J. Agric. Sci. Mansoura Univ., 34 (4): 2577 - 2591, 2009

GENETIC VARIATION IN STEM DIAMETER IN RELATION TO DROUGHT AND HEAT TOLERANCE IN WHEAT (*Triticum aestivum* L.)

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ABSTRACT

Variation in stem diameter and other stem attributes of wheat in relation to yield components were analyzed in a 7- parent F_1 diallel cross in favorable, drought and combined drought heat environments. In addition 12 F_2 populations were also tested under heat stress. Polygenes with mainly additive effects were involved in the control of stem diameter which segregated in normal distributions in the F_2. The narrow-sense heritability was of comparable magnitude under favorable (0.73); drought (0.62) and drought + heat stress (0.76). Whereas, heritability of stem dry weight was reduced under stress. Non-allelic duplicate interaction was operating for stem density under drought stress. Stem diameter was positively correlated under both drought and drought + heat stresses with stem weight and stem density. Stem diameter was significantly associated with 1000 kernel weight and grain yield per spike in the three environments. On he other hand stem density was only associated with single grain mass under favorable condition and with grain yield per spike under drought stress only. Such strong associations of stem diameter with single grain mass and grain yield per spike under stress indicated the importance of this character which plays a role in sustaining grain filling through providing greater capacity of storing assimilates in the stem before mobilizing it to grains.

Keywords: Drought and hear tolerance, stem diameter in wheat

INTRODUCTION

Despite the wide adaptation of wheat (*Triticum aestivum L.)* which can be grown in many different environments ranging from temperate-irrigated to dry and high-rain-fall areas and from warm-humid to dry-cold conditions (Acevedo *et al.,* 2002 and Lillemo *et al.*, 2005). However, drought and heat stresses are of common occurrence during grain filling in wheat growing areas with a mediterranean climate (Wardlaw, 2002). Drought stress causes 11-61% reduction in kernel mass (Cseuz *et al.,* 2002) while heat stress causes 10-15% yield loss which is mainly due to reduced single kernel weight (Wardlaw and Wrigley ,1994) . Drought and heat stresses during anthesis and grain filling cause reduction in kernel number and size ,grain yield and harvest index (Blumenthal, 1995 and Veisz *et al.*, 2005); grain growth duration (Ishag and Mohamed ,1996 and stone and Nicholas, 1995 a,b) as well as kernel weight per spike (Denecic *et al.*, 2000) . Grain growth and development in wheat depend on Carbohydrates from three sources: (i) carbohydrates produced after anthesis and translocated directly to the grains, (ii) carbohydrates produced after anthesis but stored temporarily in the stem before being remobilized to the grains, and (iii) carbohydrates produced before anthesis stored mainly in the stem and remobilized to grains during grain filling (Gallager *et al*, 1975; Daniels *et al*, 1982; Kobata *et al*, 1992 ;

Ehdaie *et al.,* 2006 a). Under drought and heat stresses, photosynthesis rapidly declines after anthesis which limits the contribution of current assimilates to the grain leading to reduction in kernel dry weight (Wardlaw and Willenbrink , 2000) .

The wheat canopy rapidly respires during grain filling (Gent and Kiyomoto ,1985 and McCullough and Hunt , 1989). Flag leaf photosynthesis alone cannot support both respiration and grain growth under terminal stress (Rawson *et al.,* 1983). A substantial amount of the carbohydrates used during grain filling in wheat must come from reserves assimilated before anthesis (Gent, 1994). Stem characteristics such as internode length, internode weight, internode specific weight of the wheat plant were found to be affecting accumulation and mobilization of stem reserves with maximum specific weight appeared to be correlated with stem mobilized dry matter (Ehdaie *et al* , 2006 b) . Stem diameter and stem density may play an important role in stabilizing grain yield in stressful environments and could be used as selection criteria for enhancing drought and heat tolerance.

The objectives of the present study were:

(1) to analyze the genetic system controlling stem diameter and stem density in wheat under favorable , drought and heat stress conditions.
(2) to determine the relationships between stem characters and grain filling capacity under heat and drought stresses .
(3) to analyze the segregating patterns of stem diameter in a number of wheat crosses

MATERIALS AND METHODS

Seven local genotypes of bread wheat (*Triticum aestivum L.)* which are quite variable in stem diameter and other stem attributes (Fig 1) were used in this study as seen in Fig. 1.

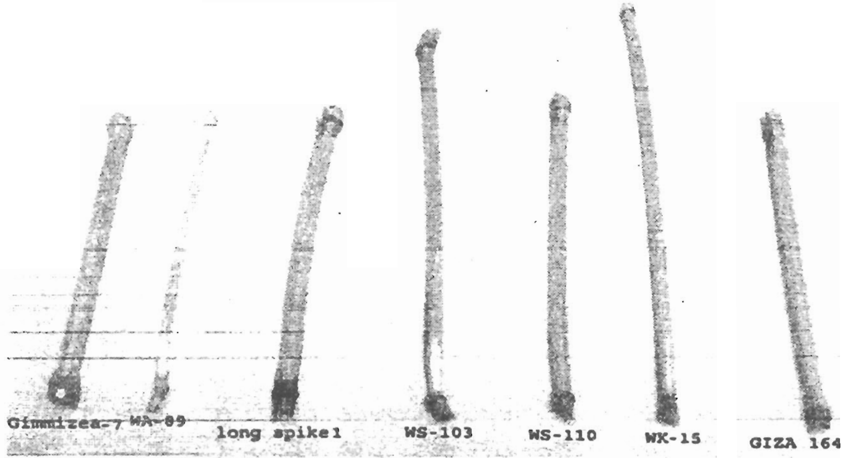
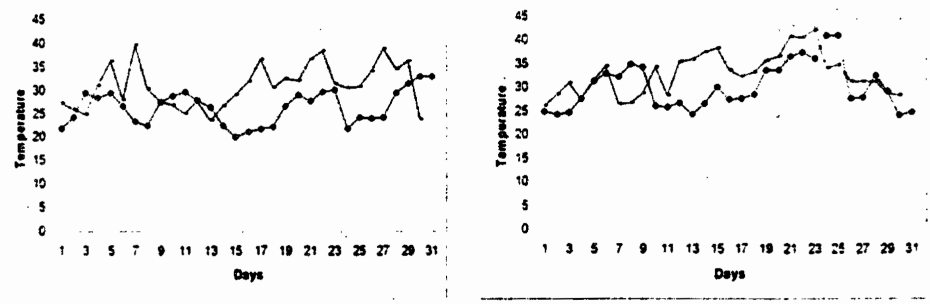


Fig.1: A photograph of the second internode for the seven parents under heat stress conditions

The seven genotypes comprised: three with large stem diameter, namely Gimmeiza-7(P_1), Long spike 1(P_3) and Giza-164 (P_7) , one with medium stem diameter (WA-89, P_2) and three with small stem diameter (WS-103 (P_4) ,WS-110 (P_5) and WK-15 (P_6)). The seven parental genotypes were crossed in a diallel fashion in 2005-2006 winter season .In the following 2006-2007 season, seeds of the seven parents and the 21 F_1 crosses were grown in favorable, drought stress and combined drought and heat stresses environments. The favorable environments was that at the fertile clay-loam soil of the Experimental Farm of Assuit Uinversity where the 28 entries of the diallel cross (reciprocal were pooled) sown in optimal date (25th November) and irrigation was applied each 14 days. For drought stress environment, seeds were sown in the same optimal date in the infertile sandy-calcareous soil at El-ghoraieb Experimental Station which is located 25 Km south of Assuit where soil contains 80% sand and 19% calcium carbonates. Irrigation was applied each 12 days with a total of five irrigations throughout season (excluding the establishment irrigation). For the combined drought and heat stresses environment, seeds were sown in the sandy-calcareous soil at El-ghoraieb Exp. St. one month later (25th December) . So as to allow the drought-stressed plants to be exposed to the heat stress that results from the rise in temperature in late March and in April while plants are at grain filling. The recorded maximum daily temperature at the experimental sites during March and April of the two growing seasons (2007 and 2008) indicated that temperature fluctuated between 25° and 30°C in March 2007 and from 25° and to 35°C in March 2008 and it was risen above 40° C by the end of the month .As for April 2007 and 2008 (Fig 2 a and b) ,temperature fluctuated around 35°C with waves that lasted for several days in which it was risen above 35°C.



(a) (b)

Fig. 2: Maximum daily temperatures ~~during~~ March, April 2007(a) and March, April 2008 (b) at the experimental site. (March, April)

For each of the three environments, the experimental layout was a randomized complete block design with three replications for the favorable environment and two for each of the two stressful environments. Each of the 28 entries of the diallel crosses were represented in each block by a family of five plants with single-seed plant randomization within blocks. Rows were set 30 cm apart while plants within rows were spaced 15 cm from each other .Each row consisted of 10 plants. In 2007-2008 winter season, 12 F_2 population forming a 3 (fathers) x 4 (mothers) North Carolina Design Π were chosen from the 21 crosses to be sown under the heat stress of a late sowing date (30th December) in the favorable environment at the University Farm in order to analyze the segregation patterns of stem characters and their association with yield attributes. The 12 F_2 populations was represented in each block by 5 rows of 1.5 m long with rows spaced 20cm apart and plants spaced 15 cm from each other within rows . The following characters were recorded for each plant of each entry:

1- Stem diameter (mm) recorded on the middle of the second internode of the main stem at anthesis using a venire caliper.

2 – Stem length (cm) at anthesis : taken as the main stem length (cm) from the soil level to the lowest spikelets of the ear of main stem.

3 – Stem dry weight (g): the weight of the main stem at anthesis that was oven dried at 70° C.

4 – Stem density (gm/cm) was obtained by dividing the dry weight of main stem on the length of main stem (cm) at anthesis, using the formula

$$Stem \quad density = \frac{the \quad weight \quad of \quad main \quad stem}{the \quad lenght \quad of \quad main \quad stem} x1000$$

5 – Grain yield per spike (g): grain yield per plant divided by number of spikes per plant.

6 –1000- kernel weights (g).

The diallel analysis and the estimation of the genetic components were carried out using the methods developed by Hayman(1954 a&b).

RESULTS

1- Main stem diameter:

Under the favorable environment, the range of means of stem diameter of the seven parents which appears in Table 1 extended from 4.41 to 6.26 mm with an average of 5.09 mm whereas those the of F_1s ranged from 4.41 to 6.02 mm with an average of 5.24 mm, marking a slight increase of F_1 over their parents. Under drought stress (optimal sowing date in sandy soil) , the range of parents extended from 3.41 to 4.94 mm with an average of 3.84 mm while those of the F_1 crosses ranged from 3.26 to 4.85 mm with an average of 3.92 mm. The average reduction in main stem diameter over parents and F_1 s due to drought stress amounted to 25%. Under combined effects of drought and heat stresses (late sowing date in the sandy soil), greater reduction in stem diameter occurred with the parental means ranging from 3.08 to 4.43 mm with an average of 3.53 mm. while the F_1 range extended from 2.83 to 4.08 mm with an average of 3.62 mm .The average reduction in main stem diameter over parents and F_1's due to the combined drought and heat stresses amounted to 31 % , marking a 6 % reduction due to heat stress alone. Apparently, the reduction in stem diameter due to drought stress was greater (25%) than that due to heat stress (6%).

The diallel analysis of variance of stem diameter revealed the presence of highly significant additive and non-additive variances as indicated by their corresponding mean squares in the three environments.

Significant array differences in the (Wr + Vr) values were found indicating non-additive variation between arrays whereas the array differences in the (Wr – Vr) values were non-significant indicating absence of non-allelic gene interaction. The slope of the covariance/variance (Wr/Vr) regression line was significantly deviating from zero but not from unity for the three environment giving: b = 0.65 ± 0.245, b = 0.827 ± 0.178 and b = 0.815 ± 0.238 for favorable, drought stress and combined drought and heat stresses environments, respectively. The Wr/Vr regression lines cut the Wr axis in a positive position near the origin in the three different environments, indicating partial dominance as seen in Fig. 3.

Table 1: The means of stem diameter (mm) of the 7-parents and their F_1 hybrids in favorable environment, F (upper values) and drought stress environment ,D (middle values) and) and drought + heat stresses environments ,D&H (lower values).

Parents		P_1	P_2	P_3	P_4	P_5	P_6	P_7	Array mean
P_1	F.	**6.26**	5.74	6.02	5.45	5.52	4.91	5.1	**5.69**
	D	**4.94**	4.14	4.17	4.1	4.85	4.06	4.76	**4.47**
	D&H	**4.43**	4.06	3.88	3.85	4.00	3.7	4.03	**3.99**
P_2	F.		**4.84**	5.33	4.95	4.94	4.41	5.22	**4.99**
	D		**3.45**	4.85	3.82	3.90	3.25	3.90	**3.98**
	D&H		**3.19**	4.08	3.09	3.05	3.10	3.23	**3.30**
P_3	F.			**5.87**	5.53	5.02	4.97	5.69	**5.41**
	D			**4.81**	4.13	3.97	4.35	4.43	**4.34**
	D&H			**4.00**	3.61	3.13	3.33	3.88	**3.59**
P_4	F.				**4.49**	5.05	5.02	5.19	**4.94**
	D				**3.40**	3.50	3.88	3.78	**3.64**
	D&H				**3.08**	2.96	3.20	3.39	**3.16**
P_5	F.					**4.64**	4.90	5.12	**4.88**
	D					**3.41**	3.56	3.97	**3.65**
	D&H					**3.15**	2.83	3.19	**3.06**
P_6	F.						**4.41**	4.81	**4.60**
	D						**3.88**	3.93	**3.91**
	D&H						**3.77**	3.42	**3.60**
P_7	F.							**5.17**	**5.16**
	D							**3.57**	**3.57**
	D&H							**3.097**	**3.09**

Table 2: Components of genetic variation for stem diameter in favorable environment (F) ,drought stress environment (D) and drought + heat stresses environment (D&H).

Component	Environments		
	(F)	(D)	(D&H)
D	0.52 ± 0.023	0.27 ± 0.023	0.30 ± 0.017
H_1	0.21 ± 0.056	0.18 ± 0.057	0.14 ± 0.043
H_2	0.16 ± 0.049	0.16 ± 0.05	0.063 ± 0.037
$\sqrt{H_1/D}$	0.63	0.82	0.68
N.heritability	0.73	0.62	0.76

The additive (D) genetic variance was greater than the dominance (H_1) in the three different environments with the degree of dominance $(H_1/D)^{1/2}$ being less than unity confirming that dominance was partial as seen in Table 2 . The narrow sense heritability of stem diameter was almost comparable under favorable (0.73), drought stress (0.62) and combined drought and heat stresses (0.76).

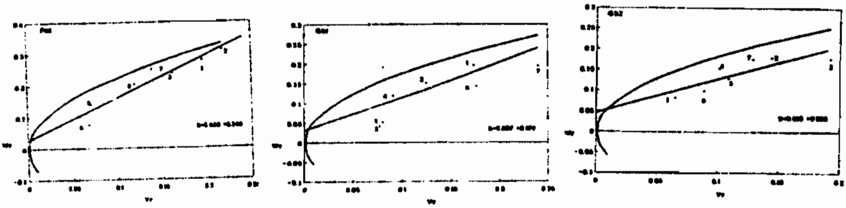

(a) (b) (c)

Fig. (3): The Wr/Vr graphs of main stem diameter in favorable environment (a) ,drought stress environment (b) and the combined drought and heat stresses environment (c).

2- Stem density:

The range of variation in stem density among the seven parents was quite wide in the favorable environment extending from 17.08 to 35 mg/cm with a parental average of 24.28 mg/cm. Meanwhile, the means of stem density of the F_1's ranged from 19.4 to 32.6 mg/cm with an average of 24.58 mg/cm as presented in Table 3 Under drought stress, stem density as averaged over parents and F_1's was reduced by 18.6% which is less than that observed in stem diameter. The average reduction in main stem density under combined drought and heat stresses amounted to 29.3% indicating a 10.7% reduction due to heat stress alone. Here again, the impact of drought stress on stem density was much stronger than that of heat stress. The diallel analysis of variance for stem density revealed highly significant additive and non-additive mean squares in the three environments with ambidirectional dominance. The slope of the Wr/Vr regression line did not significantly deviated from unity for the favorable and combined drought and heat stress environments as seen in Fig. 4. For drought stress environment, a downward curvature of the Wr/Vr relationship indicated a duplicated type of non-allelic gene interaction. The partitioning of genetic variation presented in Table 4, revealed that the additive component (D) was greater than the dominance component (H_1) in the favorable and combined drought and heat stresses environments with the narrow sense heritability being comparably of moderate magnitude in the two environments showing 0.70 and 0.66, respectively).

3- 1000 Kernel weight (in gms.):

The average of 1000 kernel weight of the 28 genotypes of the 7-parent diallel cross was reduced from 44.96 g in the favorable environments to 41.09 g under drought stress indicating 8.7% reduction due to drought whereas the reduction under combined drought and heat stresses amounted to 17.5% marking a 8.8 % reduction due to heat stress alone as seen in Table 5.

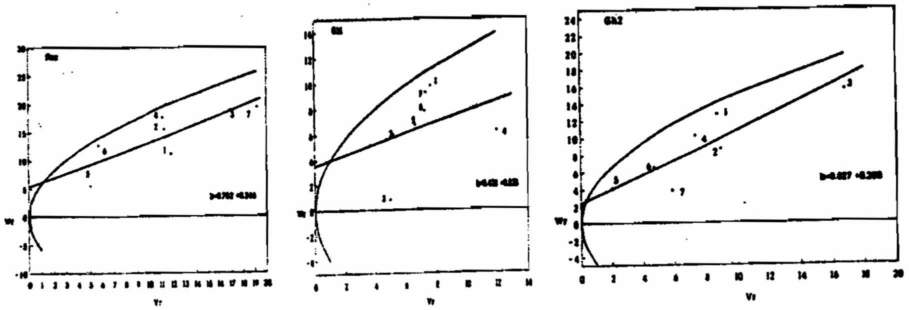
Table 3:The means of stem density of the 7-parents and their F_1 hybrids in favorable environment, F (upper values) and drought stress environment, D (middle values) and drought + heat stresses environments, D&H (lower values).

Parents		P_1	P_2	P_3	P_4	P_5	P_6	P_7	Array mean
P_1	F.	29.02	26.73	28.09	26.76	26.16	20.82	32.54	27.16
	D	25.74	20.67	23.42	20.37	18.86	18.08	22.04	21.31
	D&H	23.42	20.03	21.70	19.92	16.60	14.92	20.83	19.63
P_2	F.		21.19	28.23	25.78	20.94	19.54	22.09	22.96
	D		16.82	23.14	21.05	18.65	14.71	20.59	19.16
	D&H		15.21	20.08	19.34	15.38	13.34	19.14	17.08
P_3	F.			35.00	29.91	22.36	24.41	30.14	28.36
	D			25.98	26.25	20.01	22.31	23.70	23.65
	D&H			25.55	20.75	15.29	15.79	18.57	19.19
P_4	F.				20.60	23.42	20.72	24.89	22.41
	D				17.29	18.46	17.31	19.13	18.04
	D&H				13.94	14.33	15.60	18.11	15.49
P_5	F.					21.33	19.38	20.52	20.41
	D					18.23	14.67	17.63	16.85
	D&H					14.96	12.21	13.63	13.59
P_6	F.						17.08	22.78	19.93
	D						15.49	16.6	16.05
	D&H						14.60	14.03	14.32
P_7	F.							25.71	25.71
	D							21.45	21.45
	D&H							19.15	19.15

Table 4: Components of genetic variation for stem density in favorable environment (F) and drought stresses (D&H) environments.

Component	Environments	
	(F)	(D&H)
D	33.73 ± 2.26	19.79 ± 1.66
H_1	14.58 ± 5.44	10.49 ± 4
H_2	11.30 ± 4.79	5.93 ± 3.53
$\sqrt{H1/D}$	0.66	0.72
N.heritability	0.70	0.66

The diallel analysis revealed highly significant additive and non-additive mean squares with dominance being directional towards greater 1000 kernel weight in the three different environments. The slope of the Wr/Vr regression line was significantly deviating from zero but not from unity for the three environments as presented in Fig. 5, indicating adequacy of the additive-dominance model. The additive component of genetic variation (D) was smaller in magnitude than the dominance component (H_1) for the favorable and the combined drought and heat environments while the reverse was true under drought stress as reported in Table 6. The narrow sense heritability values were 0.38, 0.47 and 0.46 for the favorable, drought and combined drought and heat environments, respectively.



(a) (b) (c)

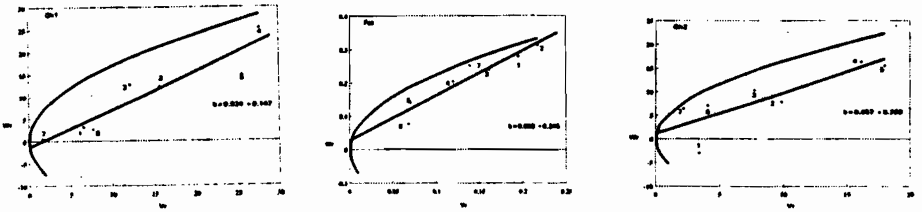
Fig. 4 : The Wr/Vr graphs of main stem density in favorable environment (a) drought stress, environment (b) and the combined drought and heat stresses environment (c).

Table 5:The means of 1000 kennel weight of the 7-parents and their F_1 hybrids in favorable environment, F (upper values) and drought stress environment, D (middle values) and drought + heat stresses environments ,D&H (lower values).

Parents		P_1	P_2	P_3	P_4	P_5	P_6	P_7	Array mean
P_1	F.	44.82	50.94	48	48.78	49.44	52.97	48.60	49.08
	D	41.01	44.78	42.00	42.00	44.32	45.11	43.12	43.19
	D&H	38.07	44.00	40.13	37.33	43.7	41.4	41.74	40.56
P_2	F.		36.50	51.76	47.40	43.00	43.22	42.04	43.99
	D		34.62	42.85	41.45	40.94	41.68	41.05	40.43
	D&H		33.19	36.11	34.98	33.20	38.76	39.20	35.91
P_3	F.			45.81	43.96	40.91	47.24	52.27	46.04
	D			43.71	41.30	39.27	45.32	45.13	43.36
	D&H			40.39	32.90	32.11	34.78	40.42	36.23
P_4	F.				33.93	42.27	45.34	46.50	42.01
	D				32. 32	36.30	41.86	41.29	39.82
	D&H				24.61	30:67	38.78	39.42	33.37
P_5	F.					35.62	42.20	46.18	41.33
	D					32.90	40.05	42.44	38.46
	D&H					31.00	34.29	40.32	35.20
P_6	F.						41.97	46.47	44.22
	D						40.15	43.02	41.58
	D&H						39.24	39.46	39.35
P_7	F.							44.36	44.36
	D							41.55	41.55
	D&H							38.03	38.03

Table 6: Components of genetic variation for 1000 kennel weight in favorable environment (F) ,drought stress environment (D) and drought + heat stresses environment (D&H).

Component	Environments		
	(F)	(D)	(D&H)
D	24.48 ± 3.86	22.29 ± 3.12	22.53 ± 6.70
H_1	50.144 ± 9.82	15.08 ± 7.52	40.12 ± 16.84
H_2	45.14 ± 8.19	15.53 ± 6.63	29.93 ± 14.84
$\sqrt{HI/D}$	1.43	0.83	1.34
N.heritability	0.38	0.47	0.46



(a) (b) (c)

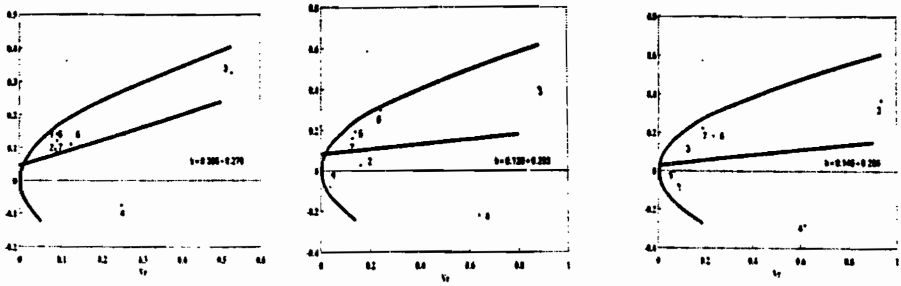
Fig. (5): The Wr/Vr graphs of 1000 kernel weight in favorable environment (a) drought stress, environment (b) and the combined drought and heat stresses environment (c).

4-Grain yield per spike :

Grain yield per spike (in gms) as an averaged over parents and their F_1's was reduced from 2.54 (gms) in the favorable environments to 2.06 gms under drought indicating 18.8% reduction as presented in Table 7. Under combined drought and heat stresses the average grain yield per spike was reduced further to 1.69 g marking 35.8% reduction relative to that of the favorable environment which indicated 17% yield reduction due to heat stress alone. Highly significant additive and non-additive mean squares were revealed by the analysis of variance with dominance being ambidirectional .

Table 7: The means of grain yield per spike of the 7-parents and their F_1 hybrids in favorable environment, F (upper values) and drought stress environment, D (middle values) and drought + heat stresses environments ,D&H (lower values).

Parents		P_1	P_2	P_3	P_4	P_5	P_6	P_7	Array mean
P_1	F.	2.79	2.67	2.54	2.84	2.55	3.38	2.69	2.78
	D	2.31	2.05	2.35	2.19	1.88	2.58	2.43	2.25
	D&H	2.01	1.88	2.01	1.85	1.80	1.68	2.09	1.90
P_2	F.		1.60	2.39	2.93	2.05	2.29	2.99	2.38
	D		1.40	2.06	2.63	1.96	1.89	2.39	2.05
	D&H		1.31	1.71	1.70	1.25	1.53	2.05	1.59
P_3	F.			3.40	1.35	2.96	2.54	3.45	2.74
	D			3.10	0.85	2.28	2.05	2.99	2.25
	D&H			2.66	0.49	1.55	1.68	1.98	1.67
P_4	F.				1.94	2.66	2.32	2.55	2.37
	D				1.57	1.96	1.58	2.07	1.79
	D&H				0.96	1.17	1.37	1.7	1.30
P_5	F.					2.08	2.13	2.92	2.38
	D					1.47	1.74	2.07	1.76
	D&H					1.24	1.39	1.65	1.43
P_6	F.						1.90	2.71	2.31
	D						1.65	1.93	1.79
	D&H						1.36	1.14	1.25
P_7	F.							2.66	2.66
	D							2.19	2.19
	D&H							1.98	1.98



(a) (b) (c)

Fig. 6 : The Wr/Vr graphs of grain yield per spike in favorable environment (a) drought stress, environment (b) and the drought and heat stresses environment (c).

The slope of the Wr/Vr regression line did not deviate significantly from zero for the three environments as seen in Fig 6, with the array differences in the (Wr – Vr) values being significant ,indicating that non-allelic gene interaction was operating. However, the sharp discontinuity in the distribution of the points representing the seven parents along the regression line with parent No.3 (Long spike) occupying a position at the far end of the line and the points representing the other parents clustering at the other and near the origin suggested that a major $gene_{(s)}$ might differentiate the two groups of parental genotypes.

Associations between stem attributes and yield components:

Stem diameter was positively correlated with 1000 kernel weight and with grain yield per spike in the three different environments as presented in Table 8.

Table 8: Phenotypic correlation between stem attributes and yield components in favorable (upper values) drought stress (middle values) and combined drought and heat stresses (lower values)

Character		Stem dia	Stem d	1000 ke weig	Grain yi per spi
Stem diameter	F.		0.3	0.56*	0.40*
	D		0.69	0.53*	0.40*
	D&H		0.81	0.56*	0.50**
Stem density	F.			0.49*	0.36
	D			0.35	0.43*
	D&H			0.28	0.35
1000 kernel weight	F.				0.61**
	D				0.51**
	D&H				0.58**
Grain yield per spike	F.				
	D				
	D&H				

* $P < 0.05$ ** $P < 0.0$

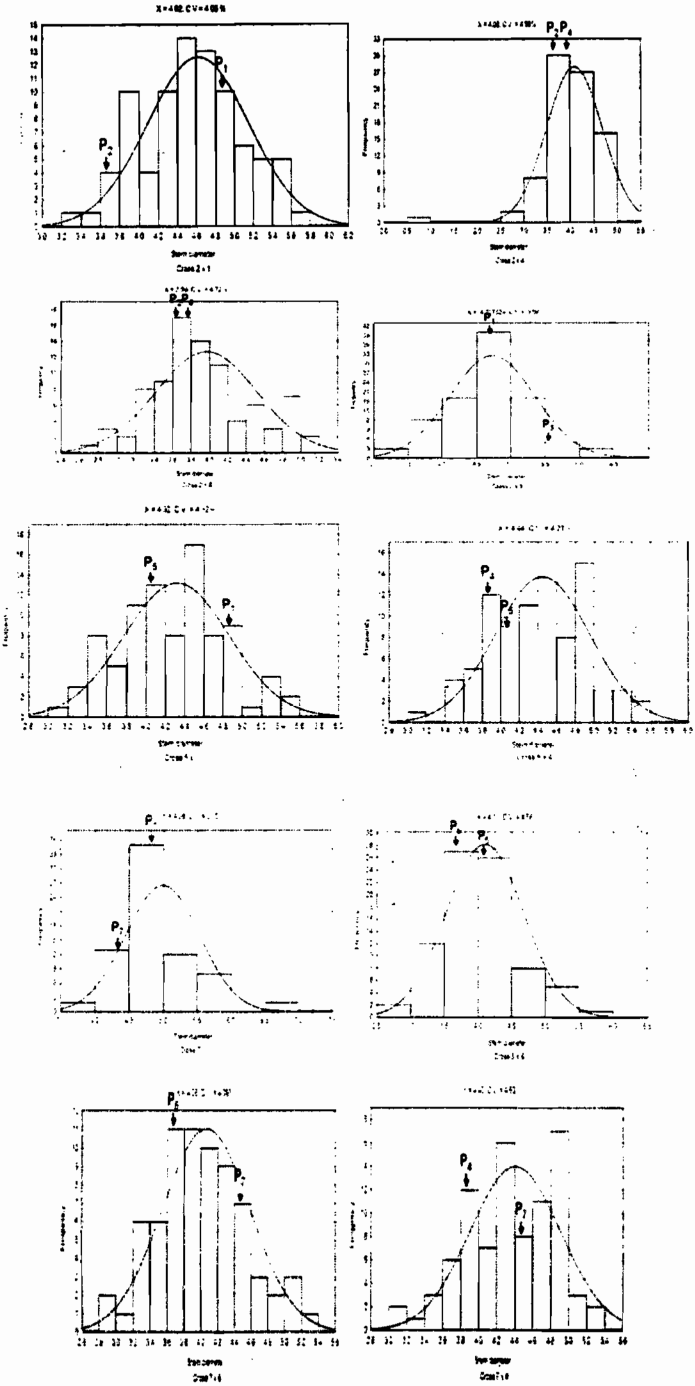


Fig. 7: Distribution of F_2 segregates for stem diameter of main stem under heat stress condition

While stem density was only positively correlated with 1000 kernel weight under favorable conditions and with grain yield per spike under drought stress. Stem diameter displaced positive association with stem density under drought and combined drought and heat stresses. The association between 1000 kernel weight and grain yield per spike was positive and highly significant in the three different environments

Segregation for stem diameter under heat stress:

The distribution of the segregates of the 12 F_2 populations for stem diameter under heat stress as presented in Fig. 7 proved to be continuous and approaching normality indicating that this trait is quantitatively inherited and controlled by polygenes. Transgressive variation was apparent in most of the 12 crosses indicating that the genes controlling this trait were highly dispersed among the parental genotypes.

Associations between stem attributes and yield components in F_2 segregates under heat stress :

Stem diameter displayed significant positive correlation with 1000 kernel weight under heat stress in the 12 F_2 which were examined and presented in Table 9. It was also correlated with grain yield per spike in nine populations. Meanwhile, stem density only showed significant positive association with 1000 kernel weight in five populations and with grain yield per spike in six populations.

Table 9: Phenotypic correlation between stem attributes (stem diameter and stem density) and yield components (1000 kernel weight and grain yield per spike) in F_2 segregates under heat stress.

Cros	Stem diameter		Stem density	
	1000 kernel wei	Grain yield per s	1000 kernel wei	Grain yield per s
2 x 1	0.35**	0.05	0.03	0.21*
2 x 4	0.39**	0.36**	0.32**	0.27*
2 x6	0.45**	0.25*	0.47**	-0.12
3 x 1	0.62**	0.31**	0.16	0.04
3 x4	0.29*	0.28*	0.23	-0.07
3 x 6	0.39**	0.30**	0.42**	0.35**
5 x 1	0.33**	0.01	0.12	-0.04
5 x 4	0.43**	0.25*	0.17	0.17
5 x 6	0.29**	0.22*	0.11	0.31**
7 x 1	0.29*	0.14	0.04	0.60**
7 x4	0.41**	0.20*	0.32**	0.14
7 x6	0.57**	0.42**	0.41**	0.24*

DISCUSSION

Stem diameter of the wheat plant has proved to be a quantitatively inherited trait, indicting that the variation was controlled by polygenes which mainly showed additive effects that segregated out in the F_2 generation displaying continuously normal distributions .Despite the considerable reductions in mean stem diameter under drought (25%) and combined drought and heat stresses (31%), the narrow sense heritability estimates were moderately high where they were : 0.62 and 0.76 in the two environments , respectively. This indicated that the relative magnitude of the additive to the non-additive variance was not affected. In the favorable, drought and combined drought and heat stresses environments, stem diameter was positively correlated with 1000 kernel weight ($r = 0.56$, 0.53 and 0.56 , $P < 0.01$,in the three different environments, respectively) as well as with grain yield per spike ($r = 0.40$, 0.40 and 0.50, respectively , $P < 0.05$). On the other hand, stem density displayed positive association with 1000 kernel weight only under favorable environment ($r = 0.49$, $P < 0.01$) and with grain yield per spike only under drought ($r = 0.43$, $P < 0.01$) despite the strong correlation between stem density and stem diameter under stress ($r = 0.69$ under drought and $r = 0.81$ under combined drought and heat stresses, $P < 0.01$).Moreover, while stem diameter displayed significantly positive association under heat stress with 1000 kernel weight in the 12 F_2 populations and with grain yield per spike in nine of the 12 F_2 populations analyzed stem density showed positive association with 1000 kernel weight in only five F_2 populations and with grain yield per spike in only six of the 12 F_2 populations. Such strong associations of stem diameter with 1000 kernel weight and grain yield per spike under stress demonstrated clearly an important role of this character in sustaining grain filling and supporting grain growth, possibly through providing greater stem capacity for storing assimilates that are formed before anthesis be remobilized to grains after anthesis. Since a substantial amount of the carbohydrates used during grain filling in wheat must come from reserves assimilated before anthesis (Gent, 1994), larger stem diameter and stem density would be advantageous under stress for grain filling. According to Ehdaie *et al.* 2006b, internode length, internode weight and internode specific weight of the stem of the wheat plant affect the accumulation and mobilization of stem reserves with maximum specific weight being correlated with stem mobilized dry matter. Selection for larger stem diameter seems to be feasible and practical since it is easily scorable in large populations with a reasonably high heritability under stress. Such courses of action would enhance grain filling as well as grain yield under drought and heat stress.

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الاختلافات الوراثية في قطر ساق نبات القمح وعلاقاتها بتحمل الجفاف والحرارة.

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تم تحليل النظام الوراثي المتحكم في قطر ساق نبات القمح وغيرها من خصائص الساق في تلقيح دائري لسبع آباء اختبر تحت الظروف البيئية المواتية وظروف الجفاف وظروف الجفاف والحرارة معا، كما درست الأنعزالات في ١٢ عشيرة جيل ثاني تحت إجهاد الحرارة. وجد أن البوليجينات ذات الآثار المضيفة تتحكم في صفة قطر الساق والتي أظهرت انعزالا في توزيعات طبيعية في الجيل الثاني كما كانت درجة توريث هذه الصفة متقاربة تحت البيئة المواتية (٧٣ر٠) وبيئة الجفاف (٦٢ر٠) وبيئة الجفاف + الحرارة (٧٦ر٠) ، بينما انخفضت درجة توريث صفة الوزن الجاف للساق تحت الإجهاد البيئي. أظهرت صفة قطر الساق تلازما معنويا مع وزن الساق الجاف تحت ظروف إجهاد الجفاف وظروف إجهاد الجفاف + الحرارة معا . كما اتضح وجود تلازم معنوي بين قطر الساق وكل من وزن الألف حبه ومحصول الحبوب بالسنبلة في البيئات المواتية واجها الجفاف وإجهاد الجفاف والحرارة معا . وتلك التلازمات تحت ظروف الإجهاد تشير إلى الدور الهام الذي تلعبه صفة قطر الساق في تعضيد ملئ الحبوب بتوفيرها قدرة اختزانية اكبر لنواتج التمثيل الضوئي بالساق قبل تحريكها إلى الحبوب .