

Genetic studies of agronomic and physiological traits in tomato (*Lycopersicon lycopersicum* mill.) Under heat stress conditions

ABSTRACT

Field experiments were conducted at National Horticultural Research Institute, Bagauda (11°33'N; 8°23'E) in the Sudan Savannah and Institute for Agricultural Research, Samaru (11°11'N; 07°38'E) in the Northern Guinea Savanna ecological zones of Nigeria between July-October, 2014 rainy season to estimate ~~genotypic~~ ~~Genotypic~~ Coefficient of ~~V~~variation (GCV), ~~P~~phenotypic Coefficient of ~~V~~variation (PCV), heritability, ~~G~~genetic ~~A~~advance (GA) and ~~G~~genetic ~~A~~advance as percent of ~~M~~mean (GAM) for agronomic and physiological

traits of tomato under heat stress conditions. The study comprised 15 hybrids, their parental lines along with four checks were laid out in partially balanced lattice design with three replications. Analysis of variance revealed significant variation among the genotypes for all traits except fruit diameter, indicating sufficient variability existed among the genotypes. The estimates of PCV were higher than GCV. High GCV and PCV values were recorded for number of clusters per plant, and number of fruits per plant suggesting high genetic variability for these traits. Broad-sense heritability varied from 5.20% to 98.92%, while the estimates of GA showed a wide range from 0.09 to 161.13. High estimates of Broad-sense heritability coupled with high GAM were observed for the number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit length, fruit shape index and yield per plant indicating additive gene effects for the hereditary pattern of roles. Based on the results of the study, simple selection based on phenotypic performance of these traits would provide better response and also considered for higher fruit yield under heat stress conditions.

KEYWORDS: Tomato, Variability, Heritability, Genetic ~~A~~advance and Heatstress.

24 INTRODUCTION

25 Tomato (*Lycopersicon lycopersicum* Mill.) belongs to the family Solanaceae, genus *Lycopersicon*,
subfamily

26 Solanoideae and tribe Solaneae where pepper, potato, tobacco and eggplant belong (Taylor, 1986).

27 Tomato is very rich in vitamins, minerals (iron and phosphorus), essential amino acids, sugars and dietary
28 fibers. It contains a high level of lycopene, an antioxidant that reduces the risks related to several cancers
29 and neurodegenerative diseases (Srinivasan, *et al.*, 2010). The optimal temperatures required for tomato
30 cultivation are between 25-30°C during photoperiod and 20°C during the dark period (Camejo *et al.*,
31 2005), and an increase of 2-4°C over the optimal temperature adversely affects gamete development and
32 inhibits the ability of pollinated flowers to develop into fruits and thus reduced fruit yield (Peet *et al.*, 1997,
33 Sato, *et al.*, 2001; Firon, *et al.*, 2006). Heat stress becomes a major limiting factor for field production of
34 tomatoes (Foolad, 2007). — High temperature during the growing season is detrimental to growth and
35 reproductive development which reduces fruit size, yield and fruit quality (Abdul-Baki, 1991, Dane *et al.*,
36 1991, Wessel-Beaver and Scott, 1992, Scott, 2000). In Nigeria, the major growing area of tomato lies
37 between latitudes 7.5° 11' and 13.0° N and within a range temperature of 22-30°C. Tomato is usually
38 grown during the rainy season in Nigeria and high temperature during the rainy season caused a
39 significant reduction of fruit size, increment in flower abortion, decrease in fruit set which reduced fruit
40 yield and shortage of supply which results in high cost. Thus, there is need to develop high yielding
41 variety with acceptable fruit setting ability under high temperature through proper breeding program to
42 fulfill the demand of tomato production during rainy season. It is vital to have knowledge of the nature and
43 magnitude of genetic variability created through hybridization for various traits under heat stress
44 conditions, since the nature and magnitude of variability are pre-requisite for any crop improvement which
45 would assist breeders in planning a successful breeding program. Genotypic coefficient of variation and
46 phenotypic coefficient of variation are useful for finding the amount of variability present among —the
47 genotypes. Heritability is the proportion of genetic variance to the total variance which help in determining
48 the influence of location in the expression of the trait and the extent to which improvement is feasible after
49 selection (Robinson, *et al.*, 1949). However, heritability alone is not adequate to make an efficient
50 selection in segregating generation. Therefore, high heritability accompanied by genetic advance is

appropriate parameters for selection of a trait and served as an indication of additive gene action for such trait. Sharanappa and Mogali (2014) recorded higher PCV values than GCV for all traits under rainy season. High PCV and GCV were observed for number of fruits per plant, number of flowers per plant, average fruit weight, number of clusters per plant and fruit yield per plant, while high broad-sense heritability and genetic advance as percent over mean were recorded for number of fruit per plant, number of flowers per plant, average fruit weight and fruit set percentage (Meena and Bahadur, 2014). Ullah *et al.* (2015) and Pawar *et al.* (2016) reported higher PCV values than GCV for days to 50% flowering, plant height, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit weight, fruit length, fruit diameter, fruit yield per plant and high heritability was also recorded for the traits. The present investigation was conducted to study nature and magnitude of variability, heritability and genetic advance of agronomic and physiological traits under heat stress conditions.

MATERIAL AND METHODS

The experiment consists of two heat tolerant (Icixina and Rio Grande) and four heat susceptible tomato (Tima, Tropimech, Petomech and Roma Savana) which were crossed using half diallel mating design in the screen house. The 15 hybrids, 6 parents and 4 checks (Roma VF, UC82 B, Thorgal F₁ and Jaguar F₁) were evaluated at National Horticultural Research Institute, Bagauda Research Farm (11°33'N; 8°23' E) in the Sudan Savannah and Institute for Agricultural Research Farm, Samaru (11°11'N; 07°38'E) in the Northern Guinea Savanna ecological zones of Nigeria in a 5 × 5 partially balanced lattice design with three replications; between July to October, 2014 rainy season to synchronize flowering stage with heat period (September and October) as shown in Table 1. The plot size was 2 × 2m and 1m alleys. Seedlings were raised in nursery 17th July, 2014 and transplanted to the field about 30 days after sowing on three rows at inter-row spacing of 60cm and intra-row of 50cm on 17th August, 2014. Fertilizer (N:P:K-15:15:15) was split and applied at the rate of 45kgN, 45kg P₂O₅ and 45kgK₂O/ha and Urea (46%) at the rate of 64.4kgN/ha at two and five weeks after transplanting, respectively. All agronomic practices were kept uniform in all plots. Data were randomly taken on five centered plants for observations and measurements leaving the plants on either end of the plot to avoid the border effect. Data were recorded for agronomic traits (plant height, days to 50% flowering, number of branches per plant, number of

clusters per plant, number of flowers per cluster, number of flowers per plant, number of fruits per cluster, number of fruits per plant, average fruit weight, fruit length, fruit diameter, fruit shape index, fruit yield per plant and percentage fruit set) and physiological traits (leaf chlorophyll content and canopy temperature depression). The leaf chlorophyll content and canopy temperature depression were measured using SPAD chlorophyll meter (SPAD 502plus. Konica Minolta, Tokyo, Japan) and handheld infrared Thermometer (Spectrum Technologies, Inc. U.S.A), respectively. Canopy temperature depression was calculated using equation 1. Analysis of variance was computed using computer statistical software (SAS Institute, 2004). Genotypic variance, genotype ~~location~~ location variance, phenotypic variance and environmental variance were estimated from table 2 using equation 2, 3, 4 and 5, respectively. The estimates of the genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and classified according to Shivasubramanian and Menon (1973) as: low = 0-10%, moderate = 10-20% and high = 20% and above. Heritability were calculated according to Singh and Chaudhary (1985) and categorized according to Robinson *et al*, (1949) as follows: low = 0-30%, moderate = 30-60% and high = 60% and above, while genetic advance (GA) and genetic advance as percent of mean (GAM) were computed according to formula of Johnson *et al*, (1955).

$$\text{Canopy temperature depression} = T_a - T_c \dots\dots\dots (1)$$

Where: T_a = Air temperature

T_c = canopy temperature

$$\sigma_g^2 = \frac{M_g - M_{gl}}{rl} \dots\dots\dots (2)$$

$$\sigma_{gl}^2 = \frac{(M_{gl} - M_e)/r}{l} \dots\dots\dots (3)$$

$$\sigma_{ph}^2 = \sigma_g^2 + \sigma_{gl}^2 + \sigma_e^2 \dots\dots\dots (4)$$

$$\sigma_e^2 = \frac{M_e}{rl} \dots\dots\dots (5)$$

98 Where: σ_g^2 = Genotypic variance, σ_{ph}^2 = Phenotypic variance, σ_{gl}^2 = Genotype $\times$ location variance, σ_e^2 =
 99 environmental variance, r = Replications, l = Locations, M_g = Genotype mean square, M_{gl} = Genotype
 100 $\times$ location mean square and M_e = Error mean square.

101 Table 1: Average temperature and rainfall for the experimental sites

Month	Bagauda			Samaru		
	Maximum	Minimum	Rainfall	Maximum	Minimum	Rainfall
	Temperature	Temperature	(mm)	Temperature	Temperature	(mm)
	(°C)	(°C)		(°C)	(°C)	
July	32.2	22.6	24.06	30.9	22.38	11.71
August	31	24.13	30.86	29.83	22.43	26.74
September	32.67	27.11	14.07	31.17	21.72	11.04
October	32.92	24	45.2	33.73	21.23	2.33

102 Source: National Horticultural Research Institute, Bagauda and Institute for Agricultural Research,
 103 Samaru, meteorological data units.

104 RESULTS AND DISCUSSION

105 VARIABILITY

106 Analysis of variance revealed highly significant ($P = .01$) differences for all traits except fruit diameter and
 107 significant ($P = .05$) for canopy temperature depression (Table 2), indicating presence of sufficient and
 108 significant variability existed among genotypes selected for the study which can be exploited through
 109 selection. Similar results were reported by Shankar et al. (2013) and Meena and Bahadur (2014). Pawar
 110 et al. (2016) also observed highly significant variation for plant height, fruits per cluster, fruit length, fruit
 111 diameter, number of fruits per plant and fruit yield per plant. The genotype $\times$ location mean squares were
 112 highly significant ($P = .01$) for number of branches per plant, number of flowers per plant, percentage fruit

set and leaf chlorophyll content and significant ($P = .05$) for plant height and number of clusters per plant; while days to 50% flowering, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, average fruit weight, fruit length, fruit diameter, fruit shape index, fruit yield per plant and canopy temperature depression recorded non-significant difference among genotypes. The significant genotype $\times$ location suggested that the locational conditions have influence in the performance of the genotypes regard to the traits, hence there is need to test the genotypes over different locations across years to identify their suitability for utilization as suitable germplasm for tomato improvement under heat stress.

Genotypic variance was higher than the environmental variance for all traits (Table 3) except fruit diameter, leaf chlorophyll content and canopy temperature depression, indicating more contribution of genetic variance to the total variation and therefore the characters could be considered and exploited for selection in earlier generations. Genotypic coefficient of variation and phenotypic coefficient of variation are important in studying of the nature and magnitude of variability of different traits, because it measures the range of variability which is prerequisite for any crop improvement. The phenotypic coefficient of variation values were higher than the genotypic coefficient of variation, thereby suggesting the strong influence of the environmental factors on the expression of the characters (Table 3). The results confirmed the findings of Meena and Bahadur (2014), Razman *et al.* (2014), Sharanappa and Mogali (2014), Ullah *et al.* (2015) and Pawar *et al.* (2016). The difference between GCV and PCV values were minimum for the number of flowers per cluster, number of fruits per cluster and fruit diameter, indicating there is least effect of environment on the expression of the traits, hence selection could be applied to improve these traits in an early segregating population. Similar results were also reported by Reddy *et al.* (2013) for number of flowers per cluster and number of fruits per cluster and Meena and Bahadur (2014) for fruit diameter. The results (Table 3) showed that GCV value was high for number of fruits per plant (27.46) and number of clusters per plant (20.22) indicating that genetic variance contributing more to total variation, hence selection could be carried out in earlier generations. Moderate GCV values were observed for number of branches per plant (10.94), number of flowers per cluster (12.05), number of fruits per cluster (11.73), average fruit weight (19.44), fruit length (12.44), fruit shape index (13.15), fruit yield

per plant (19.32) and percentage fruit set (16.85); Whereas, lowest GCV values were recorded for plant height (5.51), days to 50% flowering (2.35), fruit diameter (3.13), leaf chlorophyll content (4.92) and canopy temperature depression (2.18). The results correspond to findings Ullah *et al.* (2015), Ahmad *et al.* (2016) and Pawar *et al.* (2016). The highest PCV values were observed for number of fruits per plant (30.31) followed by average fruit weight (25.52), number of flowers per plant (24.46), number of clusters per plant (22.96), fruit yield per plant (22.40), percentage fruit set (22.52) and number of branches per plant (21.25). High PCV values were recorded for these traits shows that the traits are under influence of environmental effects than of genetic effects. Number of flowers per cluster (12.32), number of fruits per cluster (11.88), fruit length (13.34) and fruit shape index (14.26) also exhibited Moderate PCV values, while the lowest PCV values were recorded for plant height (8.51), days to 50% flowering (3.07), fruit diameter (3.83), leaf chlorophyll content (6.76) and canopy temperature depression (9.55). The moderate GCV and PCV values observed for the traits indicated the presence of moderate variability was existed among the genotypes for these traits suggesting improvement of base population through intercrossing in F₂ followed by recurrent selection. GCV and PCV values were higher for the number of clusters per plant and number of fruits per plant, suggesting the presence of high genetic variability of the traits. The results were in accordance with findings of Shalini (2009) and Sharanappa and Mogali (2014).

HERITABILITY AND GENETIC ADVANCE

Highest estimates of broad sense heritability (Table 3) was noticed for days to 50% flowering (68.00), number of clusters per plant (77.51), number of flowers per cluster (95.68), number of fruits per cluster (98.92), number of fruit per plant (82.02), fruit length (86.86), fruit diameter (66.67), fruit shape index (85.00), fruit yield per plant (74.40) and moderate for plant height (41.09), number of branches per plant (26.52), number of flowers per plant (58.38), percentage fruit set (56.66) and leaf chlorophyll content (52.95). Whereas, the lowest broad-sense heritability was recorded by canopy temperature depression (5.20). The high broad sense heritability values indicated that the location has less influence on the expression of the traits, hence the traits were heritable, which can be transferred to the progeny and improved by simple selection under heat stress conditions. Moderate heritability values show both additive and non-additive gene actions are important in influencing the expression of these traits under

high temperature across locations. Low broad-sense heritability might be due to confounded effects of other stresses such as drought and mineral imbalance; therefore selection should be delayed to later segregating generations. Ullah *et al.* (2015) reported high broad sense heritability for days to 50% flowering, flowers per cluster, fruits per cluster, number of fruits per plant, fruit length, fruit diameter, fruit yield and Henareh (2015) for number of fruits per plant . Nevertheless, high heritability alone is not enough to demonstrate the response to selection. Hence, high heritability coupled with high genetic advance as percent of mean are important parameters in response to selection of a trait. Estimates of genetic advance showed a wide range from 0.09 for canopy temperature depression to 161.13 in fruit yield per plant. High broad-sense heritability and genetic advance as percent of mean were recorded for number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit length, fruit shape index and fruit yield per plant indicating additive gene effects for the inheritance of the traits. The traits can be considered and selected for further improvement through simple breeding methods like pure line, single seed descent and mass selection for higher fruit yield under high temperature conditions. Reddy *et al.* (2013) observed high heritability and GAM for number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit length, fruit yield per plant and Pawar *et al.* (2016) for fruit diameter. High estimates of heritability with low GAM observed for days to 50% flowering and fruit diameter attributed to non-additive gene effects in controlling their inheritance.

CONCLUSION

The results show that there is adequate and significant variability existed among the genotypes which could be harnessed through selection to improve the traits under heat stress. High heritability and genetic advance as percent of mean were observed for most of the traits indicating existence of additive gene effects in the expression of the traits. Therefore, pure line, single seed decent and mass selection could be exploited to improve the traits under heat stress conditions.

193 Table 2: Mean squares for sixteen agronomic and Physiological characters combined across locations

Source of variation	df	PHT	DFPFL	NBPP	NCPP	NFLPC	NFLPP	NFRPC	NFRPP
Location	1	6084.75	74.91	7408.92	1912.66	0.52	182490.07	0.02	8198.32
Block(replication × location)	24	73.19	12.56	49.26	14.56	0.53	232.19	0.73	52.44
Replication(location)	4	128.97	10.17	39.59	14.23	0.78	796.08	0.28	91.45
Genotype	24	138.51**	27.53**	74.18**	57.40**	3.01**	1535.64**	1.86**	200.66**
Genotype × location	24	80.47*	8.81	54.51**	12.91*	0.13	639.14**	0.02	36.01
Error	72	42.13	5.53	11.65	6.85	1.09	205.10	0.31	33.15

194 df: Degree of freedom, PHT: Plant height, DFPFL: Days to 50% flowering, NBPP: Number of branches per plant, NCPP: Number of clusters per
 195 plant, NFLPC: Number of flowers per cluster, NFLPP: Number of flowers per plant, NFRPC: Number of fruits per cluster and NFRPP: Number of
 196 fruits per plant. ** and * are significantly different at 1% and 5% levels of probability, respectively.

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201 Table 2 continued

Source of variation	df	AFW	FRL	FRD	FRSI	FRYPP	PFRS	LCC	CTD
Location	1	29.06	0.57	0.69	0.01	6507841.92	1082.13	3080.85	338.19
Block(replication × location)	24	198.45	0.30	0.13	0.04	23057.13	38.21	70.80	2.59
Replication(location)	4	255.96	0.40	1.23	0.16	1921.78	56.10	151.88	10.65
Genotype	24	325.04**	2.36**	0.12	0.20**	66310.62**	491.53**	71.41**	4.23*
Genotype × location	24	136.43	0.31	0.04	0.03	16974.22	213.03**	109.22**	4.01
Error	72	99.24	0.25	0.12	0.03	14090.34	69.53	42.67	2.47

202 df: Degree of freedom, AFW: Average fruit weight, FRL: Fruit length, FRD: Fruit Diameter, FRSI: Fruit shape index, FRYPP: Fruit yield per plant,
 203 PFRS: Percentage fruit set, LCC: Leaf chlorophyll content and CTD: Canopy temperature depression. ** and * are significantly different at 1% and
 204 5% levels of probability, respectively.

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208 Table 3: Genetic parameters for sixteen agronomic and Physiological characters combined across locations

Parameter	PHT (cm)	DFPFL	NBPP	NCPP	NFLPC	NFLPP	NFRPC	NFRPP
Mean	56.44	69.76	16.55	13.47	5.75	65.41	4.72	19.08
σ_e^2	7.02	0.92	1.94	1.14	0.18	34.18	0.05	5.53
σ_g^2	9.67	3.12	3.28	7.42	0.48	149.42	0.31	27.44
σ_{gl}^2	6.39	0.55	7.14	1.01	-0.16	72.34	-0.05	0.48
σ_{ph}^2	23.09	4.59	12.36	9.57	0.50	255.94	0.31	33.44
GCV (%)	5.51	2.53	10.94	20.22	12.05	18.69	11.73	27.46
PCV (%)	8.51	3.07	21.25	22.96	12.32	24.46	11.80	30.31
h_b^2 (%)	41.90	68.00	26.52	77.51	95.68	58.38	98.92	82.05
GA	4.15	3.00	1.92	4.94	1.40	19.24	1.13	9.78
GAM (%)	7.35	4.30	11.61	36.66	24.28	29.41	24.04	51.23

209 PHT: Plant height, DFPFL: Days to 50% flowering, NBPP: Number of branches per plant, NCPP: Number
 210 of clusters per plant, NFLPC: Number of flowers per cluster, NFLPP: Number of flowers per plant,
 211 NFRPC: Number of fruits per cluster and NFRPP: Number of fruits per plant.

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216 Table 3 continued

Parameter	AFW (g)	FRL (cm)	FRD (cm)	FRSI	FRYPP (g)	PFRS (%)	LCC	CTD (°C)
Mean	28.84	4.70	3.69	1.28	469.29	40.43	51.02	8.79
σ_e^2	16.54	0.04	0.02	0.01	2348.39	11.59	7.11	0.41
σ_g^2	31.44	0.34	0.01	0.03	8222.73	46.42	-6.30	0.04
σ_{gl}^2	6.20	0.01	-0.01	0.00	480.65	23.92	11.09	0.26
σ_{ph}^2	54.17	0.39	0.02	0.03	11051.77	81.92	11.90	0.71
GCV (%)	19.44	12.44	3.13	13.15	19.32	16.85	4.92	2.18
PCV (%)	25.52	13.34	3.83	14.26	22.40	22.39	6.76	9.55
h_b^2 (%)	58.03	86.86	66.67	85.00	74.40	56.66	52.95	5.20
GA	8.80	1.12	0.19	0.32	161.13	10.56	3.76	0.09
GAM (%)	30.51	23.88	5.26	24.98	34.33	26.13	7.38	1.02

217 AFW: Average fruit weight, FRL: Fruit length, FRD: Fruit Diameter, FRSI: Fruit shape index, FRYPP: Fruit
 218 yield per plant, PFRS: Percentage fruit set, LCC: Leaf chlorophyll content and CTD: Canopy temperature
 219 depression.

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