S.A. & Saeed, M. (2013). Genetic analysis for yield and yield contributing variables in upland cotton. *Journal of Food, Agriculture & Environment*, 11, 624–630.
- Batool, S., Khan, N.U., Makhdoom, K., Bibi, Hassan, Z., G., Marwat, K.B., Farhatullah, Raziuddin, M.F., and Khan, I.A. (2010). Heritability and genetic potential of upland cotton genotypes for morphoyield traits. *Pakistan Journal of Botany*, 42, 1057–1064.
- Boyer, J.S. (1982). Plant productivity and environment. *Science*, 218, 443–448.
- Burke, J. J., & Wanjura, D. F. (2010). Plant responses to temperature extremes. *Physiology of cotton* (pp. 123-128). Dordrecht: Springer Netherlands.
- Desalegn, Z., Ratanadilok, N. & Kaveeta, R.. (2009). Correlation and heritability for yield and fiber quality parameters of Ethiopian cotton (*Gossypium hirsutum* L.) estimated from 15 (diallel) crosses. *Kasetsart Journal of Natural Science*, 43, 1–11.
- El-Refae, R.A. & El-Razek, U.A.A. (2013). Generation mean analysis for yield, its components and quality characteristics in four crosses of Egyptian cotton (*Gossypium barbadense* L.). *Asian Journal of Crop Science*, 5, 153–166.
- Esmail, R.M. (2007). Genetic analysis of yield and its contributing traits in two intra-specific cotton crosses. *Journal of Applied Sciences Research*, 3, 2075–2080.

- Farooq, J., Anwar, M., Riaz, M., Farooq, A., Mahmood, A., Shahid, M.T.H., Rafiq, S.M. & Ilahi, F. (2014). Correlation and path coefficient analysis of earliness, fiber quality and yield contributing traits in cotton (*Gossypium hirsutum* L.). *Journal of Animal and Plant Sciences*, 24, 781–790.
- Griffing, B. (1950). Analysis of quantitative gene action by constant parent regression and related techniques. *Genetics*, 35(3), 303.
- Hayman, B. I. (1958). The theory and analysis of diallel crosses. II. *Genetics*, 43(1), 63.
- Hayman, B. I., & Mather, K. (1955). The description of genic interactions in continuous variation. *Biometrics*, 11(1), 69–82.
- Hayman, B.I. (1958). The separation of epistatic from additive and dominance variation in generation mean. *Heredity*, 12, 371–390.
- Hodges, H.F., Reddy, K.R., McKinnon, J.M., & Reddy, V.R. (1993). Temperature effects on cotton. Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, Starkeville, Mississippi.
- Hussain, M., Azhar, F.M. & Khan, A.A. (2009). Genetics of inheritance and correlations of some morphological and yield contributing traits in upland cotton. *Pakistan Journal of Botany*, 41, 2975–2986.
- Iqbal, M., Naeem, M., Rizwan, M., Nazeer, W., Shahid, M.Q., Aziz, U., Aslam, T. & Ijaz, M. (2013). Studies of genetic variation for yield related traits in upland cotton. *Eurasian Journal of Agricultural & Environmental Sciences*, 13, 611–618.
- Hussain, K., Akbar, M., Ashraf, F., Khan, M. I., Sarwar, M. I., Hussain, F., Iqbal, J., Imran, H. M., Gill, M. I., & Ramzan, H. N. (2022). Genotypic Characterization of Cotton (*Gossypium hirsutum* L.) for Physiological Attributes Associated with Water Stress Tolerance. *Pakistan Journal of Biochemistry and Biotechnology*, 3(2), 83–88. <https://doi.org/10.52700/pjbb.v3i2.185>
- Khan, A.I., Khan, I.A. & Sadaqat, H.A. (2008). Heat tolerance is variable in Cotton (*Gossypium hirsutum* L.) and can be exploited for breeding of better yielding cultivars under high temperature regimes. *Pakistan Journal of Botany*, 40, 2053–2058.
- Khan, N.U., Hassan, G., Kumbhar, M.B., Parveen, A., Ahmad, W., Shah, S.A. & Ahmad, S. (2007). Gene action of seed traits and oil content in upland cotton (*Gossypium hirsutum* L.). *SABRAO Journal of Breeding and Genetics*, 39, 17–29.
- Khan, T. M. & Qasim, M. U. (2012). Genetic studies of yield traits in cotton (*Gossypium hirsutum* L.). *Journal of Agricultural Research*, 50(1), 21–28.
- Mather, K., Jinks, J. L., Mather, K., & Jinks, J. L. (1982). Diallels. *Biometrical Genetics: The study of continuous variation*, 255–291.
- Mei-zhen, S., Y. Shu-xun, F. Shu-li, R. Ri-hong & H. Zhen-mao. (2005). Genetic analysis of main agronomic traits in short season upland cotton. (*Gossypium hirsutum* L.). *Cotton Sciences*, 17, 94–98.
- Meredith, W.R.J. (2005). Minimum number of genes controlling cotton fiber strength in a Backcross Population. *Crop Sciences*, 45, 1114–1119.
- Mohamed, G.I.A., Abd-El-Halem, S.H.M. & Ibrahim, E.M.A. (2009). A genetic analysis of yield and its components of Egyptian cotton (*Gossypium barbadense*, L.)

Genetic analysis of agronomic traits under Impact of heat stress

- under divergent environments. *American-Eurasian Journal of Agricultural & Environmental Sciences*, 5, 05–13.
- Mubeen, K., Afzal, M.N., Tariq, M., Ahmad, M., Muhammad, D., Shehzad, M., Aziz M., & M.W. Yonas. (2022). Sowing Date influences cotton leaf curl disease (CLCuD) incidence and productivity of non-Bt cotton cultivars. *Pure and Applied Biology*, 11(1), 26–34.
- Murtaza, N. (2006). Study of gene effects for boll number, boll weight, and seed index in cotton. *Journal of Central European Agriculture*, 6, 255–262.
- Murtaza, N., Qayyum, A., Malik, W. & E. Noor. (2006). Genetic study of yield of seed cotton and plant height in cotton genotypes. *International Journal of Agriculture and Biology*, 8, 630–635.
- Nadeem, K. & Azhar, F.M. (2004). Genetic analysis of seed cotton yield and its components in *Gossypium hirsutum* L. *International Journal of Agricultural Biology*, 6, 865–868.
- Nadeem, K. & Azhar, F.M. (2004). Genetic analysis of seed cotton yield and its components in *Gossypium hirsutum* L. *International Journal of Agriculture and Biology*, 6, 865–868.
- Naveed, M., Azhar, F.M. & Ali, A. (2004). Estimates of heritabilities and correlations among seed cotton yield and its components in *Gossypium hirsutum* L. *International Journal of Agriculture and Biology*, 6, 712–714.
- Oosterhuis, D.M. (2002). Day or night high temperatures: A major cause of yield variability. *Cotton Grower*, 46, 8–9.
- Panni, M.K., Khan, N.U., Fitmawati, S.B. & Bibi, M. (2012). Heterotic studies and inbreeding depression in F₂ populations of upland cotton. *Pakistan Journal of Botany*, 44, 1013–1020.
- Potdukhe, N. R. (2001). Heterosis and identification of superior crosses in upland cotton. *Crop Improvement-India*, 28(2), 187–190.
- Rahman, H. U. (2006). Number and weight of cotton lint fibres: variation due to high temperatures in the field. *Australian journal of agricultural research*, 57(5), 583–590.
- Rahman, M.H.U, Ahmad, I., Ghaffar, A., Haider, G., Ahmad, A., Ahmad, B., Tariq, M., Nasim, W., Rasul, G., Fahad, S., Ahmad, S. & Hoogenboom, G. (2020). Climate resilient cotton production system: A case study in Pakistan. In: Ahmad S., Hasanuzzaman M. (eds), *Cotton Production and Uses*. Springer, Singapore. https://doi.org/10.1007/978-981-15-1472-2_22.
- Razzaq, A., Muhammad M., Zafar, A.A., Pengtao L, Fariha, Q., Laviza, T.Z., Fiza, S., Abdul H.L., Youlu, Y., & Wankui, G. (2023). Biotechnology and solutions: Insect-Pest-Resistance management for improvement and development of Bt cotton (*Gossypium hirsutum* L.). *Plants*, 12(23), 4071.
- Reddy, V.R., Baker, D.N. & Hodges H.F. (1991a). Temperature effects on cotton canopy growth, photosynthesis, and respiration. *Agronomy Journal*, 83, 699-704.
- Reddy, V.R., Hodges, H.F., McCarty, W.H. & McKinnon, J.M. (1996). *Weather and cotton growth: Present and Future*. Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, Starkeville, Mississippi
- Simmonds, N. W. (1979). *Principles of crop improvement*.

- Soomro, Z.A. (2000). Genetic architecture of quantitative and qualitative traits *G. hirsutum*. M. Phil. Thesis, Sindh Agriculture University, Tandojam, Pakistan.
- Steel, R.G.D., Torrie, J.H. (1980). Principles and procedures of statistics. A biometrical approach. 2nd edition. McGraw-Hill, New York.
- Tariq M., Abdullah, K., Ahmad, S., Abbas, G., Rahman, M.H.U. & Khan, M.A. (2020). Weed management in cotton. In: Ahmad S., Hasanuzzaman M. (eds) Cotton Production and Uses. Springer, Singapore. https://doi.org/10.1007/978-981-15-1472-2_9
- Tariq, M., Afzal, M.N., Ahmad, M., Qayyum, A. & Khan, M.A. (2018). Performance of pre and post-emergence herbicides for weed control in cotton (*Gossypium hirsutum* L.). *Pakistan Journal of Weed Science Research*, 24(2), 147–154.
- Tariq, M., Afzal, M.N., Muhammad, D., Ahmad, S., Shahzad, A.N., Kiran, A. & Wakeel, A. (2018). Relationship of tissue potassium content with yield and fiber quality components of Bt cotton as influenced by potassium application methods. *Field Crops Research*, 229, 37–43.
- Tariq, M., Fatima, Z., Iqbal, P., Nahar, K., Ahmad, S. & Hasanuzzaman, M. (2021). Sowing dates and cultivars mediated changes in phenology and yield traits of cotton-sunflower cropping system in the arid environment. *International Journal of Plant Production*, 1–12.
- Tariq, M., Khan, M.A., Muhammad, W. & Ahmad, S. (2022). Fiber Crops in Changing Climate. In: Ahmed, M. (eds) Global Agricultural Production: Resilience to Climate Change. Springer, Cham. https://doi.org/10.1007/978-3-031-14973-3_9
- Tariq, M., Yasmeen, A., Ahmad, S., Hussain, N., Afzal, M.N. & Hasanuzzaman, M. (2017). Shedding of fruiting structures in cotton: factors, compensation and prevention. *Tropical and Subtropical Agroecosystem*, 20, 251–262.
- Zafar, S., Afzal, H., Ijaz, A., Mahmood, A., Ayub, A., Airish, N., Hussain, S., Ul-Hassan, M., Sabir, M.A., Zulfiqar, U., Zulfiqar, F. & Moosa, A. (2023). Cotton and drought stress: An updated overview for improving stress tolerance. *South African Journal of Botany* 161, 258–268.

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- Iqbal, J., Hussain, K. Ijaz, H.M., Sarwar, M.A., Ashfaq, M., Tariq, M., Zafar, M. (2023). Exploring the impact of heat stress on inheritance patterns of key agronomic traits in upland cotton (*Gossypium Hirsutum* L.) through generation mean analysis *Journal of Agriculture and Food* 4(2): 80 – 93.